IAF/IAA SPACE LIFE SCIENCES SYMPOSIUM (A1)
Human Physiology in Space (2)

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A COMPUTER-VISION MODEL FOR MEASURING FAT FRACTION CHANGES IN SPACE RESEARCH

Abstract

Introduction: Prolonged exposure to microgravity during space missions induces significant deleterious adaptations in the lumbopelvic muscles, including an increase in fat fraction (FF). This accumulation of FF in lumbopelvic muscles has been observed after spaceflight and head-down tilt (HDT) bed rest. While magnetic resonance imaging (MRI) is the gold standard for assessing FF, manual segmentation of individual muscles is time-consuming and limited to a few images per lumbar level. To address these limitations, we developed and evaluated the accuracy and reliability of a convolutional neural network (CNN)-based computer vision model for automatic segmentation of lumbopelvic muscles. Using pre-existing MRI data from a 60-day bed rest analogue study, this model offers a scalable and efficient approach for future studies on muscle deconditioning in spaceflight and bed rest settings.

Methods: Twenty-four healthy participants (16 males, 8 females) were recruited for the AGBRESA (Artificial Gravity Bed Rest, European Space Agency) project held at envihab in Cologne, Germany. MRI of the lumbopelvic region was performed at baseline, after 59 days of head-down tilt bed rest, and after 13 days of reconditioning. A chemical shift-based two-point Dixon sequence was used to differentiate lipid and water signals, enabling FF quantification in the lumbar multifidus (LM), lumbar erector spinae (LES), quadratus lumborum (QL), psoas major (PM), gluteus maximus (GMax), gluteus medius (GMed), and gluteus minimus (GMin) muscles. Manual segmentation was performed by two operators who delineated each slice, while the CNN-based model automatically segmented the same muscles across all MRI slices. Accuracy and reliability were assessed using Pearson correlations, intraclass correlation coefficients (ICC), and the Bland-Altman method.

Results: For the LM, LES, and GMed muscles, FF values were 1.4%, 1.6%, and 0.8% higher with manual segmentation compared to the computer-vision model, respectively. For the PM, QL, GMax, and GMin muscles, FF was 1.7%, 0.9%, 0.8%, and 1.4% lower with manual segmentation than with the computer-vision model, respectively. The CNN model demonstrated high efficiency and accuracy, with strong positive correlations (r ¿ 0.80, p ¡ 0.001) between automatic and manual segmentations, particularly for LM (r = 0.954, ICC = 0.940) and LES (r = 0.911, ICC = 0.940).

Conclusions: The CNN-based model rapidly segmented all lumbopelvic muscles within seconds, offering a reliable and efficient alternative to manual segmentation which typically requires many months. This approach holds significant promise for advancing research on muscle deconditioning in both spaceflight and clinical contexts by enabling efficient, comprehensive muscle health evaluations.