Traumatic Hindfoot Injury Produces Long-Term Musculoskeletal Outcomes Comparable to Transtibial Amputation: the ADVANCE Study

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IMPERIAL

Disclosure

- This author declares no conflict of interest.

- This presentation represents original work and has received all necessary institutional and ethical approvals.
- The ADVANCE Study has approval from the Ministry of Defence Research Ethics Committee (MODREC; protocol No:357/PPE/12).

Background – The ADVANCE Study

- Investigation into the long-term health outcomes of the UK Military personnel injured during the Afghanistan War (2002-2014)(1).
- Assess the sustained effects of severe combat trauma, including blast injuries, gunshot wounds, traumatic amputations, and knee injuries.
- The study focuses on understanding both physical and psychological outcomes.

Over 500 injured

Comparison group

Over 500 non-injured

ADVANCE
WITH KNOWLEDGE AS OUR GUIDE

ARMED SERVICES TRAUMA REHABILITATION OUTCOME STUDY

(1) A. N. Bennett; BMJ Open; 2020

ADVANCE

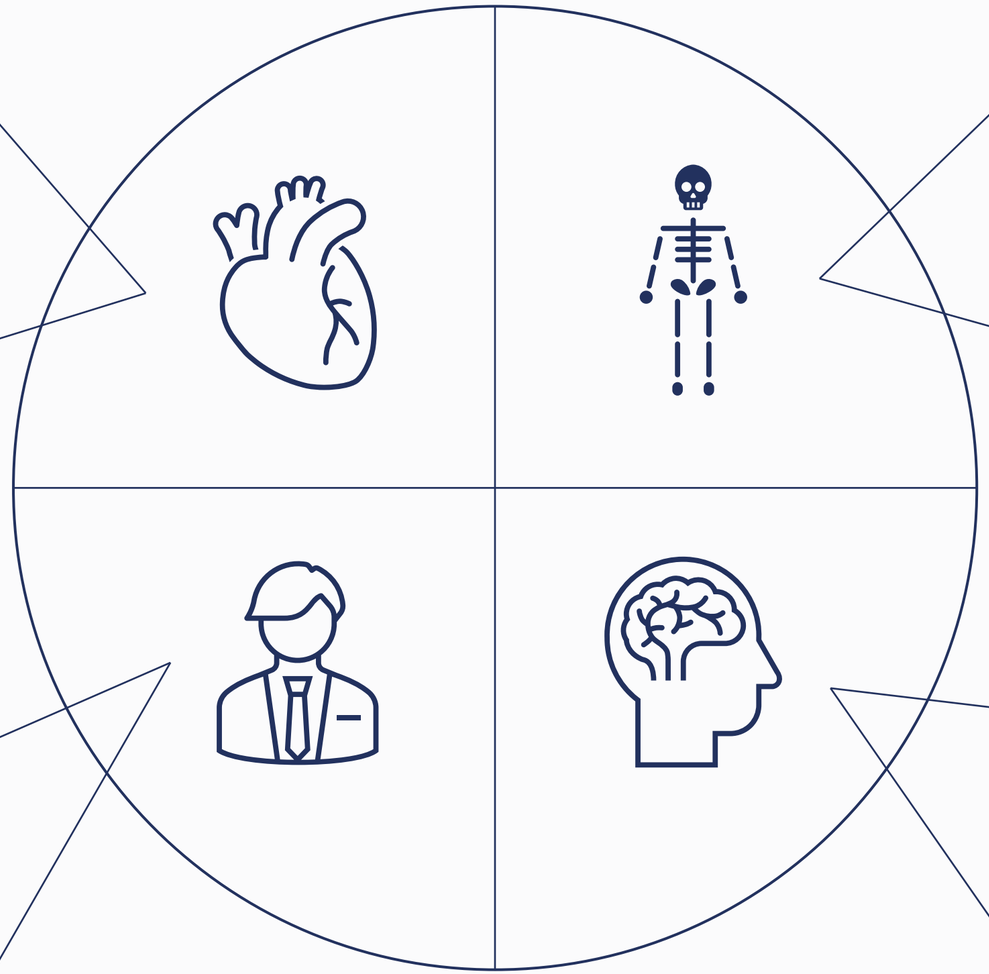
What data are we collecting?

Cardiovascular
Biometric data
Vicorder assessment
Heart rate variability
Serum samples
QRISK
Respiratory function

Musculoskeletal
Knee radiographs
Hip radiographs
DEXA scan for osteoporosis and body composition
Physical function and pain questionnaires
Axial spondyloarthritis

Additional data
Pain
Gait analysis
MRI (traumatic brain injury)
Memory
Proteomics

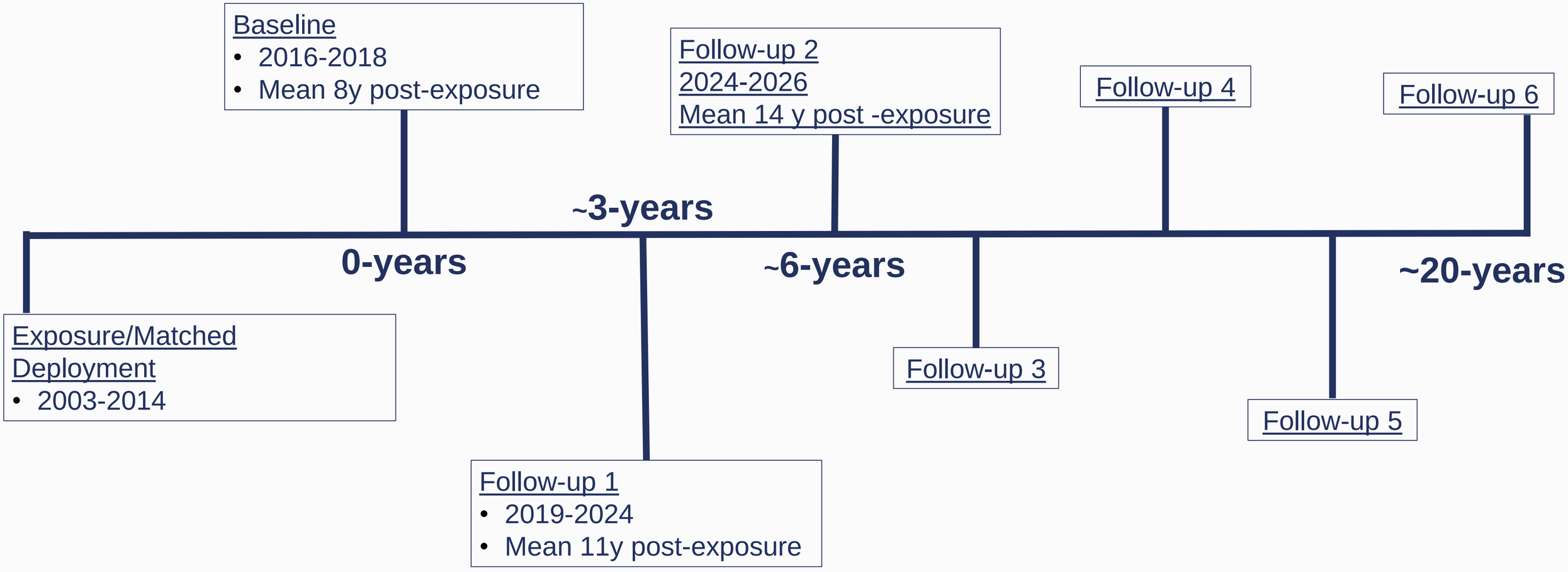
Additional data
Social support
Wearable activity monitoring
Audiology
Effect of trauma care
Ageing



Sociodemographic
Deployment
Rank and regiment
Ethnicity
Employment
Education
Reason for leaving the Armed Forces

Mental health
Alcohol and drug use
Depression and anxiety
Post-traumatic growth
Post-traumatic stress disorder
Sleep

Data collection timeline



Background – Blast injuries to the foot and ankle

- Extremity injuries represent nearly 70% of all combat wounds, with approximately one-third involving fractures(1).
- A significant proportion of foot and ankle blast injuries result in either amputation (33%) or a poor clinical outcome (ongoing clinical problems or amputation) long after the initial injury (74%)(2).
- Calcaneal fractures have been identified as one of the most disabling injuries(3).

Tertiary blast injury following an improvised explosive device. The comminuted fractured calcaneus (heel, white arrow) is a result of severe axial loading. (4)

(1) Ramasamy A; Trauma; 2013
(2) Ramasamy A; Orthopaedic Proceedings; 2013
(3) Ramasamy A; Journal of Trauma and Acute Care Surgery; 2011
(4) Ramasamy A; Journal of The Royal Society Interface; 2011

Background – Gait changes and secondary injury

Pain and structural damage → compensatory gait adaptations → long-term consequences for joint health and biomechanics

↓

Increased risk of knee osteoarthritis (OA) and decreased bone mineral density (BMD)(1-3).

The lower extremity functions as an integrated kinetic chain →

e.g. trauma at a distal site

compensatory changes and secondary injury in adjacent segments(4).


Osteoarthritis and Cartilage

OARSI OSTEOARTHRITIS RESEARCH SOCIETY INTERNATIONAL

The relationship between foot and ankle symptoms and risk of developing knee osteoarthritis: data from the osteoarthritis initiative

K.L. Paterson † *, J. Kasza ‡, D.J. Hunter § ||, R.S. Hinman †, H.B. Menz ¶, G. Peat #, K.L. Bennell †


Contents lists available at ScienceDirect

Osteoporosis and Sarcopenia

journal homepage: http://www.elsevier.com/locate/afos

Original article

Is ankle fracture related to low bone mineral density and subsequent fracture? A systematic review

Atiporn Therdyothin [a], Nacharin Phiphopthatsanee [b], Wiwat Wajanavisit [a], Patarawan Woratanarat [a], Sukij Laohajaroensombat [a], Tulyapruek Tawonsawatruk [a, *]

(1) Paterson KL; Osteoarthritis Cartilage; 2017
(2) Riskowski JL; J Gerontol A Biol Sci Med Sci; 2015
(3) Therdyothin A; Osteoporos Sarcopenia; 2020
(4) Theisen A; Int J Exerc Sci; 2019

Background – Transtibial amputees

- The Iraq and Afghanistan conflicts have resulted in 416 amputations in the UK military(1).
- Individuals with lower limb amputation experienced more than a 4-fold increase in the odds of knee OA x-ray changes compared to uninjured participants(2).
- In studies of amputees over five years following amputation, more than 50% are diagnosed with osteoporosis and osteopenia.

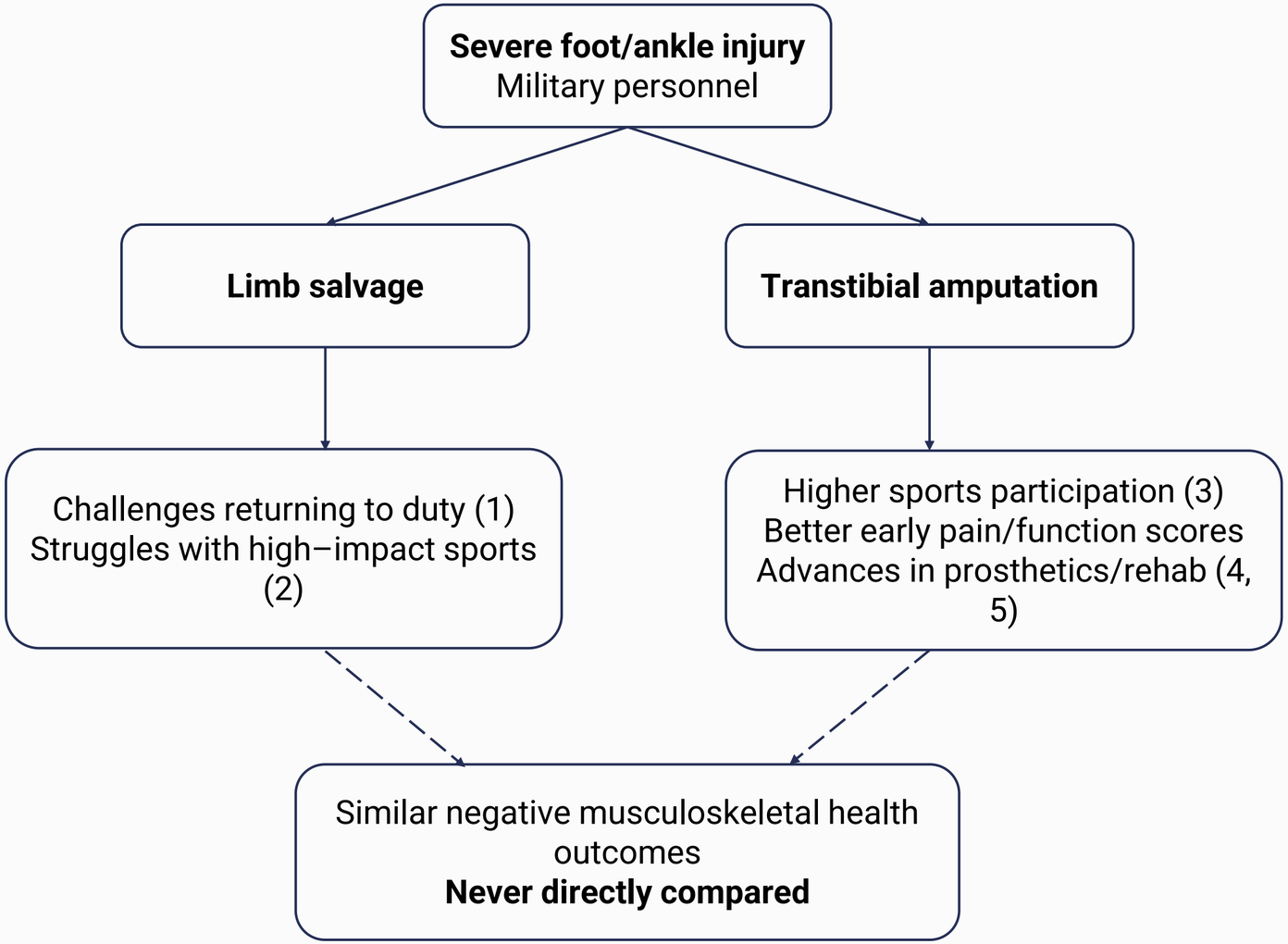
↓

localised unloading(1)

(1) Behan FP; Rheumatology Advances in Practice; 2025
(2) McMenemy L; JBMR; 2023

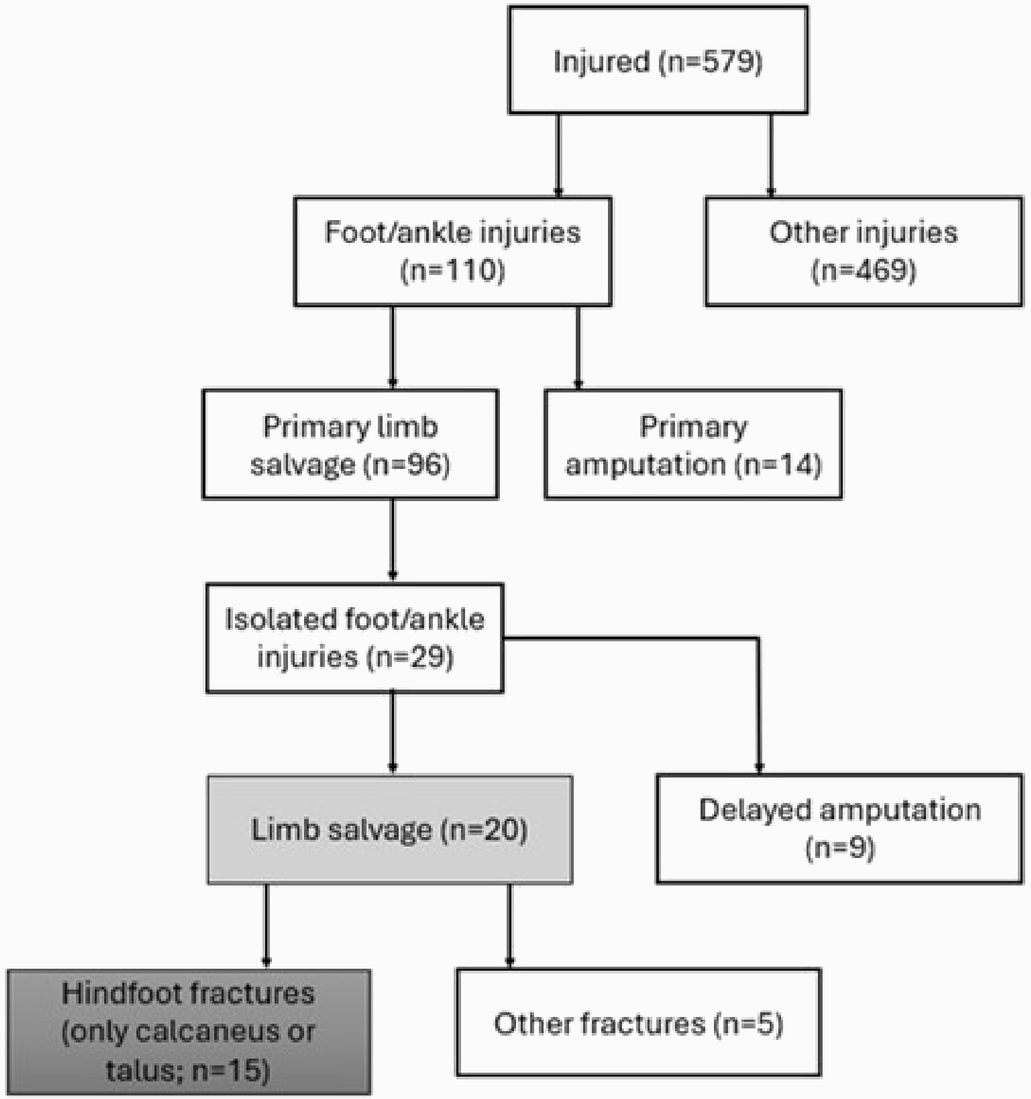
ADVANCE

Background – Limb salvage vs amputation



(1) Sheean AJ; Journal of Orthopaedic Trauma; 2014
(2) Kerkhoff YRA; Foot & Ankle International; 2017
(3) Doukas CWC; JBJS; 2013
(4) Fergason J; Foot and Ankle Clinics; 2010
(5) Ladlow P; The Journal of Bone and Joint Surgery; 2016

Cohort - Isolated Hindfoot Fractures



>30%

87% from blast

Comparison groups

Matched based on age at assessment, rank, BMI, time since a matched deployment, and ethnicity

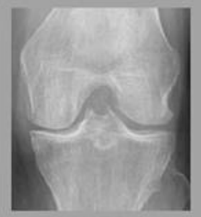
Hindfoot injured (n=15)	Unilateral TT Amputation (n=54)	Uninjured (n=55)
Age: 35.6 ± 3.4 BMI: 27.1 ± 3.3 Time since injury: 8.5 ± 2.0	Age: 33.3 ± 4.1 BMI: 28.4 ± 3.2 Time since injury: 7.8 ± 2.0	Age: 36.1 ± 3.1 BMI: 27.4 ± 3.7 Time since matched deployment: 8.4 ± 1.8

Methods

- Baseline (~8 years post-injury/deployment) and 3-year Follow-up

Objective measures:

- Radiographic OA in the knee and hip– Kellgren-Lawrence (KL) grading system

Example images					
KL Grade	**Grade0**	**Grade1**	**Grade2**	**Grade3**	**Grade4**
Classification	**Normal**	**Doubtful**	**Mild**	**Moderate**	**Severe**
Description	No radiographic features of OA	Doubtful joint space narrowing(JSN)	Definite osteophytes Possible JSN	Multiple osteophytes Definite JSN Sclerosis	Large osteophytes Marked JSN Severe scierosis

(1)

- BMD loss at the hip and spine – DEXA, t-scores

>-1 (normal), ≤-1 (osteopenia) or ≤-2.5 (osteoporosis) (2)

(1) Liu, W., Neural Processing Letters, 2022
(2) Cosman F, Osteoporos Int, 2014

Methods

Patient-reported outcomes:

Dichotomised at PASS threshold (1, 2)

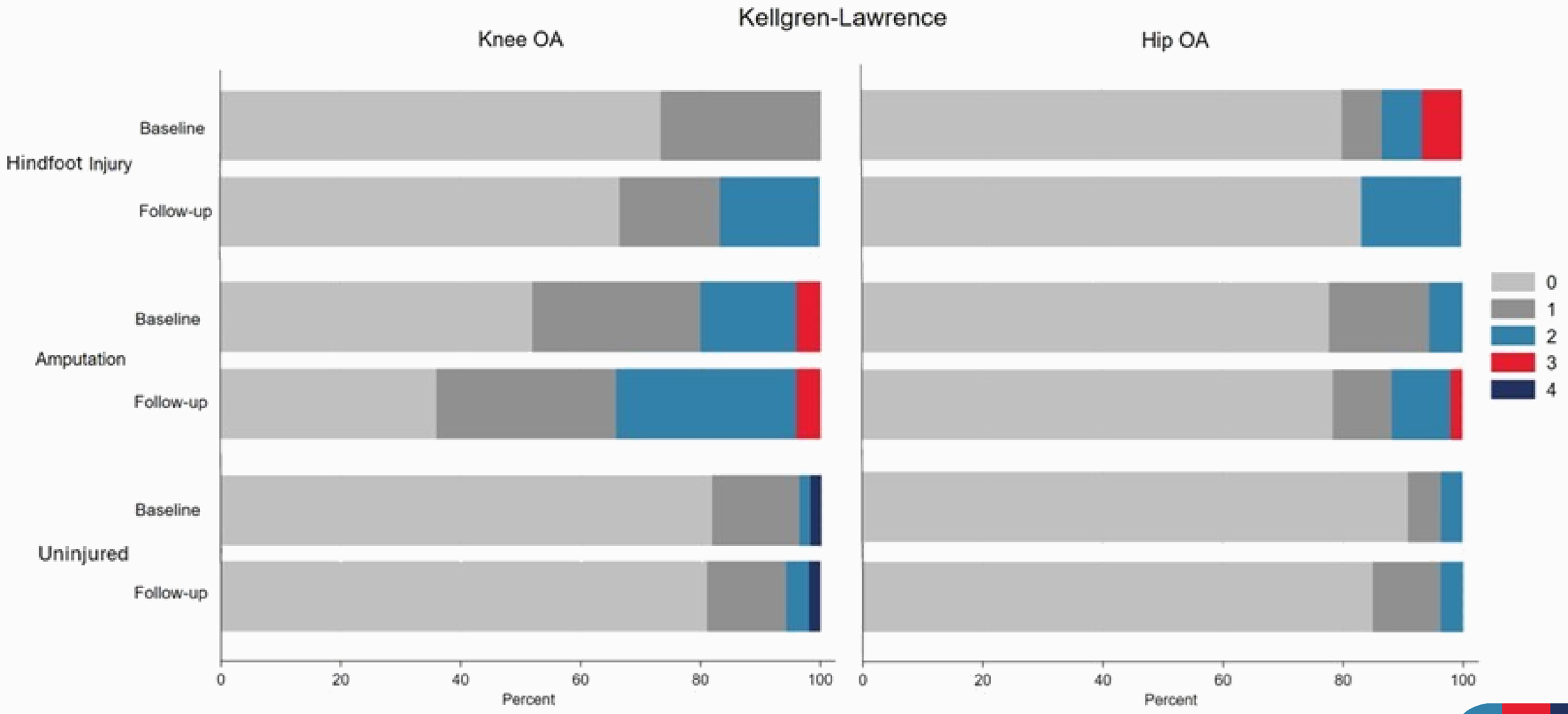
- Knee Injury and Osteoarthritis Outcome Score (KOOS)
- Non-Arthritic Hip Score (NAHS)

Continuous (3, 4)

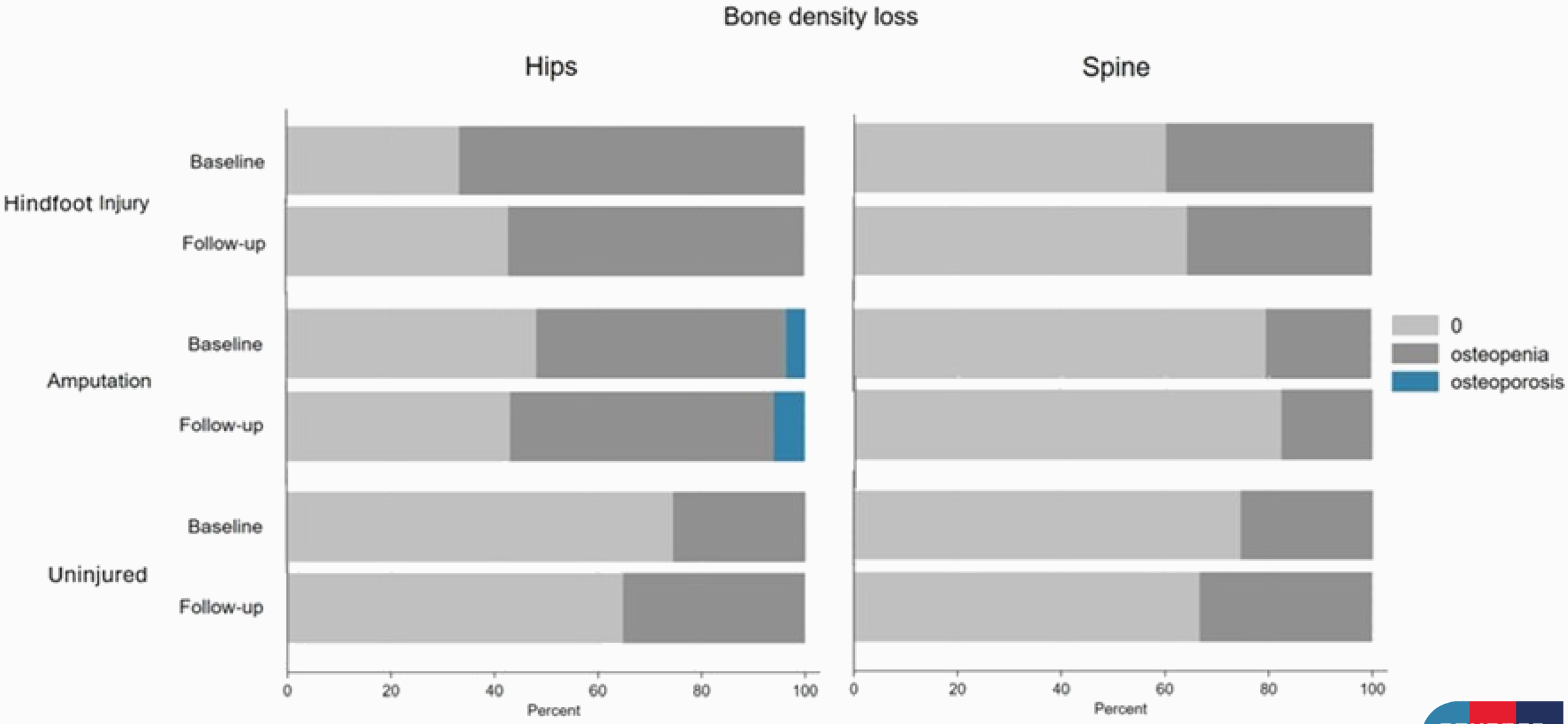
- Oswestry Disability Index (ODI)
- International Physical Activity Questionnaire (IPAQ)

(1) Wasserstein D; Osteoarthritis Cartilage; 2015
(2) Rosinsky PJ; Arthroscopy; 2021
(3) Chen Z; World Neurosurgery; 2022
(4) Forde C. Scoring the international physical activity questionnaire (IPAQ).

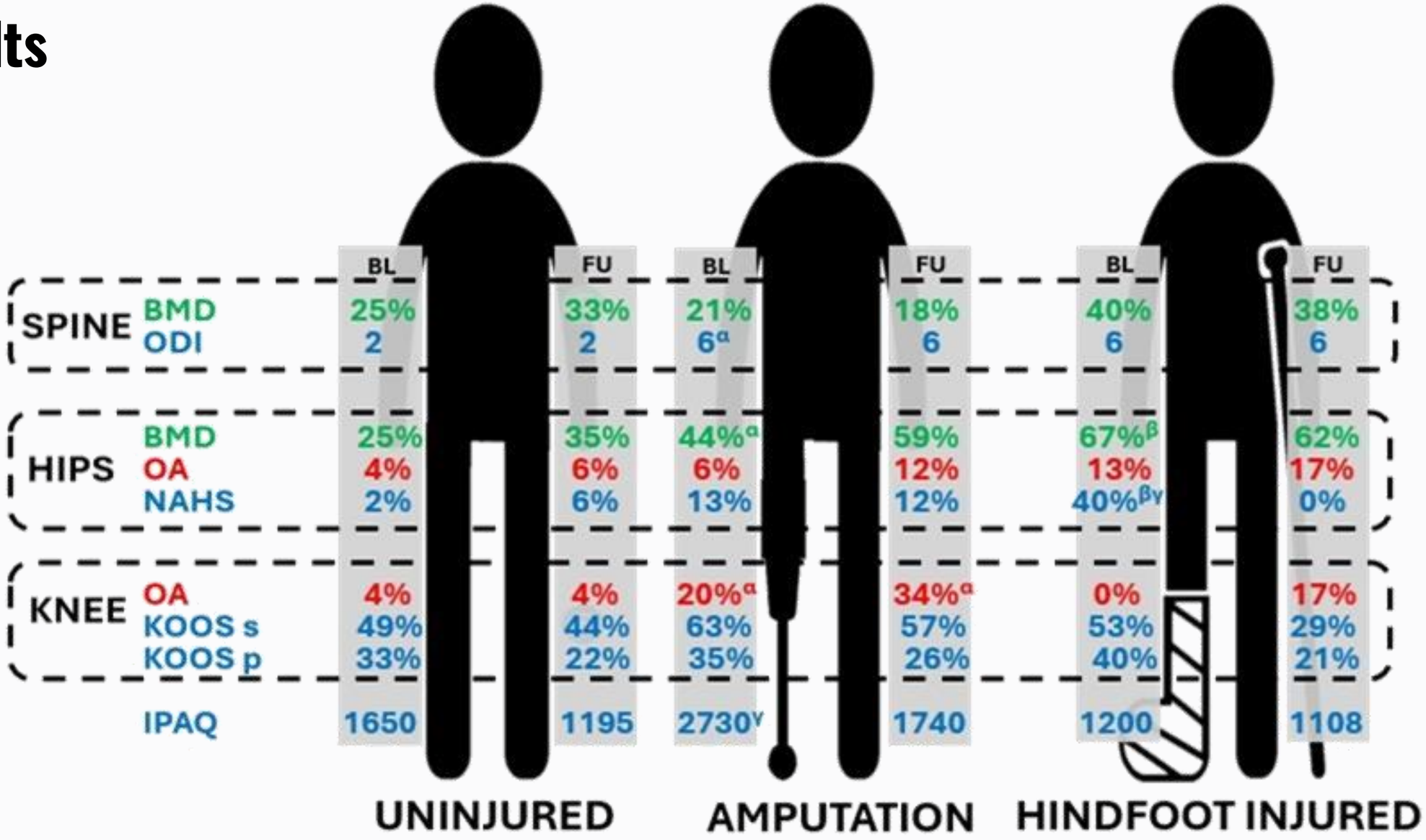
Results – Osteoarthritis



Results – Bone mineral density loss

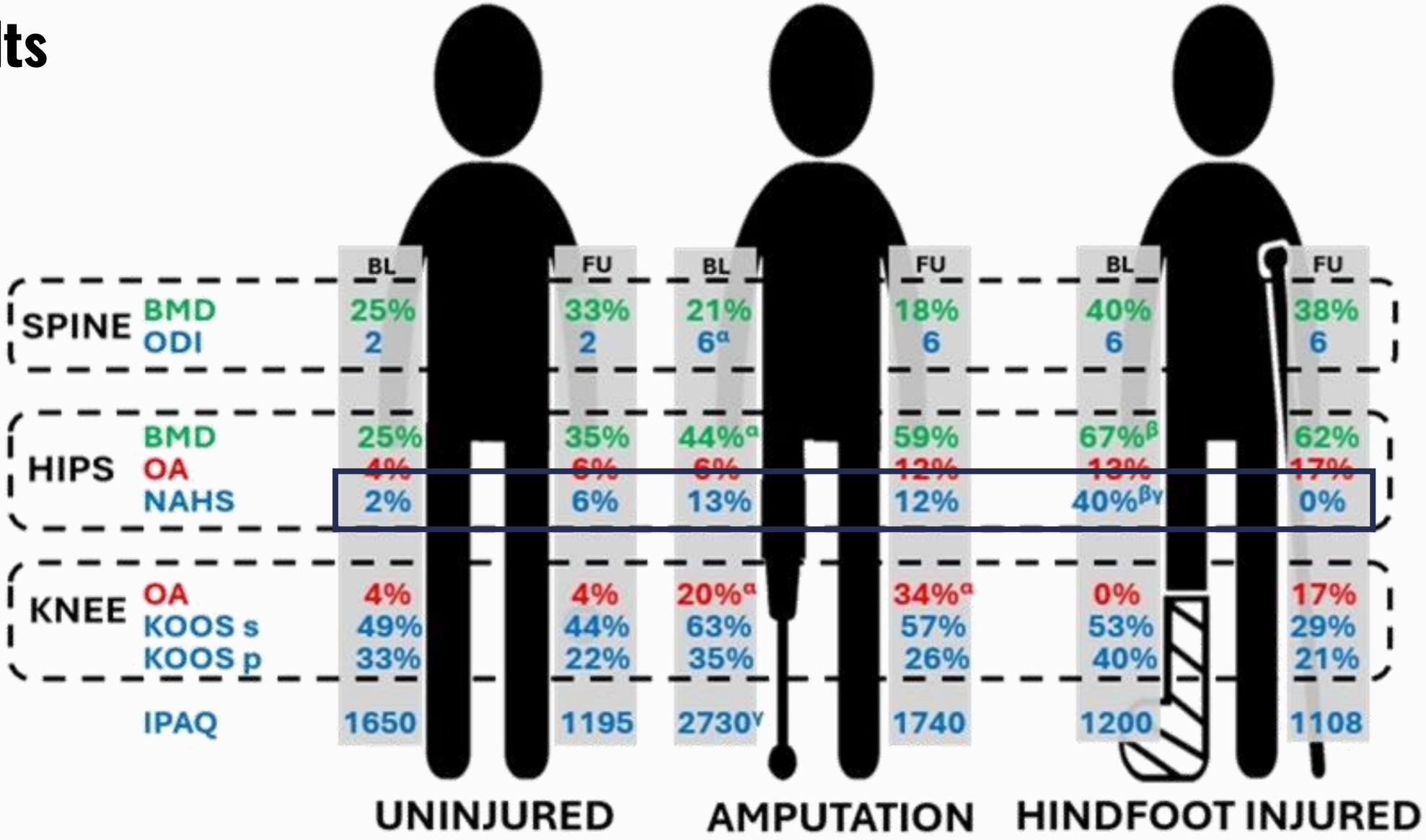


Results



Sig differences: α A v U, β H v U, γ A v H

Results



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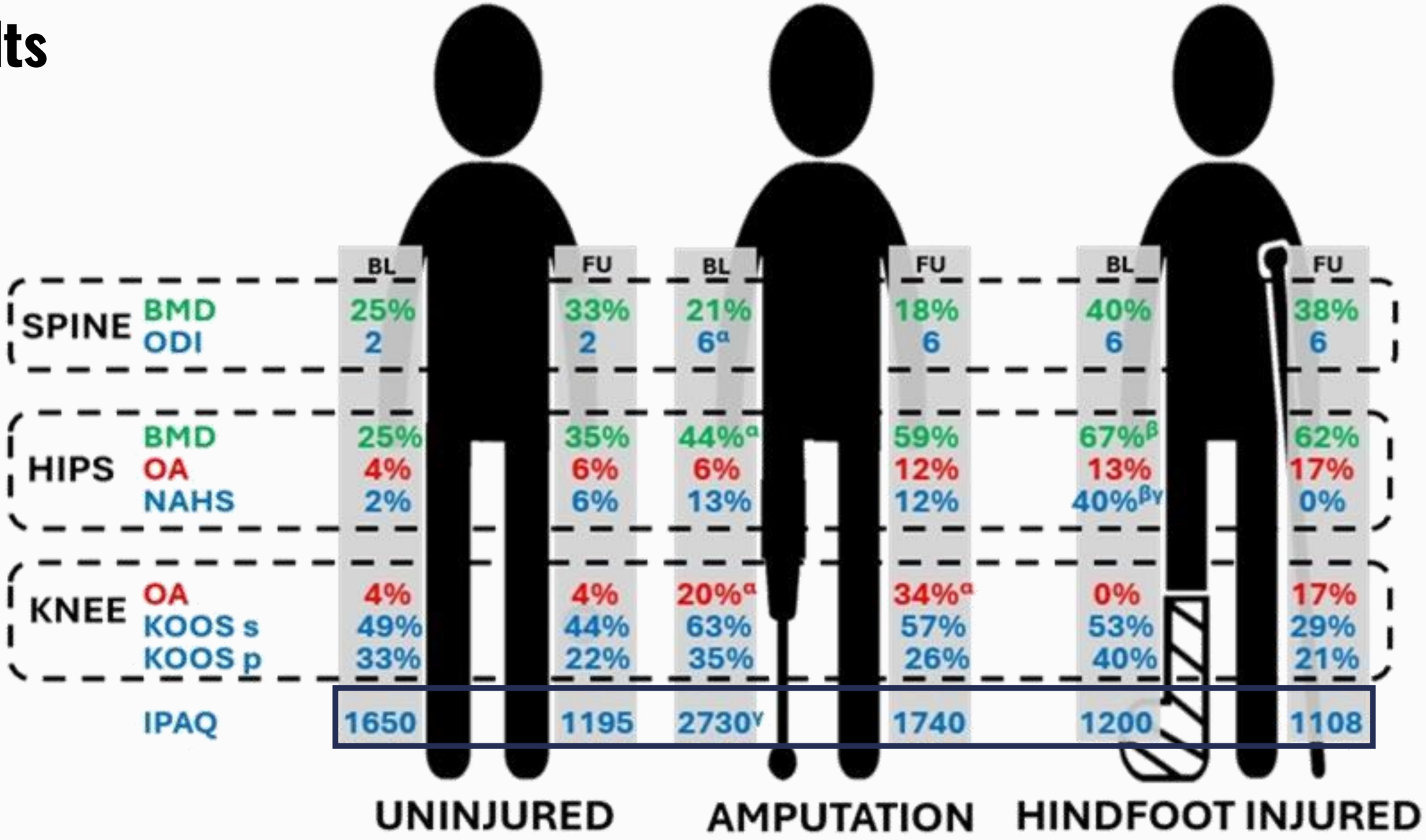
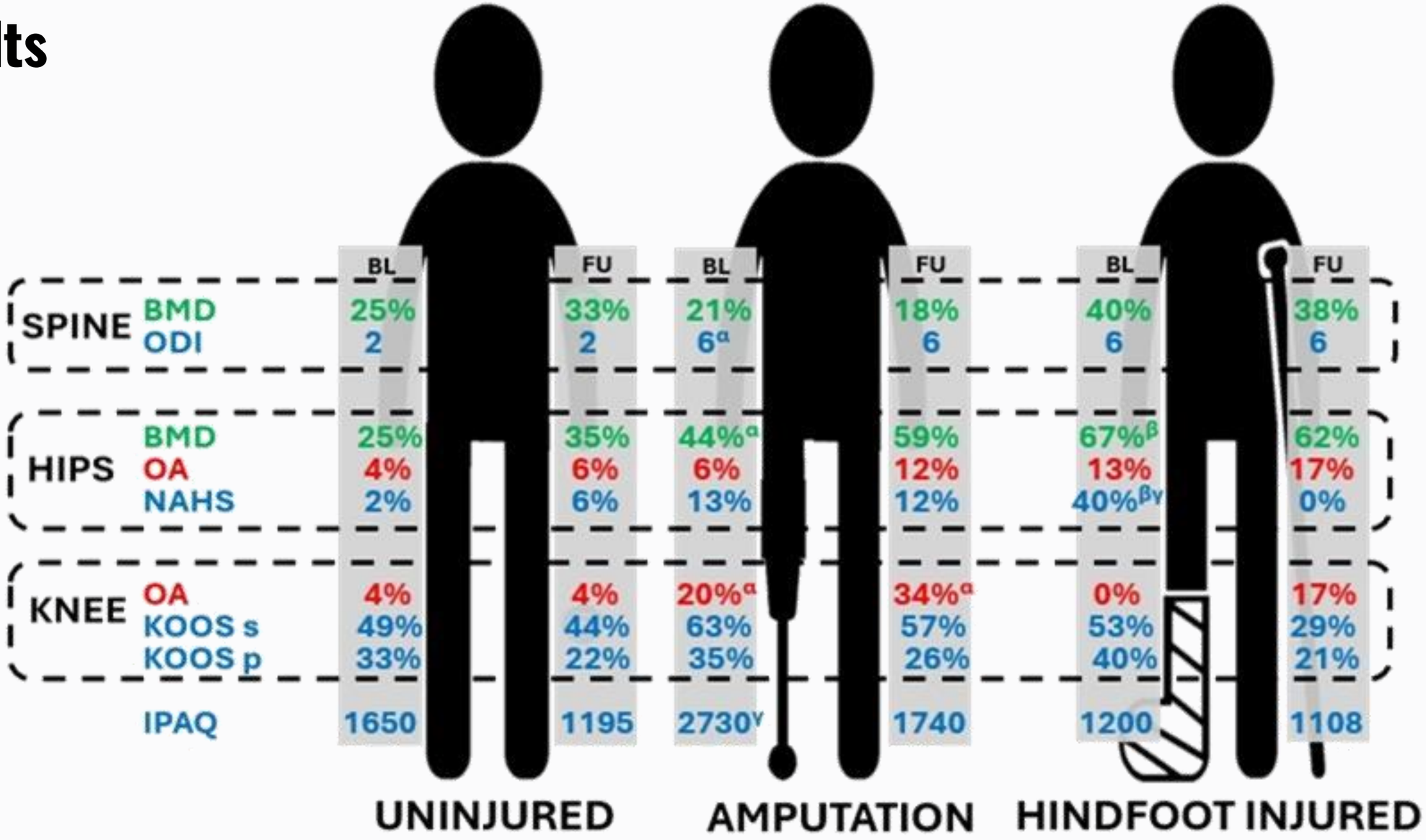


Sig differences: α A v U, β H v U, γ A v H

Results



Sig differences: α A v U, β H v U, γ A v H

Discussion

Traumatic hindfoot injuries are associated with poor musculoskeletal outcomes in the knee and hip.

Long-term secondary musculoskeletal outcomes comparable to those following transtibial amputation.

New hypothesis

1. **Biomechanical/kinetic chain:**

If outcomes in OA are comparable to those of amputees, are the gait compensations similar?

2. **Two distinct types of BMD loss:**

systemic osteopenia vs localised unloading osteopenia – different interventions

3. **Patient-reported outcomes** improve, objective findings worsen
Coupled with a decrease in physical activity

4. **Early-onset degeneration**
66.7% of the cohort, with a mean age of 36, have low BMD compared to 33.5% men over 50 in the US (1)

Needs its own research –

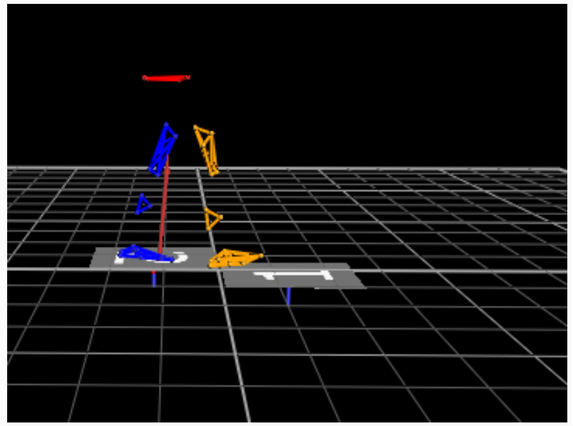
Detailed gait analysis is required to better understand the gait adaptations that drive these changes.

(1) Sarafrazi N WE; NCHS Data Brief; 2021.

Future work

- Preliminary gait analysis ⟶ motion capture data for five hindfoot-injured participants, one using a passive dynamic ankle–foot orthosis, and four healthy military controls for overground walking, stairs, sit-to-stand, and different inclines at self-selected speed.

~15 years post-injury



- Inverse kinematics and dynamics

Raw 3D motion capture data → Inverse Kinematics for Joint Angles → Inverse Dynamics for Joint Moments

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THE LIMBLESS VETERANS

ADVANCE

Thank you for listening.

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