29th ECSS Anniversary Congress, Glasgow/UK, 2–5 July 2024

Estimate of internal and external load in hypogravity locomotion with musculoskeletal modeling: a first step for evaluating a countermeasure

Natalucci, V., Cowburn, J.2, Luciano, F.1, Herssens, N.3, Albracht, K.4,5, Braunstein, B.4, Schungel, V.5, Colyer, S.2, Rittweger, J.6, Weber, T.3, Green, D.A.3,7, Pavei, G.1, Minetti, A.E.1, Cazzola, D.2

1 University of Milan, 2 University of Bath, 3 European Space Agency, 4 German Sport University, 5 University of Applied Sciences Aachen, 6 Institute of Aerospace Medicine DLR, 7 Kings College London

INTRODUCTION:
Microgravity is known to have a detrimental effect on the human musculoskeletal (MSK) system. Although various countermeasures have been tested during missions, most astronauts still suffer from muscle wasting and bone loss on their return to Earth (e.g. Demontis et al. 2017). In the future, astronauts will locomote once settled on Moon or Mars, but little is known about the load of daily locomotion in such environments and the potential effect on the MSK system. The aim of this study was to calculate external and internal load during different gaits in emulated Moon and Mars gravity levels.
METHODS:
Hypogravity levels were emulated with a body weight suspension system in the L.O.O.P. facility (Herssens et al. 2022). Three participants were asked to walk at 1.39 m/s, and run and skip at 1.39, 1.94 and 2.50 m/s on an instrumented treadmill at Earth, Mars and Moon gravity levels while motion capture system recorded the position of 66 markers. Joint angles and net joint moments were calculated using inverse kinematics and dynamics, respectively, in OpenSim.
RESULTS:
Ground reaction forces peaks were speed and gravity dependent in all gaits. Running showed the highest vertical average peak at 1.39 and 1.94 m/s in hypogravity (~1.5 BW). At 2.50 m/s, running showed highest peaks on Mars (~1.6 BW), whereas skipping and running shared the same peaks on Moon (~1.2 BW). Joint moments were gait, speed and gravity dependent at the hip and knee. Peak joint moments increased with speed and decreased with hypogravity for all gaits but showed higher values in the trailing leg during skipping compared to walking and running at all gravities and speeds. At the ankle, skipping and running showed similar values at both hypogravity levels (1-1.4 N*m*kg-1), which were lower than Earth, with highest values observed for running on Earth compared to the other two gaits. Ground reaction force and joint moment values are higher in locomotion compared with submaximal single leg hopping (Cowburn et al. 2024), a promising countermeasure.
CONCLUSION:
We have estimated, for the first time, the external and internal load during locomotion at different hypogravity levels. Such information is key to devise exercise programmes in the future to be used by astronauts as countermeasures. External and internal load showed different trends when gait-speed-gravity level were compared, with running generating the highest external load and skipping the highest internal one.

REFERENCES:
Demontis et al. (2017). Human pathophysiological adaptations to the space environment. Front Physiol 8:547.
Herssens et al. (2022). Movement in low gravity environments (MoLo) programme-The MoLo-L.O.O.P. study protocol. PLoS One 17(11):e0278051.
Cowburn et al. (2024). A novel computational framework for the estimation of internal musculoskeletal loading and muscle adaptation in hypogravity. Front Physiol 15:1329765.

Topic: Biomechanics

Presentation Poster