Static load bearing exercises of individuals with transfemoral amputation fitted with an osseointegrated implant: Reliability of kinetic data

STATIC LOAD BEARING EXERCISES DURING REHABILITATION OF INDIVIDUALS WITH TRANSFEMORAL AMPUTATION FITTED WITH OSSEOINTEGRATED IMPLANT: KINETIC ANALYSIS

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Background

The desire to solve problems caused by socket prostheses in transfemoral amputees and the acquired success of osseointegration in the dental application has led to the introduction of osseointegration in the orthopedic surgery. Since its first introduction in 1990 in Gothenburg Sweden the osseointegrated (OI) orthopedic fixation has proven several benefits[1].

The surgery consists of two surgical procedures followed by a lengthy rehabilitation program. The rehabilitation program after an OI implant includes a specific training period with a short training prosthesis. Since mechanical loading is considered to be one of the key factors that influence bone mass and the osseointegration of bone-anchored implants, the rehabilitation program will also need to include some form of load bearing exercises (LBE).

To date there are two frequently used commercially available human implants. We can find proof in the literature that load bearing exercises are performed by patients with both types of OI implants. We refer to two articles, a first one written by Dr. Aschoff and all and published in 2010 in the Journal of Bone and Joint Surgery.[2] The second one presented by Hagberg et al in 2009 gives a very thorough description of the rehabilitation program of TFA fitted with an OPRA implant. The progression of the load however is determined individually according to the residual skeleton's quality, pain level and body weight of the participant.[1]

Patients are using a classical bathroom weighing scale to control the load on the implant during the course of their rehabilitation. The bathroom scale is an affordable and easy-to-use device but it has some important shortcomings. The scale provides instantaneous feedback to the patient only on the magnitude of the vertical component of the applied force. The forces and moments applied along and around the three axes of the implant are unknown.

Although there are different ways to assess the load on the implant for instance through inverse dynamics in a motion analysis laboratory [3-6] this assessment is challenging. A recent proof- of-concept study by Frossard et al (2009) showed that the shortcomings of the weighing scale can be overcome by a portable kinetic system based on a commercial transducer[7].

Methods

In the study presented here the load was measured with an instrumented pylon, this is a pylon similar to a short training prosthesis but with a six-channel commercial transducer (JR3) embedded into it. The transducer weighs less than 800 gr and measures the forces and moments on the three axes of the implant at a frequency of 200 Hz.

The load prescribed was monitored using a loading frame featuring two handles and a loading plate with adjustable height. A one single-axis strain gauge was embedded into this plate and connected to a LCD display that provided information for the participant on the load applied on the vertical axis in real time, similar to the bathroom scale used in actual static LBE.

A total of 11 unilateral transfemoral amputees fitted with an osseointegrated implant participated in the study. All the participants were recruited and tested at the Salgrenska University Hospital, Gothenburg, Sweden. All the participants were fully rehabilitated enabling them to perform the required loads within the test protocol in one session.

The participants were only instructed to monitor the load prescribed focusing the LCD display and to take sufficient rest between trials. Only four loads (10kg, 20kg, 40kg and a maximum load depending on the body weight) were chosen to avoid extending the duration of the recording session and subsequent fatigue bias.

We want to emphasize the fact that there are important differences between the setup of the experimental study and the actual rehabilitation program. There are differences in the recording conditions, the apparatus used and the loading progression. Therefore we need to be careful with the generalisation of our results. Nonetheless there are still lessons to be learned from the data collected here as they can be used to create a standardised way to analyse the data.

The analysis of the data starts with the selection of the relevant segment of data which corresponds to the longest possible period when the force on the long axis is relatively stable during loading.

Results

At first the actual load applied on the implant during one trial is calculated by measuring the average value of the load during the trial, this variable is called the loading magnitude. The results of the mean raw forces and moments along and around the three axes of the implant show a high variability between the loads and between the participants. There is one exception for the load on the long or vertical axis and for the resultant of the load, corresponding to the fact that the load on the long axis is in agreement with the load prescribed; this is the loading compliance.

The load compliance is measured by the difference between the load applied on the long or vertical axis and the load prescribed. The obtained results show that for all the loading conditions the load on the vertical axis minus the load recommended is negative meaning that the implant is under loaded all the time. The closer to the maximum load the smaller the difference between the load applied and the load recommended.

Discussion

For further analysis we suggest to look at a few other variables, the first one being the loading variation. From a clinical point of view we want to know if the loading varies during one session of LBE. We will answer this question by measuring the root mean square error between the mean and the load applied.

Secondly we will be looking at the loading stability. From a clinical point of view we want to know if there is a possible drift of the loading during one session of static LBE. To answer this question we need to look at the slope of the loading regression line.

The third variable we suggest looking at is the loading quantity. We want to estimate the total amount of load that is applied during static LBE. Therefore we will calculate the impulse per minute.

Finally studying the loading requirement could allow us to partially validate the intended purpose of the static LBE, this is to prepare patients for independent walking. Therefore we need to look at the agreement between the load applied at the end of the static LBE and the load applied during activities of daily living.

The clinical implications of these results should be considered cautiously, given the intrinsic limitations of the study. We showed that there is a fairly high inter participant variation for F_{ML} and F_{AP} as well as for M_{ML}, M_{AP} and M_{LG}; but because presenting kinematic and dynamic data was outside the scope of this study; the possible contributions of these confounders to the loading variability remain unknown.

Conclusion

Despite of the limitations of the study, the results gathered here will be useful as a toolbox for the validation of the current static load bearing exercises. This type of study could participate in the discussion related to guidelines, duration of rehabilitation program and eventually design of an apparatus to monitor the LBE.

References

1. Hagberg, K. and R. Brånemark, One hundred patients treated with osseointegrated transfemoral amputation prostheses - the rehabilitation perspective. Journal of Rehabilitation Research & Development, 2009. 43(3): p. 331-344.
2. Aschoff, H., R.E. Kennon, J.M. Keggi, and L.E. Rubin, Transcutaneous, Distal Femoral, Intramedullary Attachment for Above-the-Knee Prostheses: An Endo-Exo Device. The Journal of Bone & Joint Surgery, 2010. 92(Supplement 2): p. 180-186.
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Static load bearing exercises during rehabilitation of individuals with transfemoral amputation fitted with osseointegrated implant: Kinetic analysis

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ISPO World Congress - Hyderabad, India - 04-07/02/2013

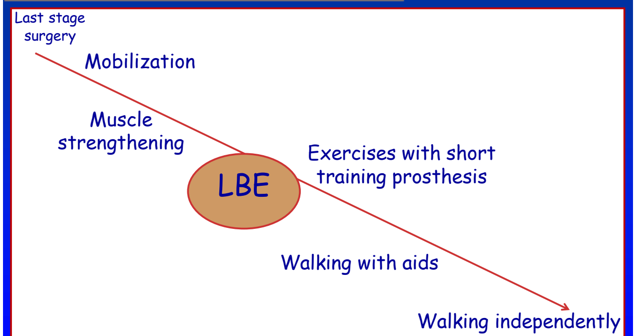
Background: OI fixation

OI fixation =

- Prosthetic benefits
- Increase in quality of life

- Hagberg, K. and R. Brånemark, Consequences of non-vascular trans-femoral amputation: a survey of quality of life, prosthetic use and problems. Prosthetics and Orthotics International, 2001. 25: p. 186-194.
- Hagberg, K., E. Haggstrom, M. Uden, and R. Brånemark, Socket versus bone-anchored trans-femoral prostheses: hip range of motion and sitting comfort. Prosthetics and Orthotics International, 2005. 29(2): p. 153-163.

Background: rehabilitation



Background: load bearing exercises - EFFT (Eska, Germany)

THE JOURNAL OF BONE & JOINT SURGERY

JB&JS

This is an enhanced PDF from The Journal of Bone and Joint Surgery

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Transcutaneous, Distal Femoral, Intramedullary Attachment for Above-the-Knee Prostheses: An Endo-Exo Device

Horst Heinrich Aschoff, Robert E. Kennon, John M. Keggi and Lee E. Rubin
J Bone Joint Surg Am. 2010;92:180-186. doi:10.2106/JBJS.J.00806

- 2-3 wk: start PWB
- 4-6 wk: FWB, secure gait

Background: load bearing exercises – OPRA fixation (Integrum AB, Sweden)

Department of Veterans Affairs

JRRD — Volume 46, Number 3, 2009, Pages 331–344
Journal of Rehabilitation Research & Development

One hundred patients treated with osseointegrated transfemoral amputation prostheses—Rehabilitation perspective

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Background: load bearing exercises – OPRA (Integrum AB, Sweden)

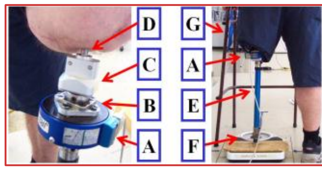
- 4-6 wk: start at 20 kg , increase 10 kg/wk
- 30 min, twice a day
- Load monitored with bathroom scale
- 11-13 wk: walking aids

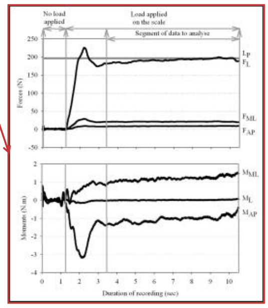
Background: need

We know:
- Magnitude of the force on the vertical axis

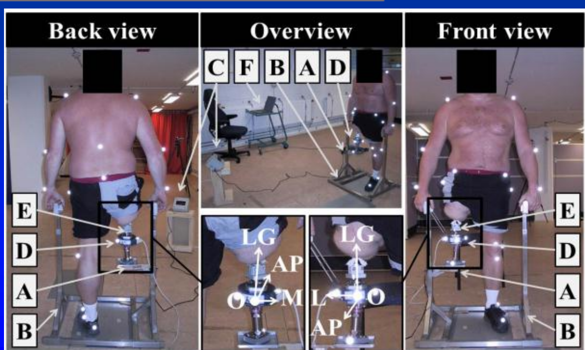
We need to improve:
- understanding of actual load (F and M) applied on three axes of the OI
- Understanding of relationship between LBE and osseointegration

Background: work done to date





Methods: apparatus

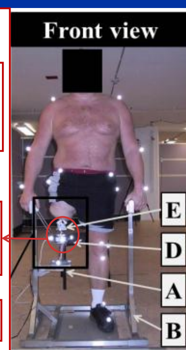


Methods: apparatus

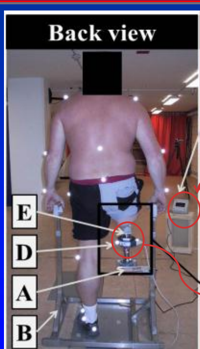
JR3
11.43 x 3.81 cm
800 g

3D load cell JR3

200 Hz



Methods: apparatus



- Self-monitoring

Monitor

single-axis load cell

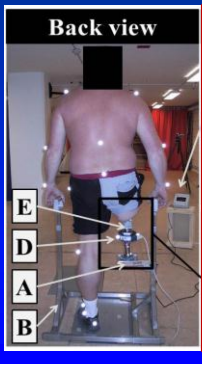
Bathroom scale

Methods: participants

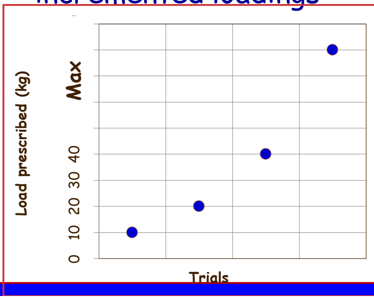
- 11 TFA-OI (3 Females, 8 Males)
- OPRA fixation
- Gothenburg

- Age: 46.8±10.5 yrs
- Height: 1.75±0.10 m
- Mass: 81.54±16.28 kg
- Time since insertion: 4.79±2.23 yrs (1.2-7.87 yrs)
- Fully rehabilitated

Methods: protocol



- 5 trials of 4 incremented loadings



Methods: protocol

- Example of recording

Methods: limitations, experimental vs clinical

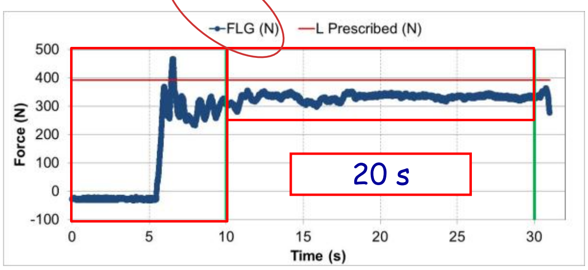
	Experimental	Clinical
Recording conditions	Fully rehabilitated participants	Patients
	On-the-fly	On-the-go
	Short recording	30 min
Loading apparatus – monitoring of the load prescribed	LCD display connected to strain gauge	Scale on stool
Loading progression	Starting load 10kg	Starting load 20kg
	Set loading progression	Individualised loading program

Methods: benefits of experimental approach

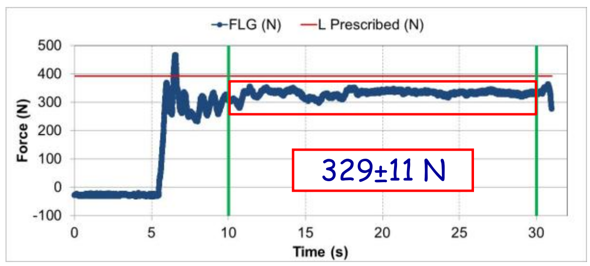
- Proposal of loading data analyse
- Validation of monitoring LBE
- Validation of loading frame for LBE

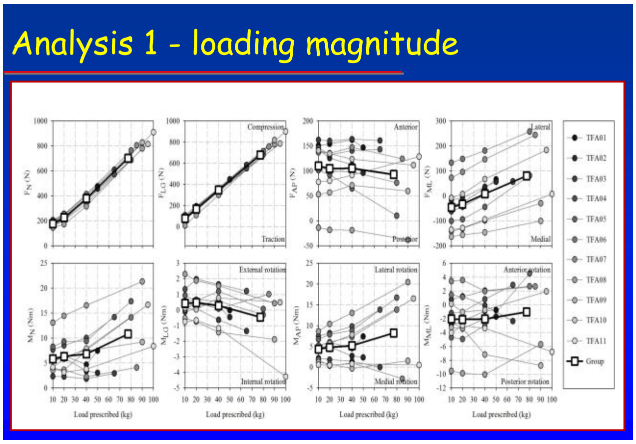
Methods: Data selection

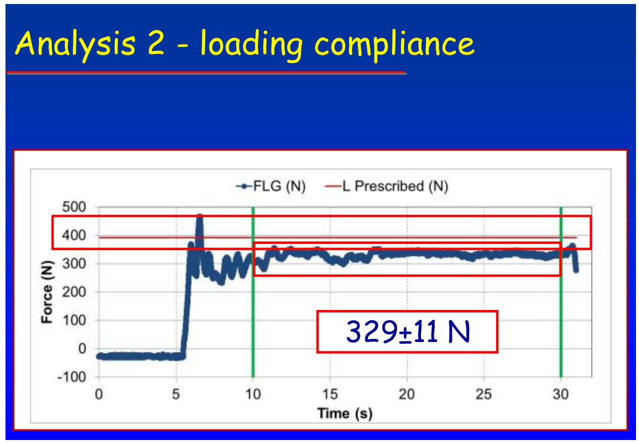
- Segment of stable loading
  - F_{AP}, F_{ML}, F_{LG}, F_N, M_{AP}, M_{ML}, M_{LG}, M_N

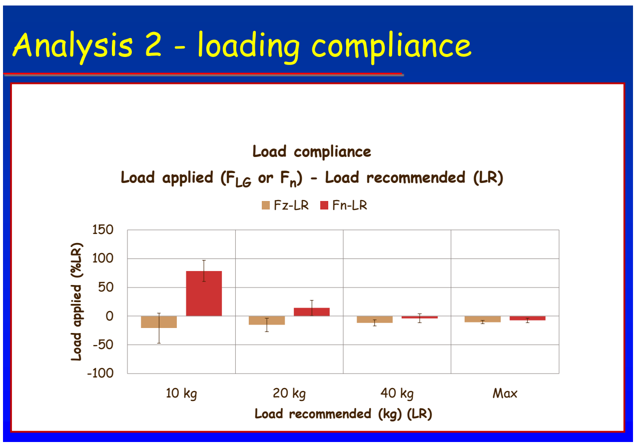


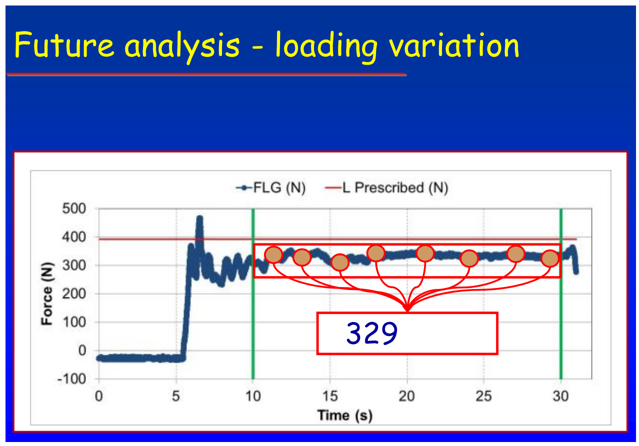
Analysis 1 - loading magnitude

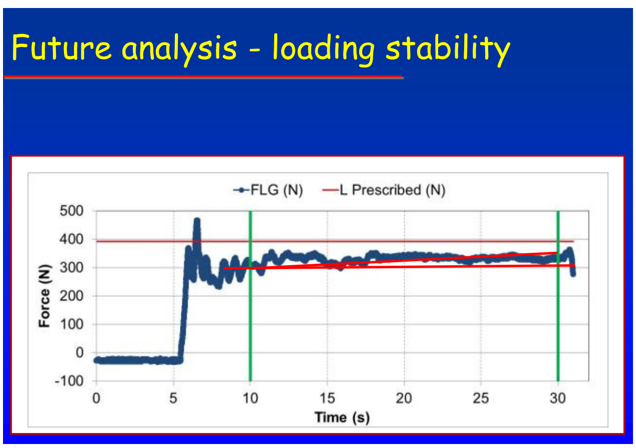


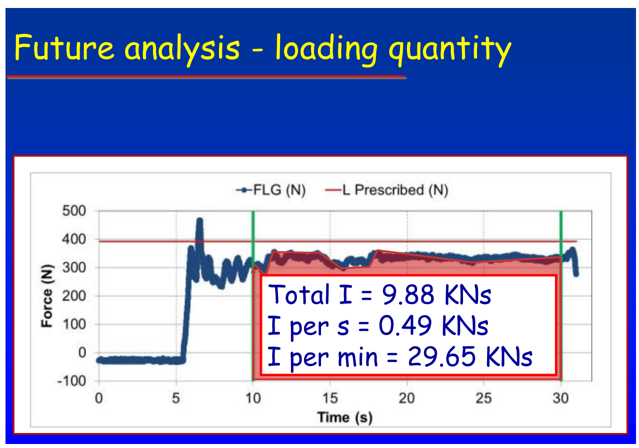

Analysis 1 - loading magnitude


Analysis 2 - loading compliance
FLG (N)
L Prescribed (N)
Force (N)
Time (s)
329±11 N

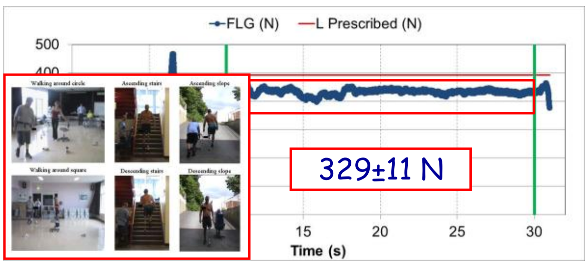

Analysis 2 - loading compliance
Load compliance
Load applied (FLG or Fn) - Load recommended (LR)
Fz-LR
Fn-LR
Load applied (%LR)
10 kg
20 kg
40 kg
Max
Load recommended (kg) (LR)


Future analysis - loading variation
FLG (N)
L Prescribed (N)
Force (N)
Time (s)
329


Future analysis - loading stability
FLG (N)
L Prescribed (N)
Force (N)
Time (s)


Future analysis - loading quantity
FLG (N)
L Prescribed (N)
Force (N)
Time (s)
Total I = 9.88 KNs
I per s = 0.49 KNs
I per min = 29.65 KNs

Future analysis - loading requirement



Discussion: limits

- Information about the variability:
  - Within loadings
  - Between participants
- No confounders:
  - Dynamics (e.g., force-plates)
  - Kinematics (e.g., lateral trunk bending)
  - Kinetics (e.g., joints moments)

Conclusion

- Toolbox for validation of current static LBE
- Exploration of possible ways:
  - to reduce the duration of rehabilitation program
  - to develop a special apparatus to monitor load bearing exercises

Questions ?

Now ! or

Later

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