Implementing Omics Technologies to Analyze Rehabilitation Strategies in Spinal Cord Injury

Alexander Stacul[1,2], Ezra Valido[1], Nicole Nyfeler[1], Alessandro Bertolo[1,3], Ramona Maria Zeh[1], Andrea Fontana[4], Carla Sabariego[1,5,6], Jürgen Pannek[4,7], Jörg Krebs[4], Margaret Hund[8], Xavier Jordan[9], Onur Boyman[10,11], Alexander Leichtle[12], Marija Glisic[1,3] and Jivko Stoyanov[1,3]

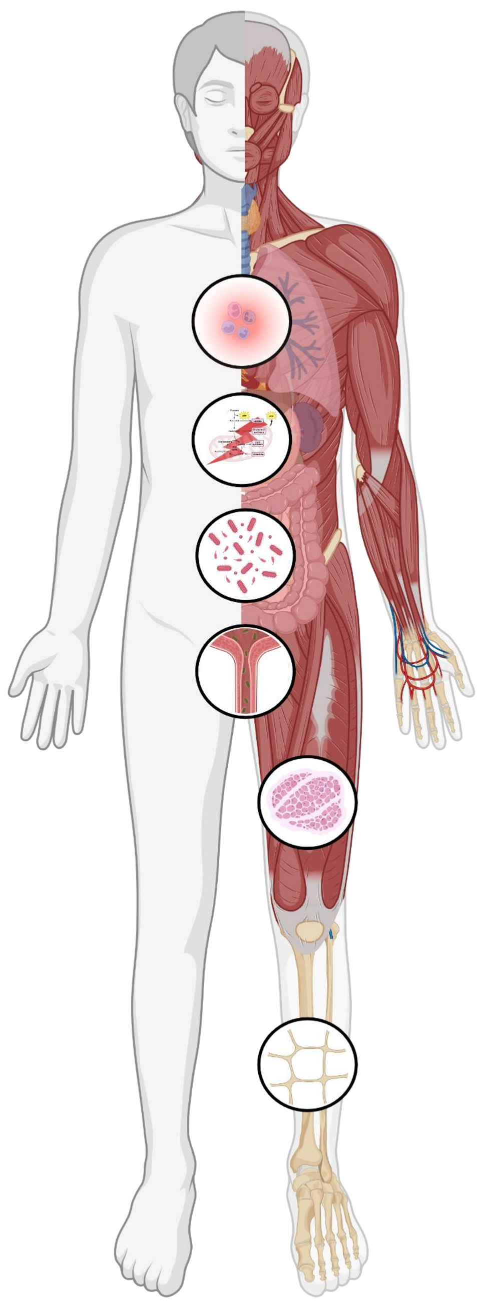
[1]Swiss Paraplegic Research, Nottwil, Switzerland; [2]Graduate School for Cellular and Biomedical Sciences, University of Bern, Bern, Switzerland, [3]Institute of Social and Preventive Medicine, University of Bern, Bern, Switzerland, [4]Swiss Paraplegic Center, Nottwil, Switzerland, Clinical Trial Unit, Swiss Paraplegic Center, Nottwil, Switzerland, [5]Faculty of Health Sciences, University of Lucerne, Lucerne, Switzerland, [6]Center for Rehabilitation in Global Health Systems, WHO Collaborating Center, University of Lucerne, Lucerne, Switzerland, [7]Department of Urology, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland, [8]REHAB Basel, Clinic for Neurorehabilitation and Paraplegiology, Basel, Switzerland, [9]Clinique Romande de Réadaptation, Sion, Switzerland, [10]Department of Immunology, University Hospital Zurich, University of Zurich, Zurich, Switzerland, [11]Faculty of Medicine and Faculty of Science, University of Zurich, Zurich, Switzerland, [12]University Institute of Clinical Chemistry, Inselspital, Bern University Hospital and University of Bern, Bern, Switzerland

Background

Spinal cord injury (SCI) can disrupt sensory, motor, and autonomic functions, significantly affecting recovery and quality of life.[1] Despite these advancements, rehabilitation remains limited due to the complexity of neuronal regeneration and plasticity.[2] Omics-based approaches (genomics, epigenomics, metagenomics, transcriptomics, proteomics, and metabolomics) can provide insights into the molecular mechanisms, such as:

- neuroinflammation (increase in proinflammatory cytokines,
- metabolic shifts/ disorders,
- gut microbiota imbalance (increase of harmful taxa),
- urinary tract infections,
- loss of muscle mass (muscular atrophy),
- loss of bone density (osteoporosis),

influencing rehabilitation outcomes.[3]



Objectives

- Give a comprehensive overview of omics technologies used in analyzing rehabilitation interventions
- Effectiveness of different interventions in SCI rehabilitation, where omics technologies are used to assess biological changes triggered by rehabilitation strategies and assess molecular outcomes.

Methods

Three databases (Embase, Medline, Web of Science) were searched. Two reviewers independently screened, extracted data and assessed risk of bias (RoB) (National Heart Lung and Blood Institute Quality Assessment Tool).

Inclusion criteria:

Age ≥18 years; traumatic SCI; assessed outcomes through omics; published in peer-reviewed journal

Exclusion criteria:

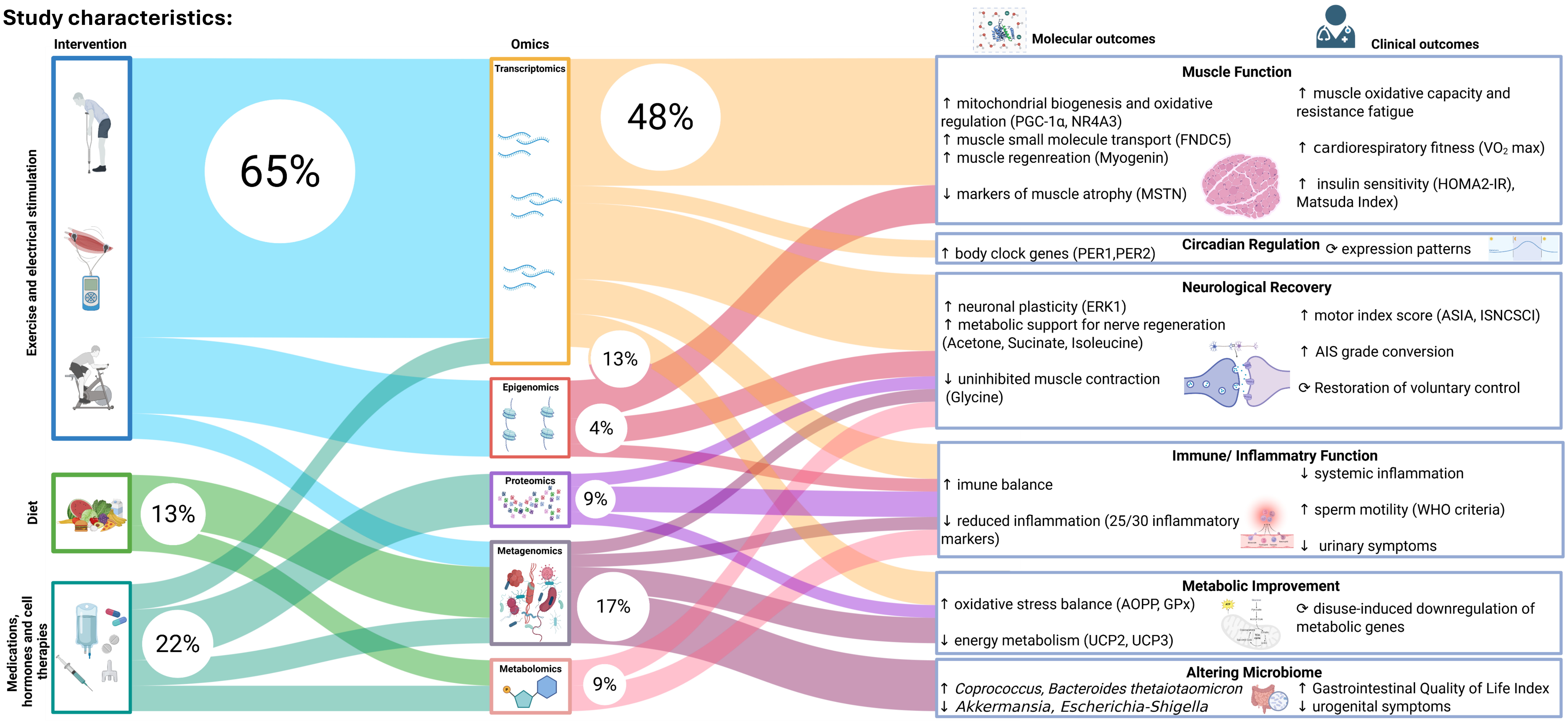
Animal studies, reviews, commentaries, and conference abstracts

Main Results

Literature research:

6,021 references retrieved, 136 full-text articles reviewed, 23 trials included (8 RCTs, 5 non-RCTs, 10 pre-post trials); 96% moderate RoB.

Study characteristics:



Conclusion

- Omics technologies are increasingly used (2012: n = 2; 2025: n = 14)
  - Enable monitoring of biological adaptations
  - Transcriptomics & metagenomics most used
- Exercise & electrical stimulation drive muscle gene adaptation
- Microbiome shifts reduce inflammation
  - Linked to better bowel and metabolic outcomes
- Epigenomics shows lasting molecular effects
  - Suggests sustained adaptation potential
- Proteomics & metabolomics detect systemic changes
  - Hormones & cell therapies → signature proteins/metabolites
- Early molecular shifts can guide rehabilitation
  - May forecast recovery ahead of clinical signs
  - Enable real-time intervention tuning
- Current evidence is promising but limited
  - Most studies small, short, and high variability
  - Need for standardized (multi)-omics clinical trials

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