

The Diabetic Foot in Remission:  
How can I prevent (severe) recurrence?



Conclusion

© Diabet Symposium  
zum Diabetischen Fuss.  
Was gibt es Neues in der Behandlung?



Keck School of  
Medicine of **USC**



ToeandFlow.com  
armstrong@usa.net  
@dgarmstrong

8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

# The Diabetic Foot in Remission:

Toward More Ulcer-Free and  
Activity-Rich Days

Dr. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

**What we will discuss:**

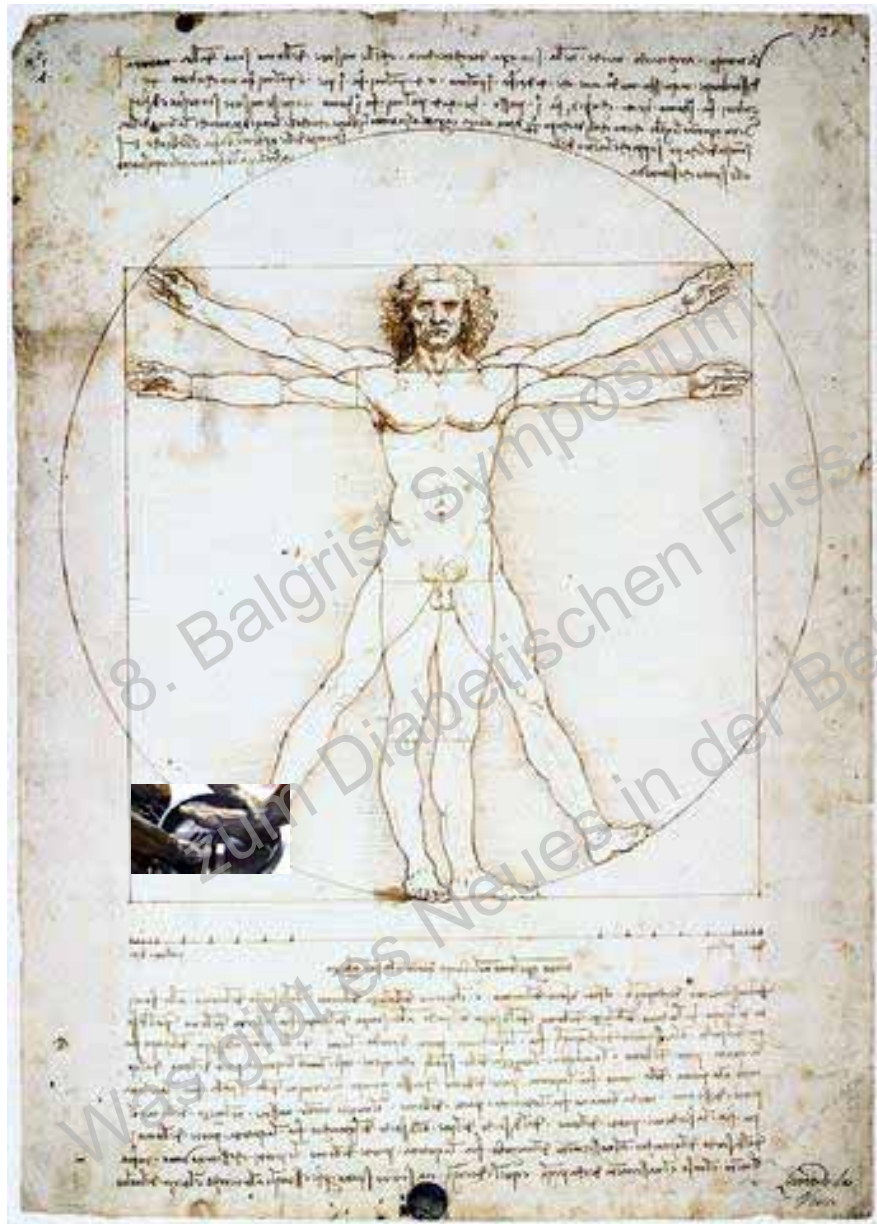
8th Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?





© Dr. Christ Sympodium  
Zum Diabetischen Fuß  
Was gibt's Neues in der Behandlung

**Humility > Hubris**



8. Balgrist Symposium  
Zum Diabetischen Fuss  
Was gibt es Neues in der Behandlung?





2009

8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?



For the first time in the history of humankind:  
Non-communicable diseases (NCDs) have become the  
leading cause of global mortality (60%)

BMJ 2009;339:b2857

For the first time in the history of humankind:  
Diabetes is now responsible for 4 million deaths each  
year, overtaking HIV/AIDS

BMJ 2009;339:b2857

# A new world view?

8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?



# Three Ages of Death



8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

# Disaster



8. Balgrist Symposium  
zum Dr. petischen Fuss  
Was gibt es Neues in der Behandlung



# Disease



# Decay

8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

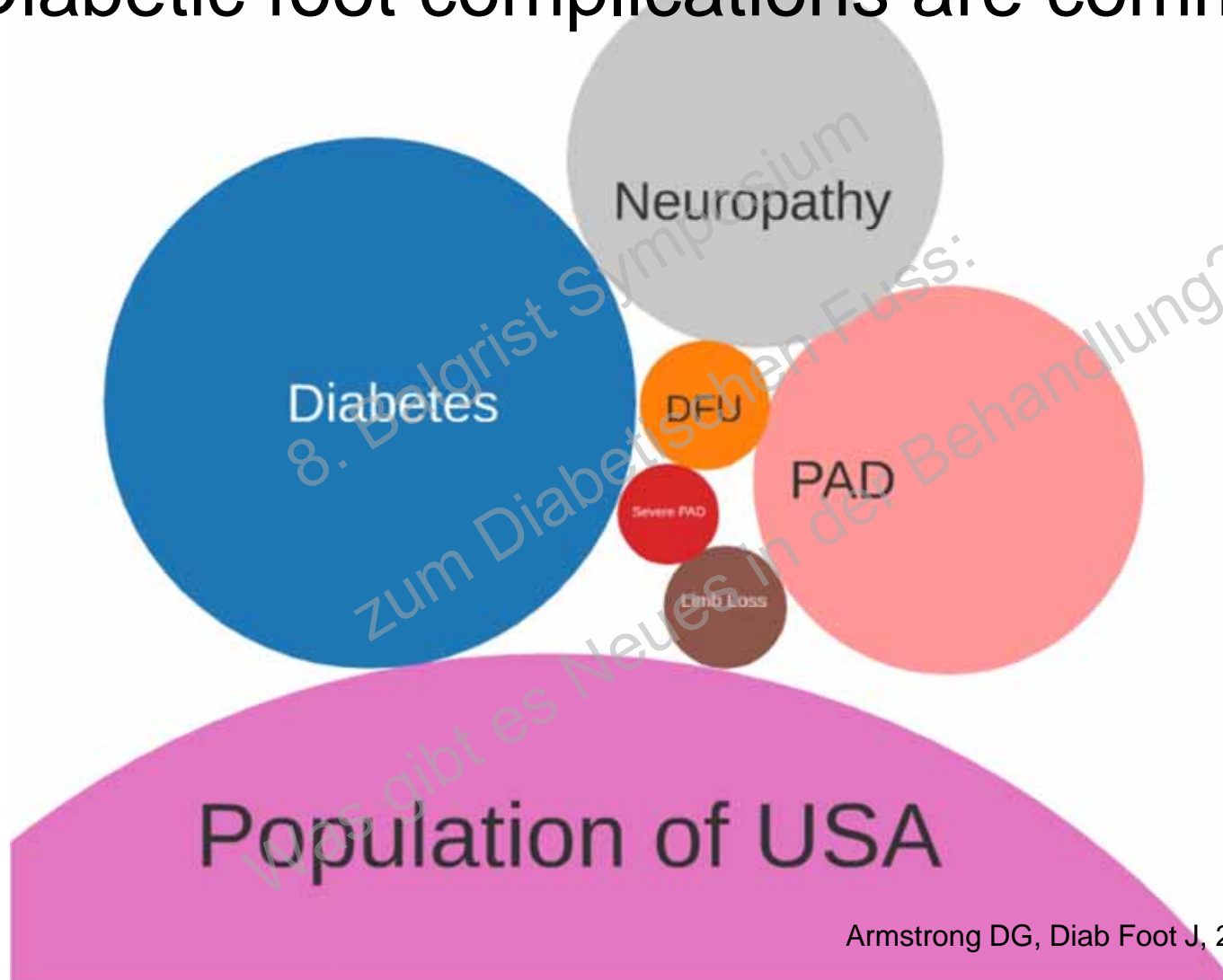






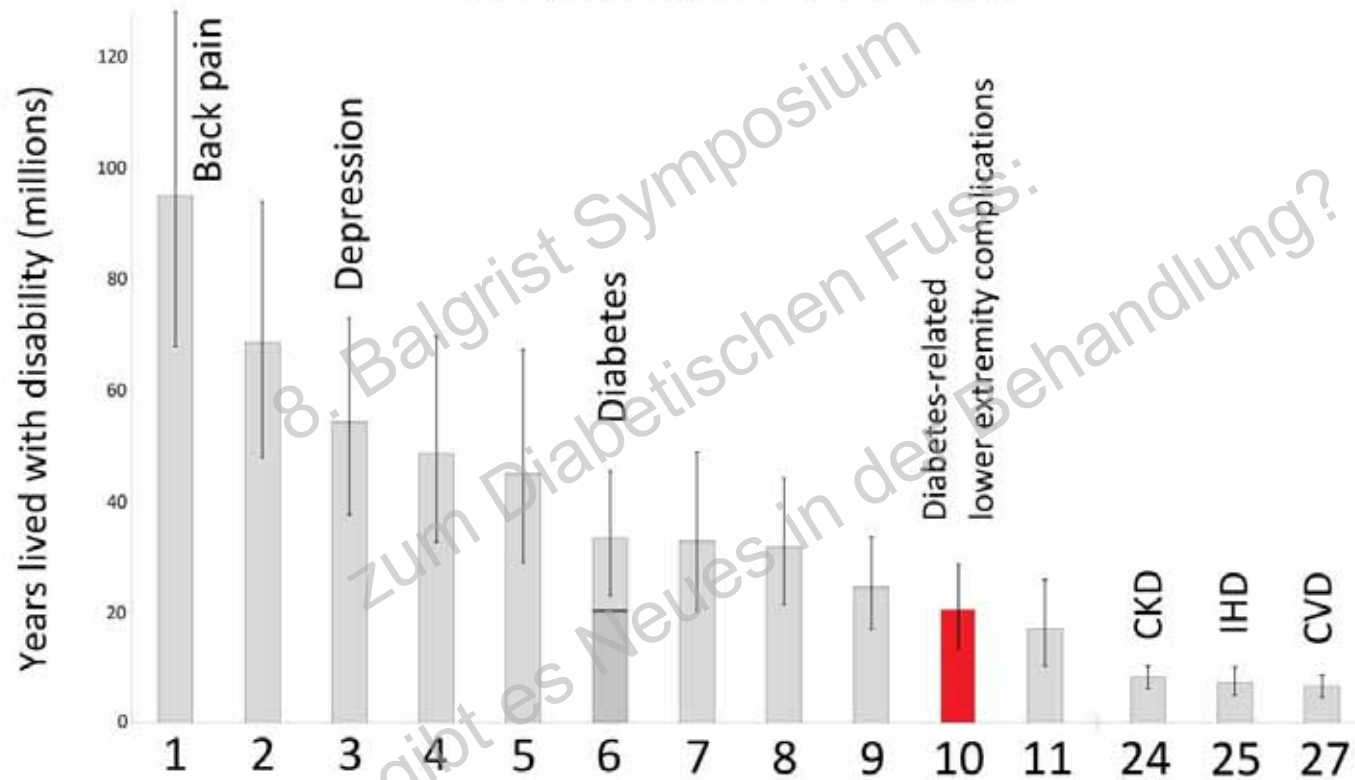
**Diabetic foot complications are common, complex and costly**

# Diabetic foot complications are common



# Diabetic foot complications are common

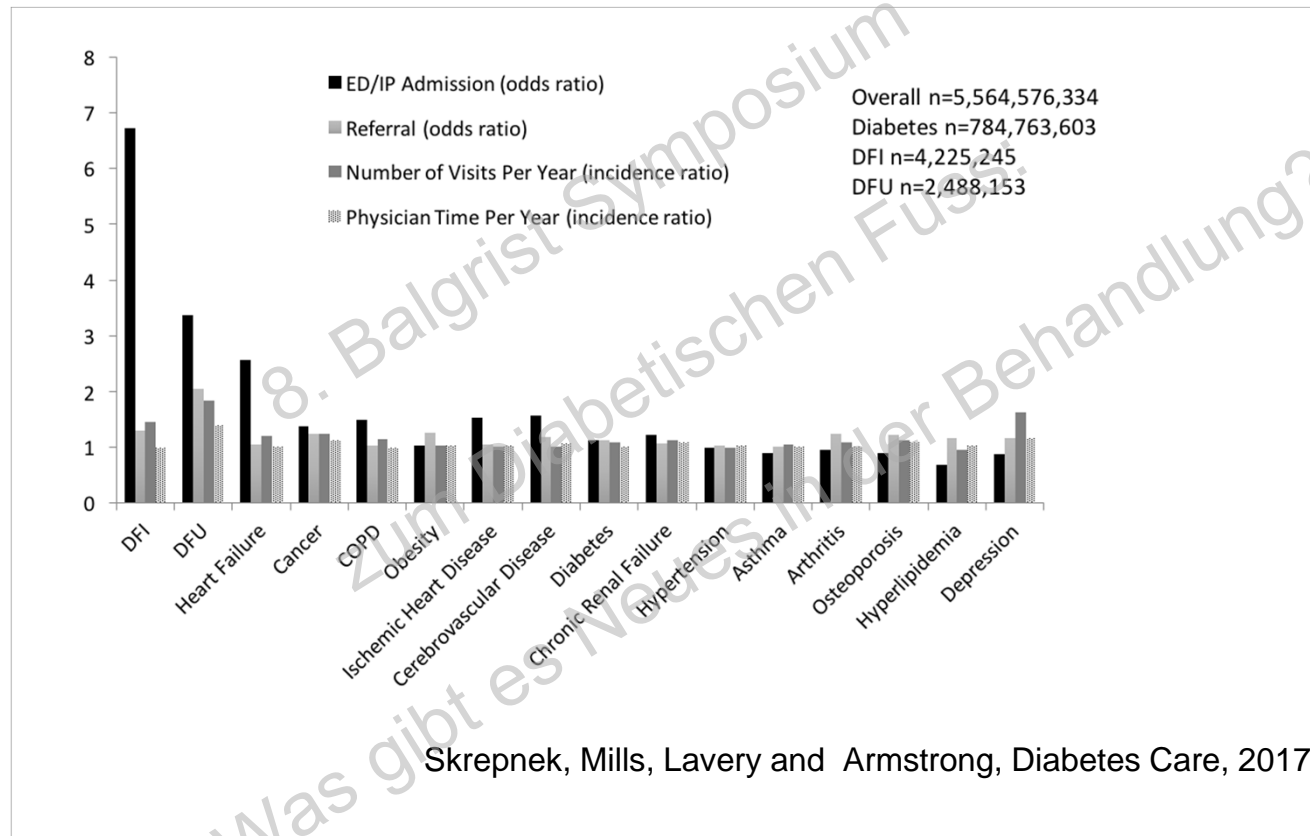
Global burden of disease



Lazzarini, Pacella, Armstrong, van Netten, Diabetic Med, 2018



# Diabetic foot complications are complex





Every 1.2 seconds, someone develops a diabetic foot ulcer

Armstrong, Boulton, Bus New England Journal of Medicine, 2017



**Every 20 seconds, someone with diabetes undergoes an amputation**  
Armstrong, Boulton, Bus New England Journal of Medicine, 2017

**Time's up.**

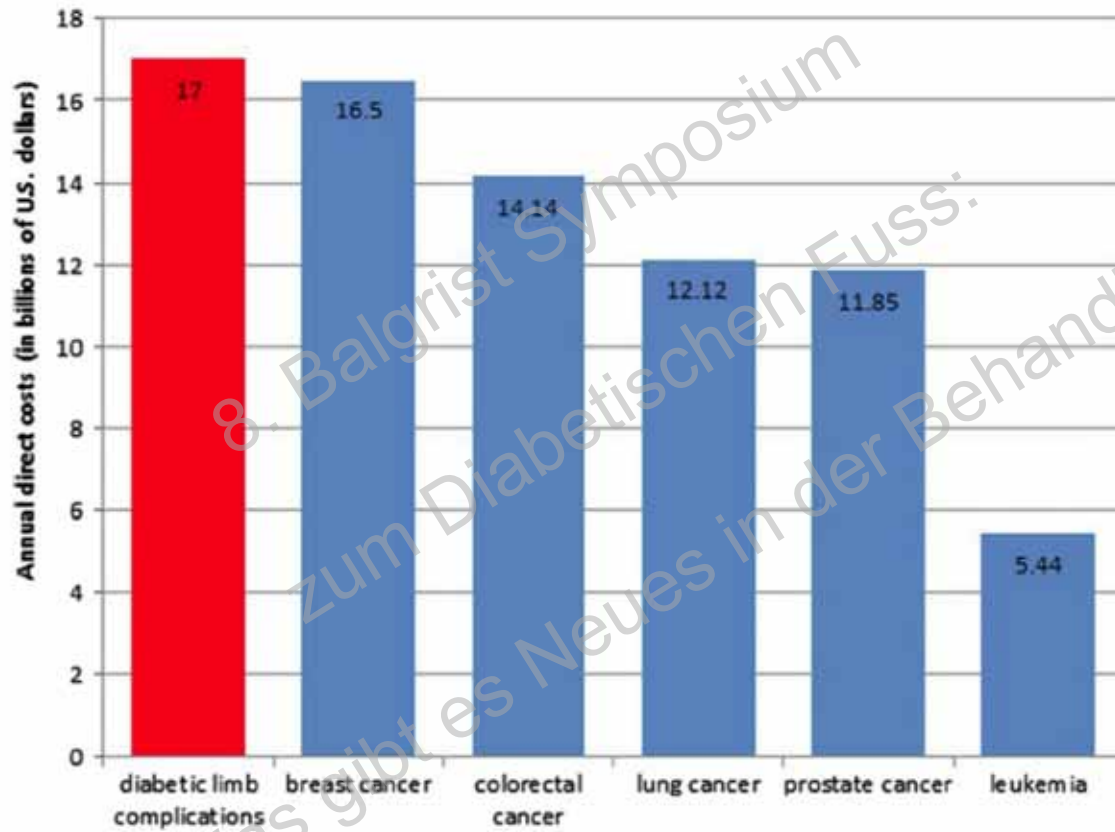
8. Balgrist Symposium  
zum Diabetischen Fuss  
Was gibt es Neues in der Behandlung?



# Diabetic Foot = Cancer?

8. Edgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?





Barshes, et al, 2013

# Relative 5 Year Mortality



Armstrong, et al, Int Wound J, 2007  
Aulivola, et al, Arch Surg, 2004  
American Cancer Society, 2000  
National Cancer Institute (<http://seer.cancer.gov>), 2007  
Moulik, et al, Diabetes Care, 2003  
Faglia, et al, Circulation, 2005  
Office Natl. Statistics, UK, 2006  
Singh, Armstrong, Lipsky, JAMA, 2006

8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

REVIEW ARTICLE

Julie R. Ingelfinger, M.D., *Editor*

# Diabetic Foot Ulcers and Their Recurrence

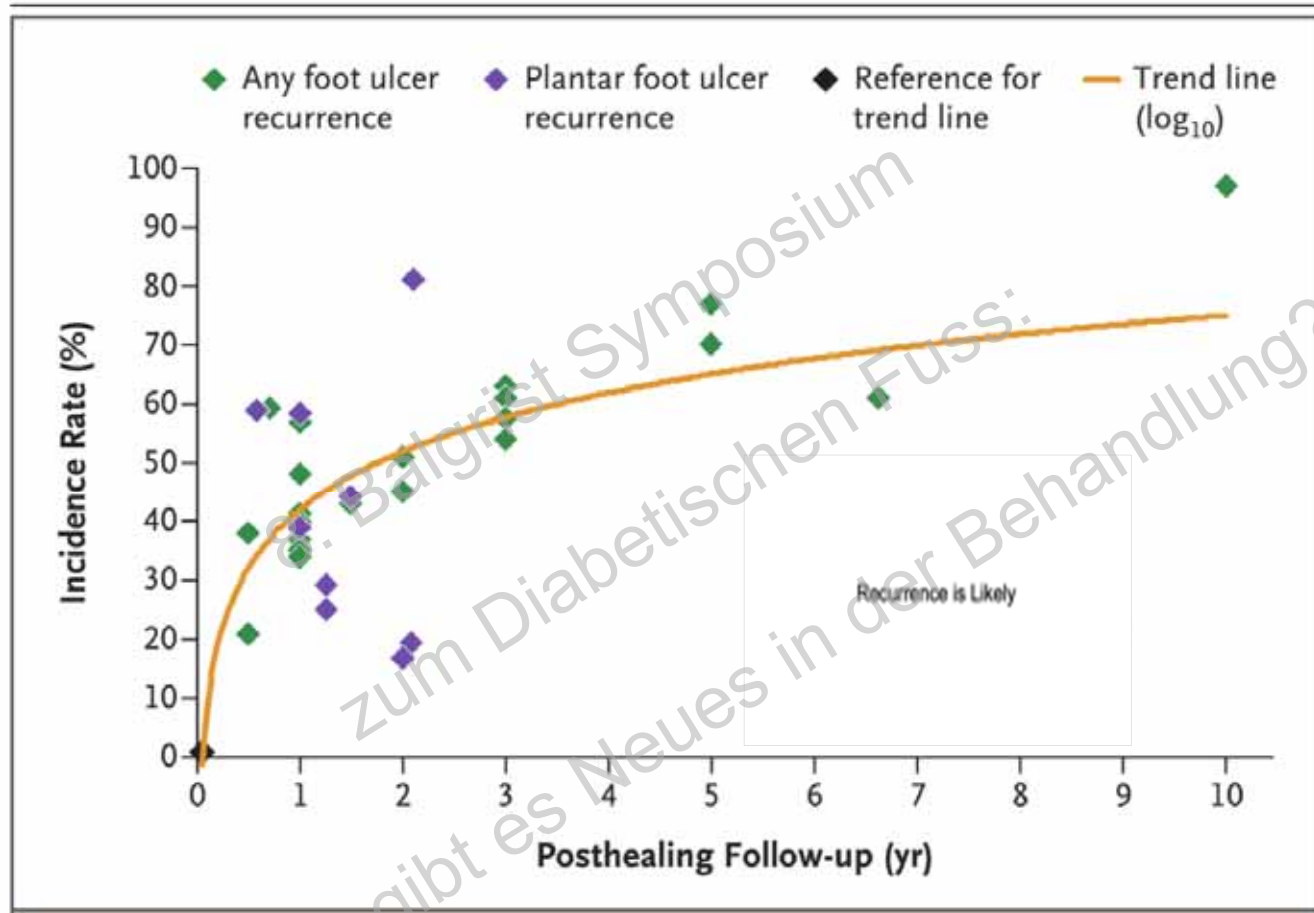
David G. Armstrong, D.P.M., M.D., Ph.D., Andrew J.M. Boulton, M.D.,  
and Sicco A. Bus, Ph.D.

**C**OMPLICATIONS OF DIABETES THAT AFFECT THE LOWER EXTREMITIES ARE common, complex, and costly. Foot ulceration is the most frequently recognized complication. In a community-based study in the northwestern United Kingdom, the prevalence of active foot ulcers identified at screening among persons with diabetes was 1.7%, and the annual incidence was 2.2%.<sup>1</sup> Higher annual incidence rates have been reported in specific populations: 6.0% among

From  
Allian  
Unive  
Tucsc  
cine,  
Manc  
A.J.M

ULCERS AND THEIR RECURRENCE

do not  
 induce  
 reach  
 mini-  
 d for  
  
 are so  
 both.  
 ulcer  
 pathy,  
 , and  
 y not  
 icture  
 ed by  
 o not  
 pathy,  
 e pro-  
 d that  
 here-



**Figure 2. Incidence of Ulcer Recurrence.**

Data are from nine prospective follow-up studies, one retrospective study, and the control groups (i.e., patients who received usual care) in nine ran-

# Recurrence is Likely

8. Podorist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?



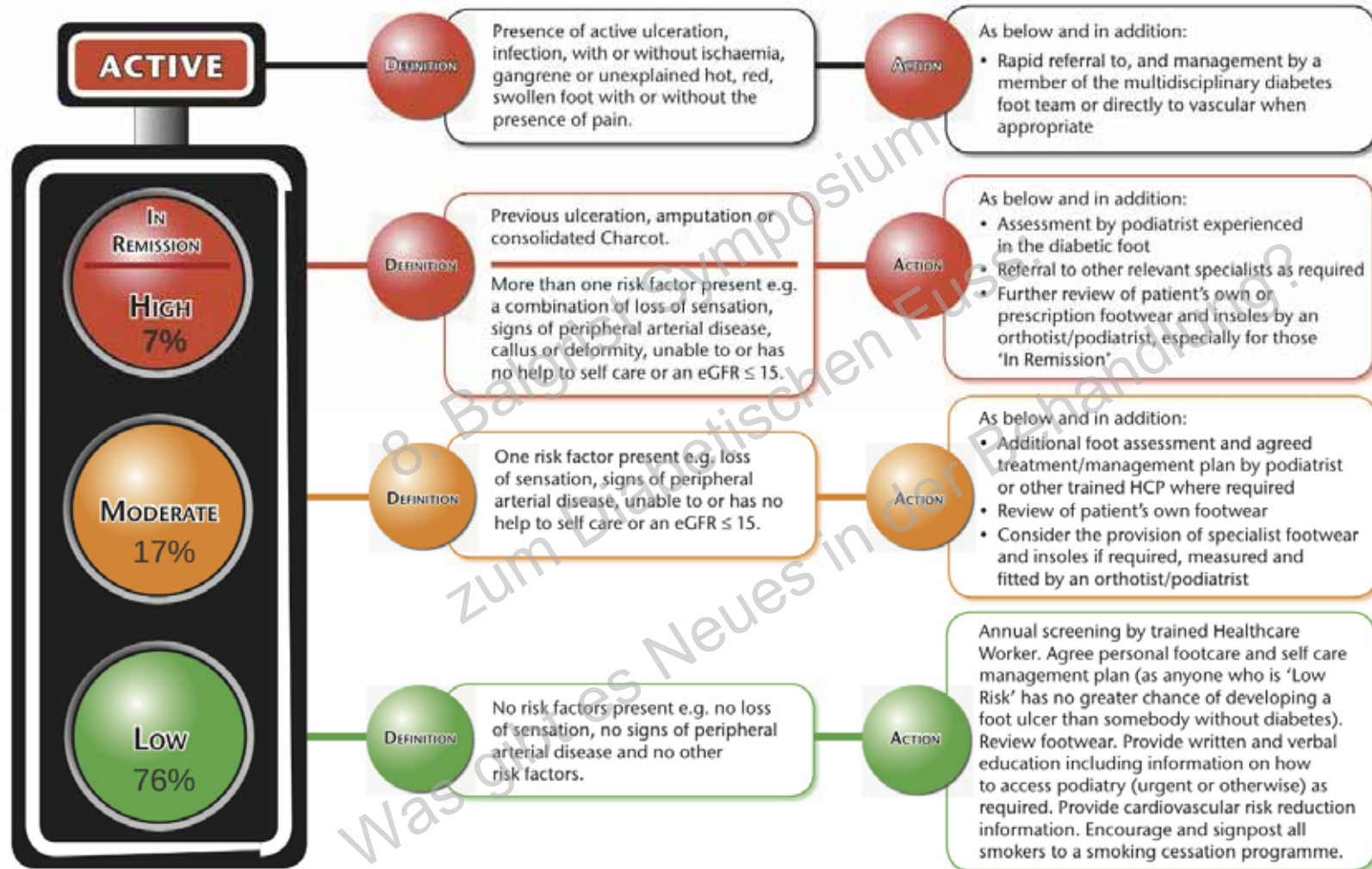
# Diabetic Foot = Cancer

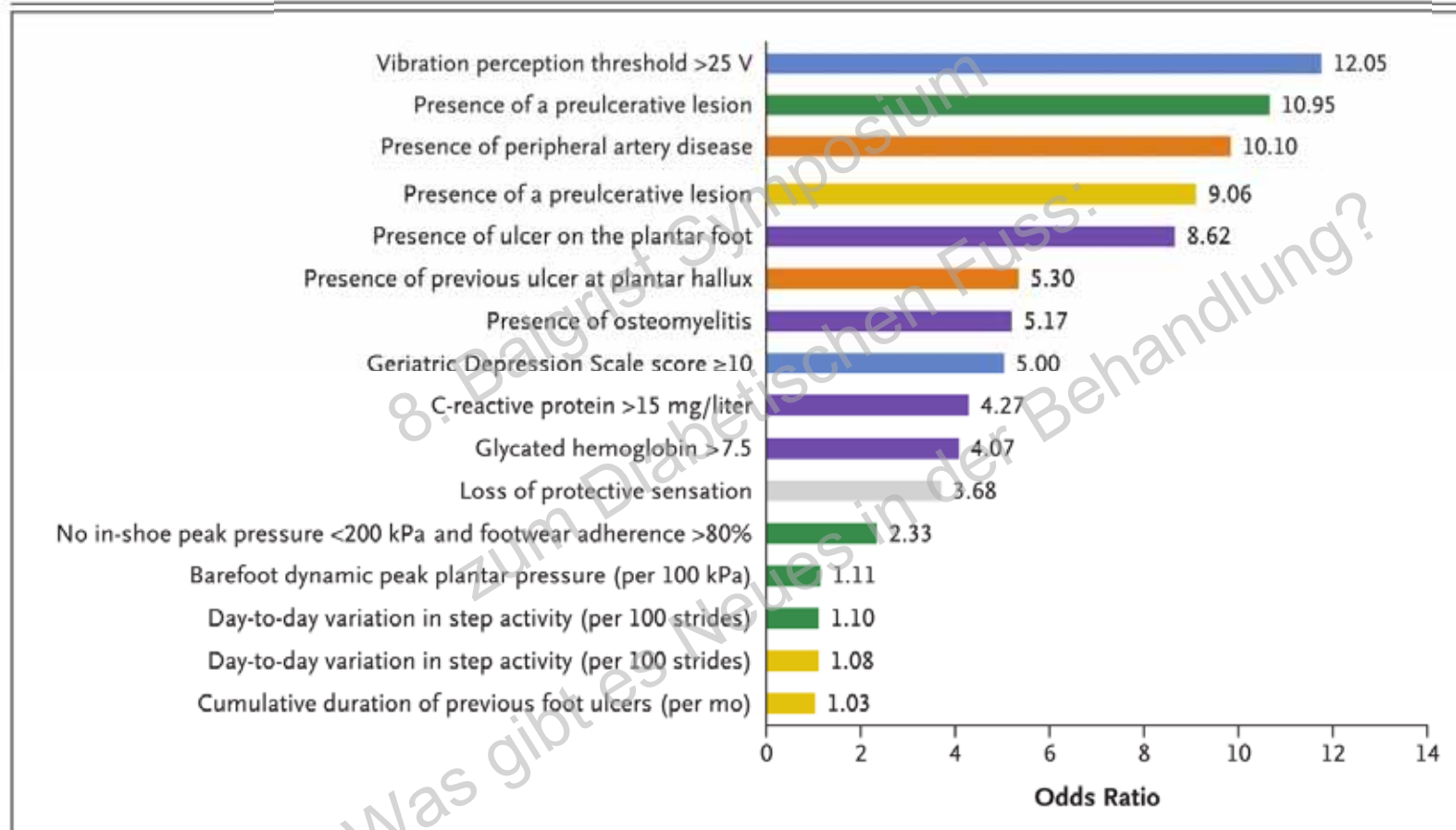
8. Ekkrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

# Wound Healing = Remission

Armstrong and Mills, JAPMA 2013  
Armstrong, Boulton and Bus, NEJM, 2019

# DIABETIC FOOT RISK STRATIFICATION AND TRIAGE





**Figure 3. Risk Factors Independently Associated with Ulcer Recurrence.**

Data are from five studies that reported an odds or risk ratio.<sup>28,33,42,52,56</sup> According to Monami et al.<sup>42</sup> (blue), risk factors for ulcer recurrence are a vibration perception threshold greater than 25 V and a Geriatric Depression Scale score of

The NEW ENGLAND JOURNAL of MEDICINE



# Callus



8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?



# Callus = Breast Lump



=



8. Balgrist Symposium  
zum Diabetischen Fuss  
Was gibt es Neues in der Behandlung?

# On Advocacy



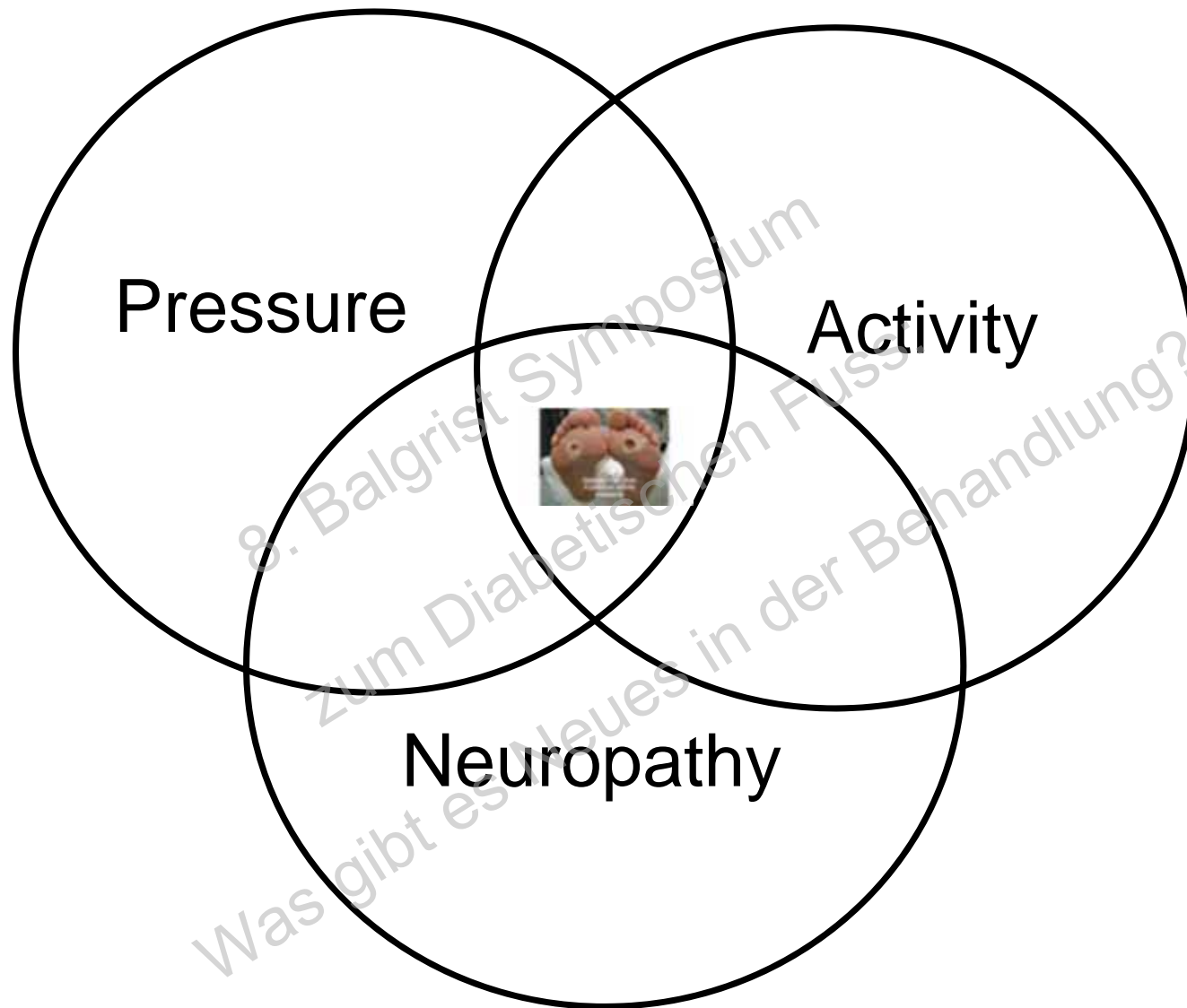
8. Balgrist Symposium  
Zur Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?



No one wants to be *defeeted*

**The Diabetic Foot In Remission:  
How can I prevent (severe) recurrence?**

8. Balgrin Symposium  
zum Diabetischen Fuß.  
Was gibt es Neues in der Behandlung?



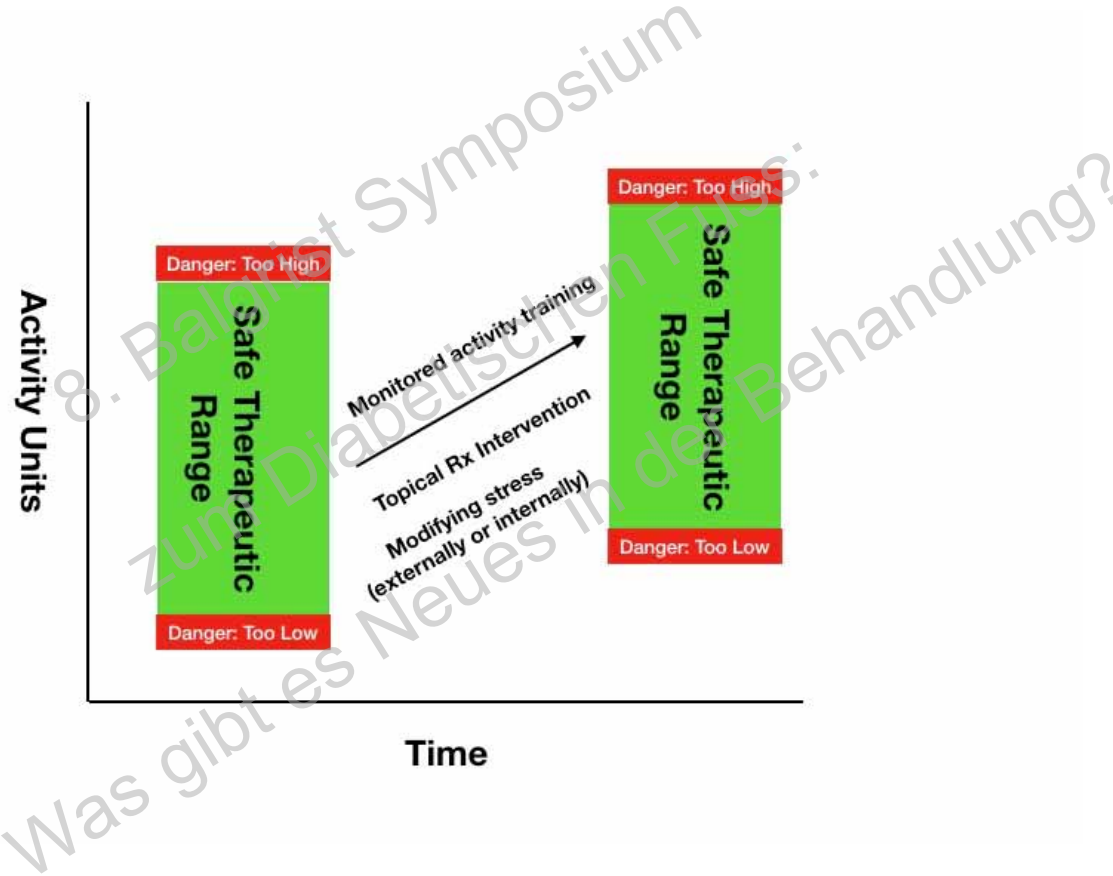




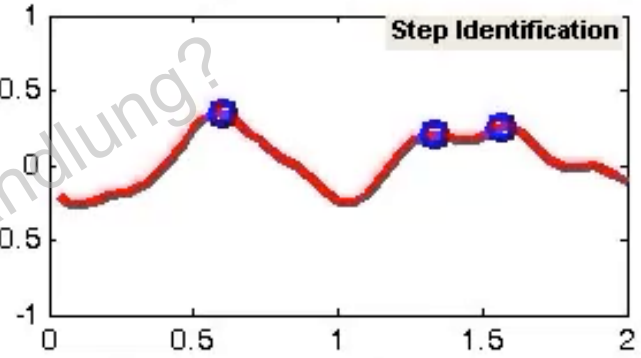
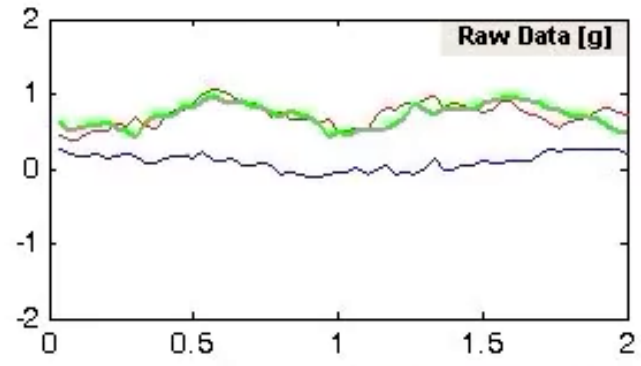
Diabetic Foot Ulcer  
A pressure activity  
imbalance

8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

# Dosing activity as a drug







- Activity**
- Lying
  - Sitting
  - Standing
  - Walking
  - Running
  - Jumping

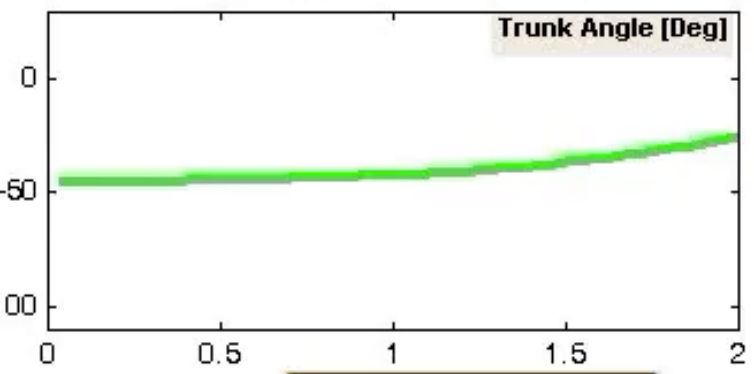
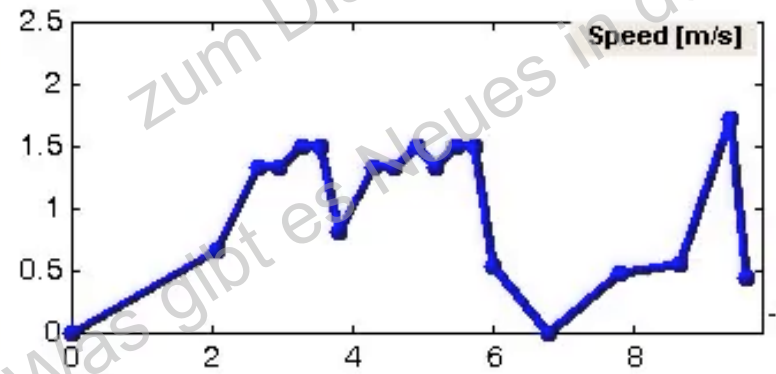
**Locomotion**

Number of Steps

**18**

Speed (m/s)

**0.4**



Start

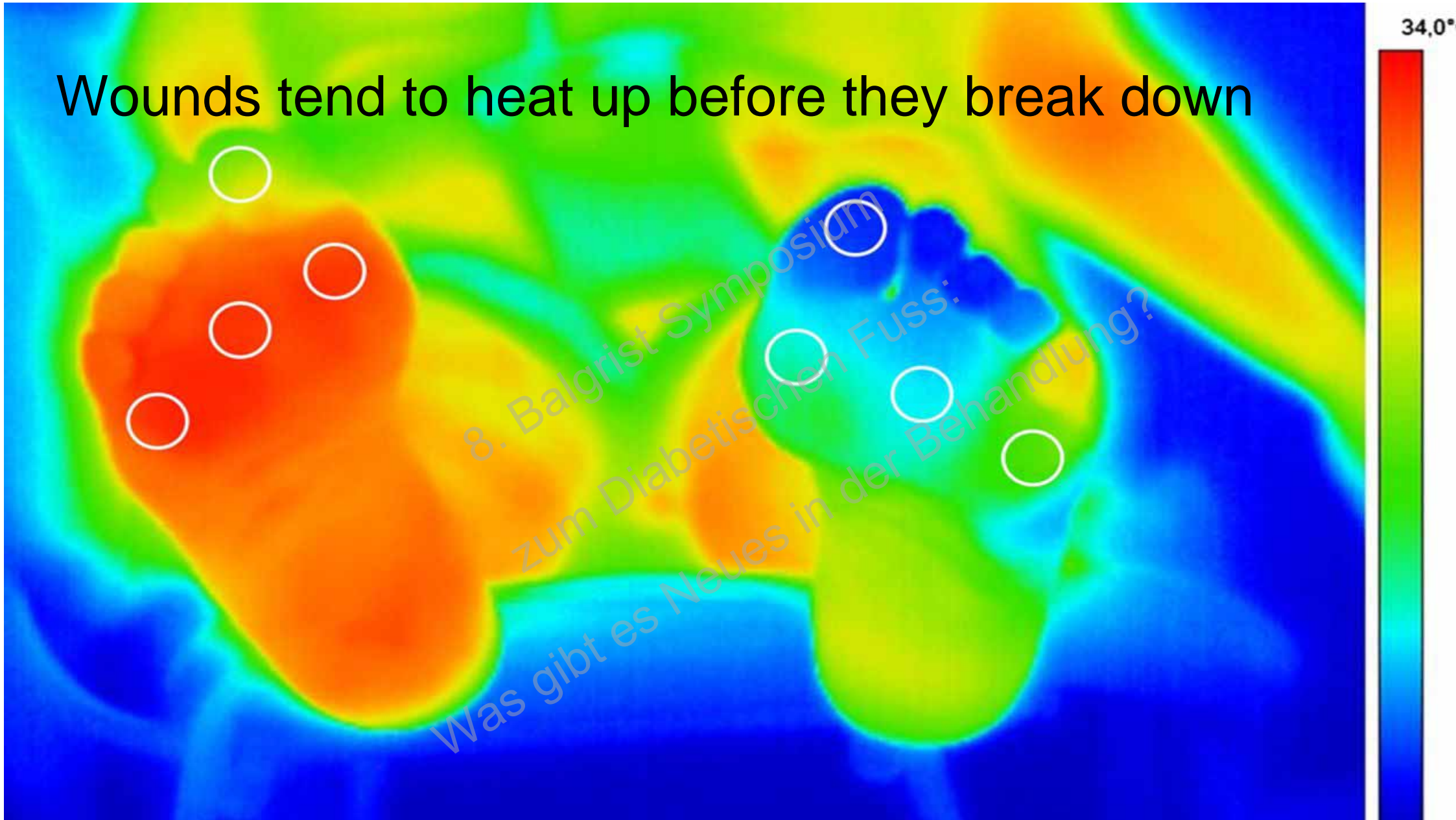
# Dosing activity as a drug

8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?



8. Badgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

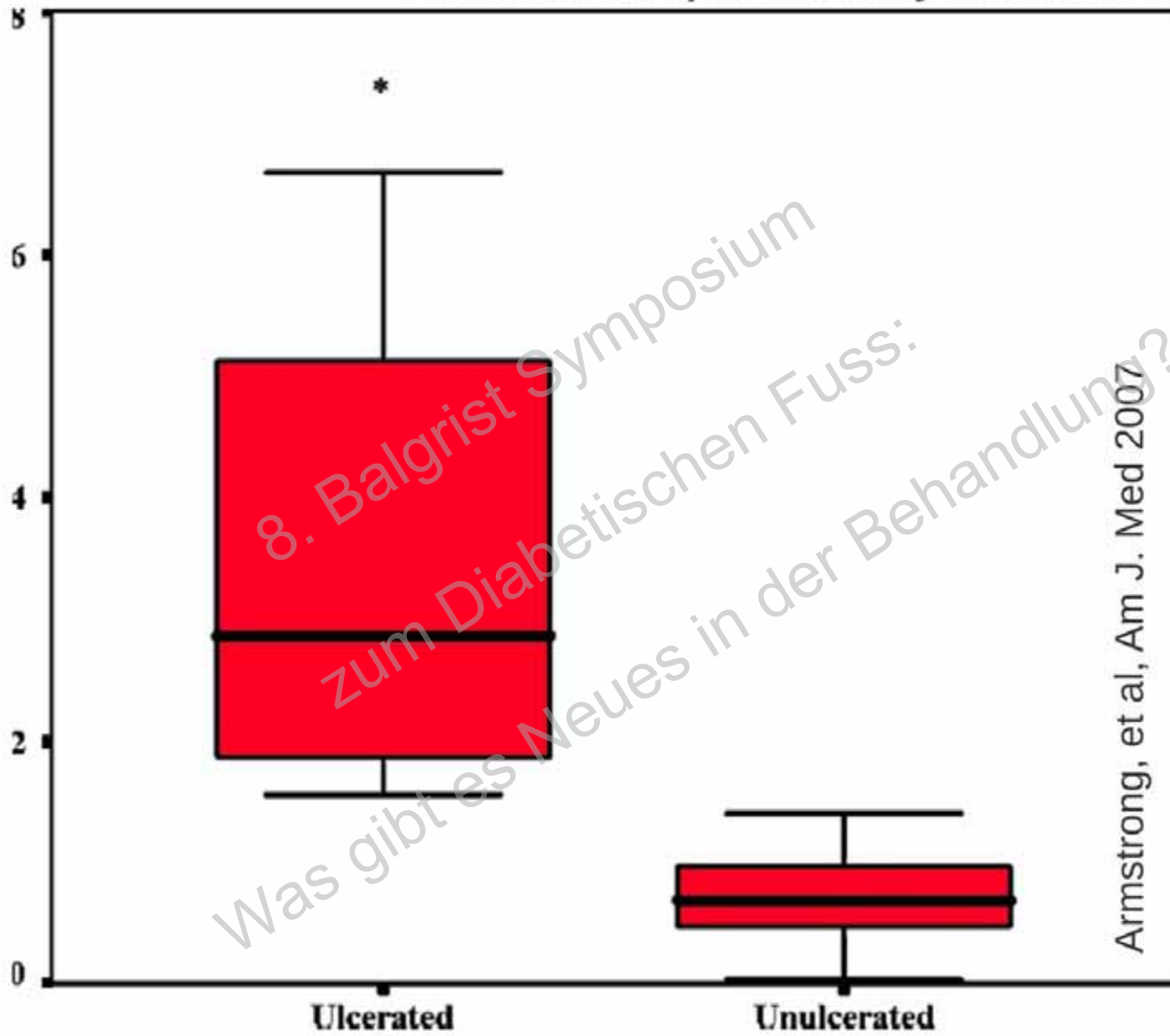
Wounds tend to heat up before they break down



Wounds tend to heal break down



*Wounds heat up before they break down*

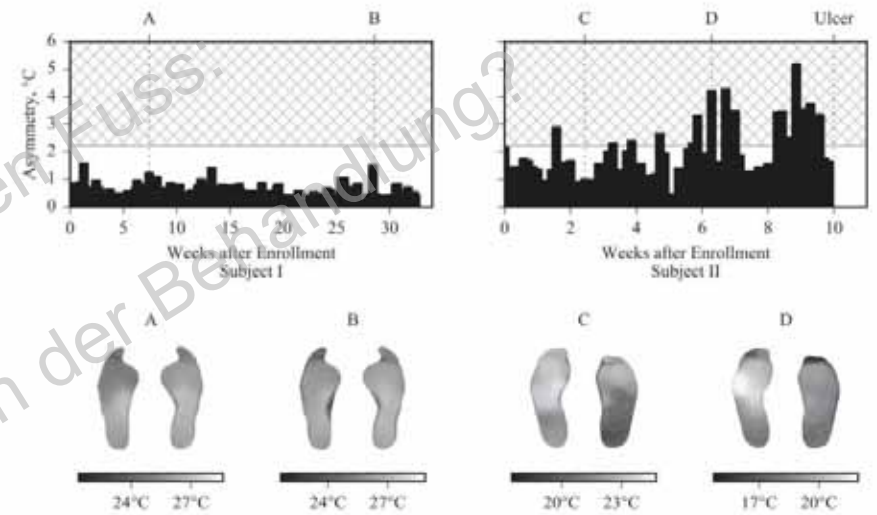


8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

Armstrong, et al, Am J. Med 2007



# Smart Bathmat



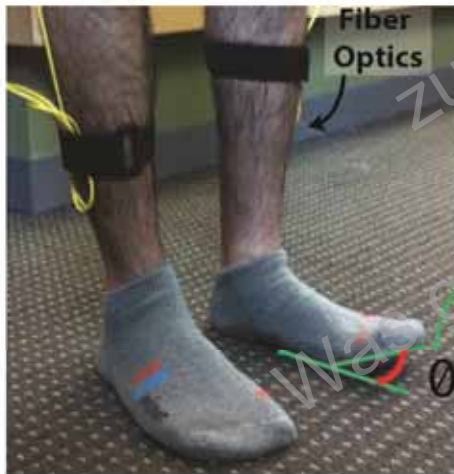
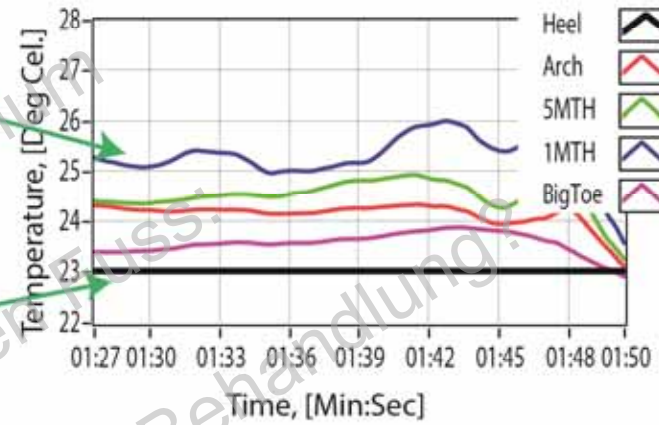
**Figure 2**—Comparison of thermometric data from a participant who did not develop a new DFU during the study (left) with the data from a participant who did (right). In the thermograms, the plantar aspect of the foot is viewed from below so that the right foot is at image left.

Frykberg (Najafi) et al, Diabetes Care 2017

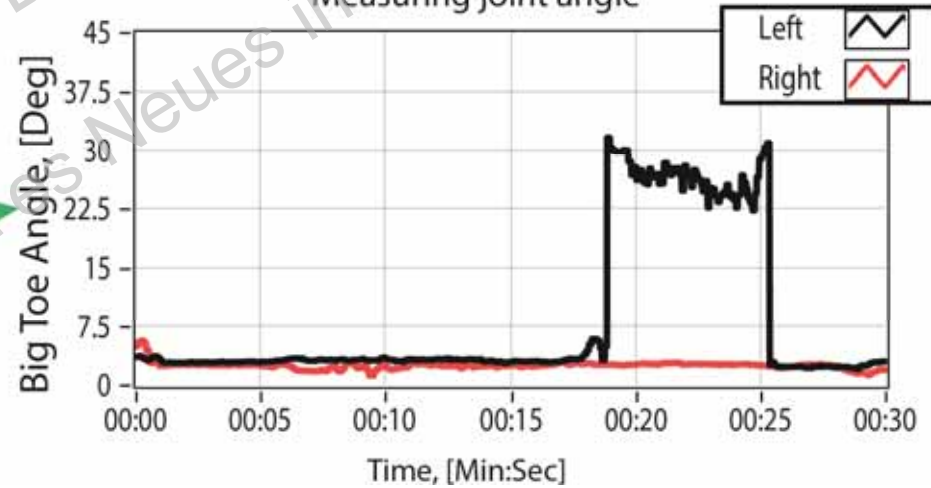
# Smart Sox



Measuring plantar temperature



Measuring joint angle





# A Subscription Prescription?



Armstrong DG, J Wound Care, 2019  
Reyzelman, et al, JIMR, 2018



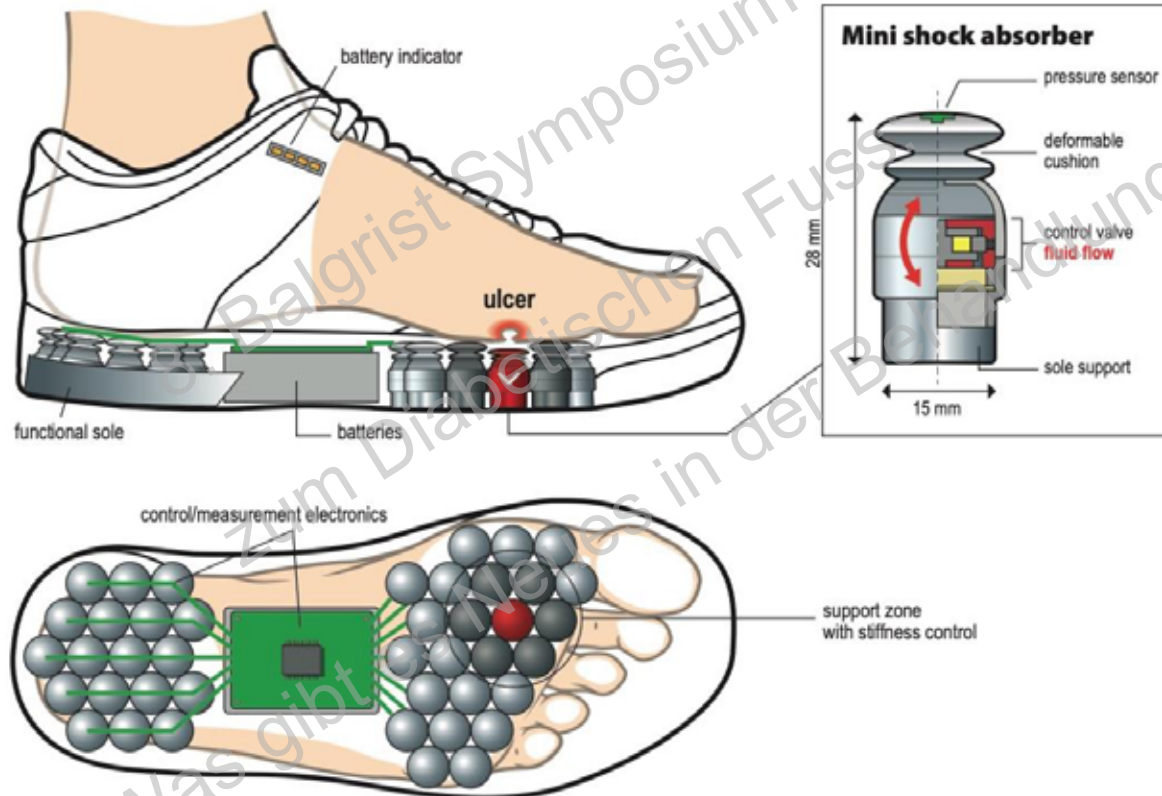
**CONGRATS! TECH COMPANY**  
**@SIRENCARE'S**  
**#DIABETICFOOT SOCK WINS**  
**@TECHCRUNCH #CES2017**  
**BATTLE**

Was gibt es Neues in der Behandlung?  
Balgrist Symposium

# Smart Shoes and Insoles?

## A smart shoe provides relief to diabetic feet

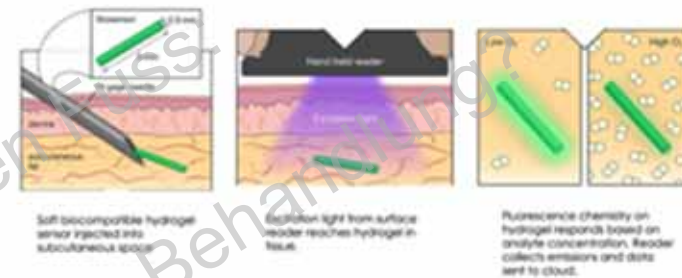
EPFL researchers together with the University Hospitals of Geneva have developed a shoe sole with valves that electronically control the pressure applied to the bottom of diabetic feet. This therapy will help treat serious foot ulcers and reduce the risk of amputation.



Graphic: Pascal Coderey / EPFL

Pataky Lab

# An Arranged Marriage? Wearables +

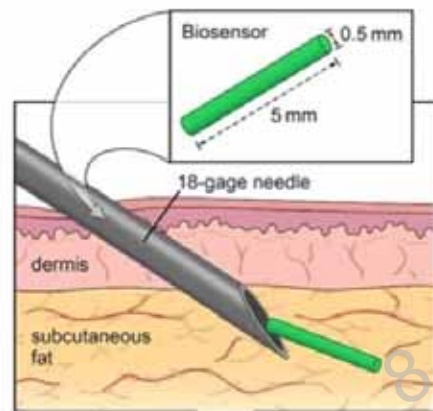


Montero-Baker, (Wiesnewski N) et al, J Vasc Surg, 2015  
Sugar, Armstrong, Hollander, et al, Gerontol, 2017  
Armstrong, Najafi, Shahinpoor, Gerontol, 2017

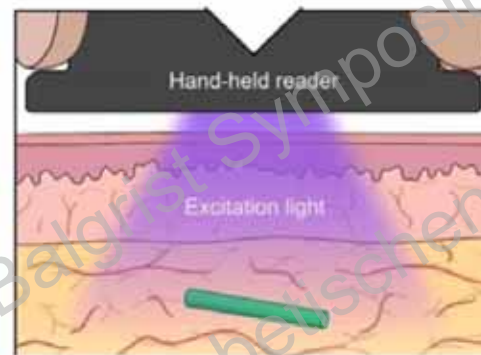


8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

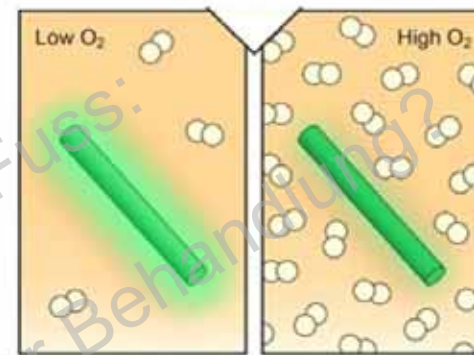
**Injectables**



Soft biocompatible hydrogel sensor injected into subcutaneous space



Excitation light from surface reader reaches hydrogel in tissue.



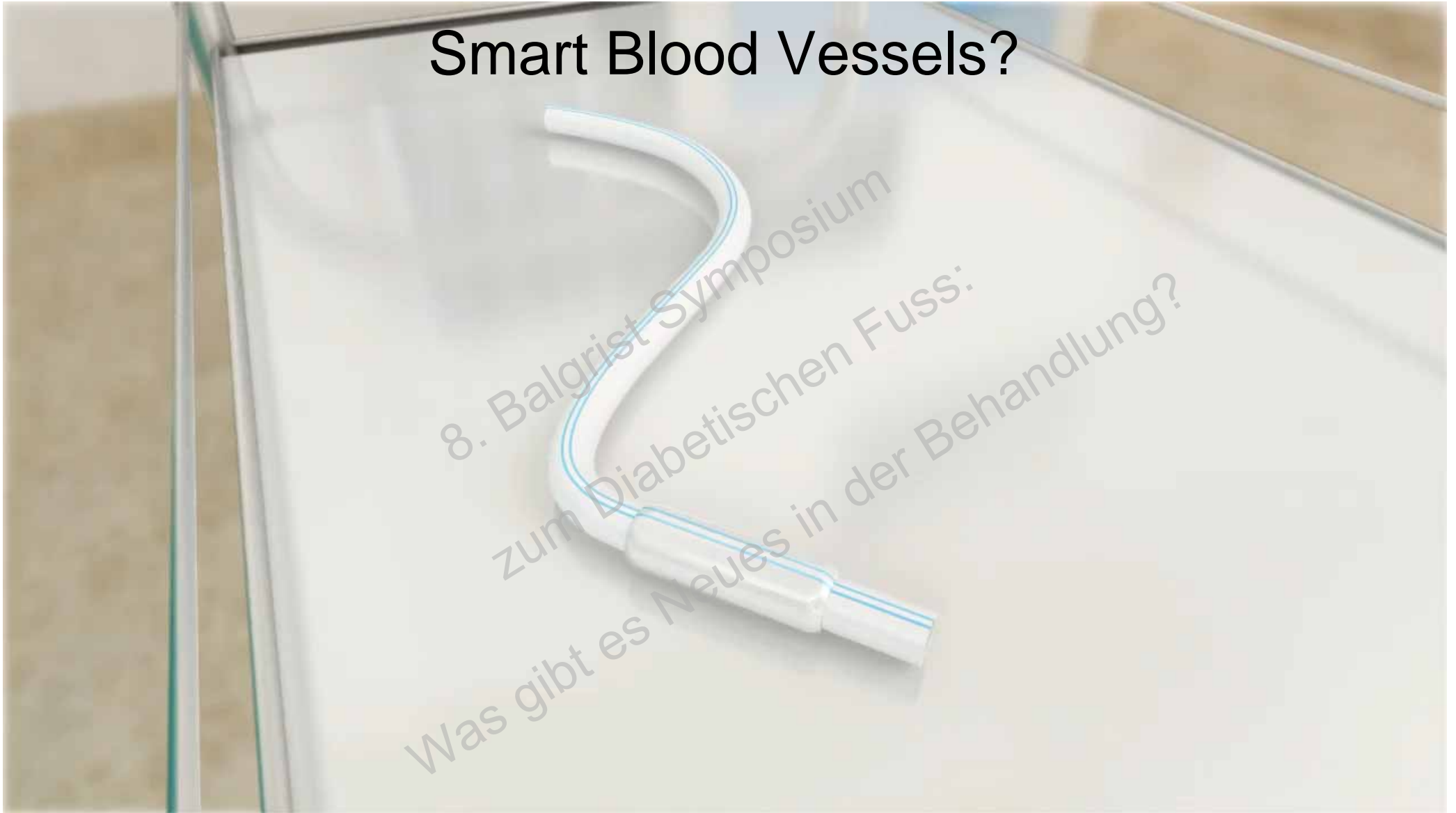
Fluorescence chemistry on hydrogel responds based on analyte concentration. Reader collects emissions and data sent to cloud.

Montero-Baker, (Wiesnewski N) et al, J Vasc Surg, 2015  
 Sugar, Armstrong, Hollander, et al, Gerontol, 2017  
 Armstrong, Najafi, Shahinpoor, Gerontol, 2017



# Smart Blood Vessels?

8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

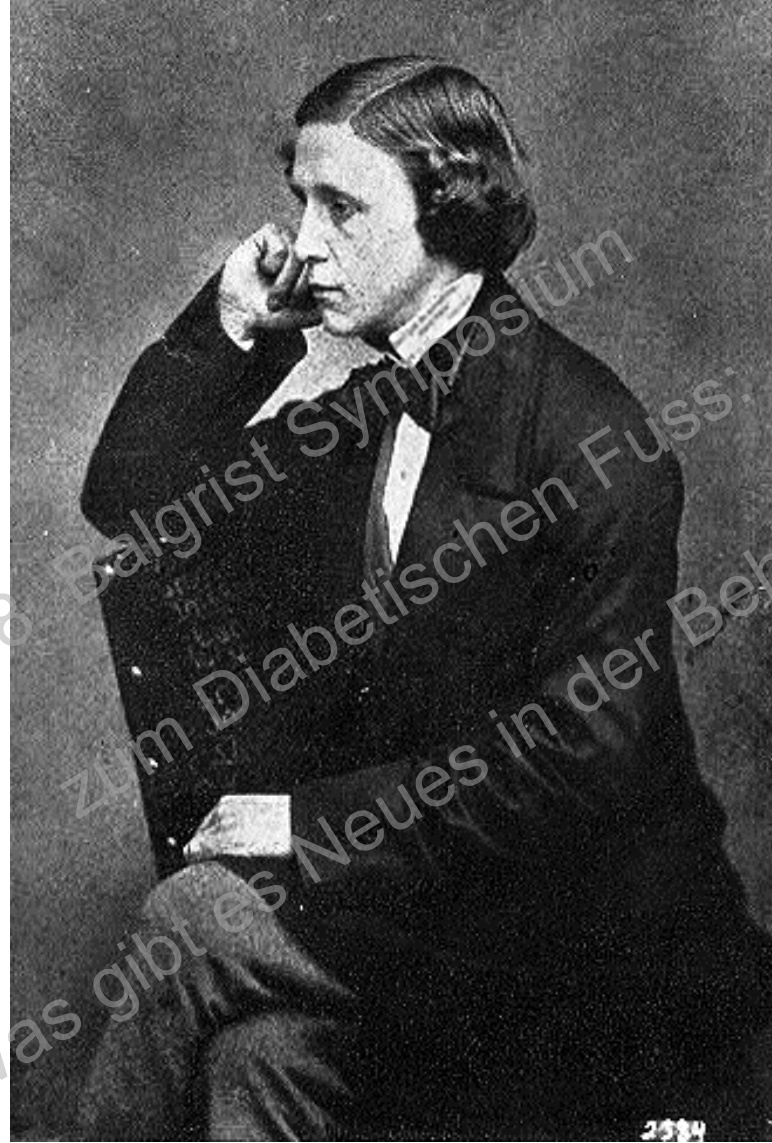


# Conclusion

8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?



8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?



8. Balgruet Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

**”Don’t just do something...  
...stand there”**

Lewis Carroll

# Conclusion

8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

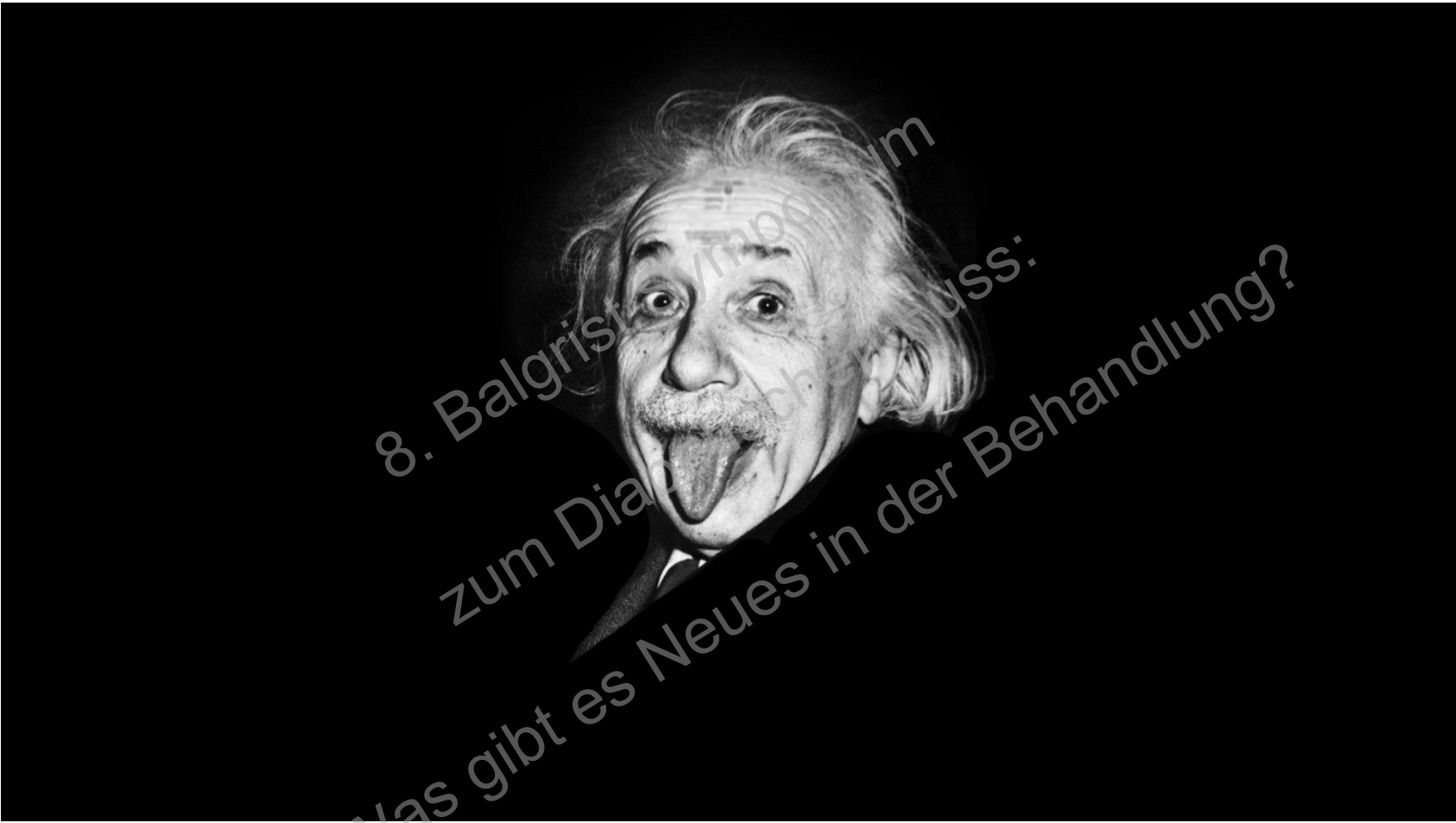




“Position yourself well  
enough, and  
circumstances will do the  
rest”

Mason Cooley

8. Badrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?



8. Balgrist / mpe / im  
zum Dia / ch / auss:  
Was gibt es Neues in der Behandlung?

“Not everything that’s counted counts...  
...and not everything that counts can be  
counted”

Einstein

8. Balgrist Symposium  
zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?

# Grand Unifying Metrics

- Ulcer-free days



- Hospital-free days



- Activity-rich days



8. Balgrist Symposium  
Zum Diabetischen Fuss:  
Was gibt es Neues in der Behandlung?



ToeandFlow.com  
armstrong@usa.net  
@dgarmstrong