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**Research Article,**

# Effect of Space Flight on Locomotion Control

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## Abstract

Gait and postural instabilities have been recorded in both American and Russian astronauts after their return to Earth. Russian researchers examined the behaviour of cosmonauts after Soyuz flights lasting between 2 and 63 days. Their findings demonstrated different gait and jumping behaviour performance declines following flying. Exaggerated leg breadth, a shift in the trunk to the side of the supporting leg, and failure to keep to the desired course were all characteristics of post flight walking.

**Keywords:** Locomotor Control, Human Spaceflight, Neural Regulation, Sensory-Motor Correlation.

## Introduction

The interaction among sensory input and motor output changes while a spacecraft is in microgravity [1]. Long-term space travel causes the central nervous system to operate differently, which opens the door for the emergence of novel motor control techniques in the unfamiliar sensory environment of microgravity. However, the adaptive state acquired during spaceflight is inappropriate for a unit gravity environment and results in alterations in motor control upon arrival on Earth, including challenges with mobility. Gait and postural instability have been seen in both American and Russian astronauts [1-17] even during short (5- to 10-day) flights. After returning from spaceflight, astronauts might experience any of the following symptoms: (1) a sense of turning; (2) a sudden loss of postural stability, particularly when rounding corners; (3) noticeably exaggerated head movements while walking; (4) a sudden loss of orientation in unstructured visual environments; or (5) significant oscillopsia while moving. The behaviour of cosmonauts during Soyuz trips lasting between 2 and 63 days has been studied by Russian researchers [3, 6, 7]. The sequential positions of various bodily joints and limbs were observed and analysed in order to determine the kinematic properties of walking, running, long leaps, and high jumps. Their research showed that after flying, various gaits and leaping behaviours perform worse. The duration of the flight was frequently linked with the durations of the postflight performance reductions. Postflight walking was characterised by wide legs, a shift in the trunk to the side of the supporting leg, and a failure to maintain the intended direction.The individuals regularly lifted their arms to the side while taking short, erratic movements to increase stability.

### Deepspace & locomotor control

Although there is experimental and anecdotal evidence to support the existence of significant locomotor disruptions following spaceflight, little is known about the underlying mechanisms that lead to these problems. Pozzo and Berthoz [18, 19] have demonstrated that during ordinary locomotion, the head is actively stabilised with relation to space with an accuracy of a few degrees. On the basis of this discovery, they postulated that top-down control would be used by the postural and gait motor control systems to maintain head stability while the body is moving. This strategy is advantageous since a steady head makes it simpler to keep a constant gaze while moving. The peak head rotational speeds in yaw, pitch, and roll are frequently maintained at 100°/s when walking and running, which is below the 350°/s saturation speed of the vestibulo-ocular reflex, according to Grossman et al. [20]. The description of gaze stability during locomotion by Grossman and colleagues [22] indicates that the angle of sight is largely maintained constant throughout walking and running. However, patients with vestibular dysfunction and neurological illnesses have lower visual acuity and unsteady visual sceneries as a result of increased head oscillation and unstable gaze during movement [23–28]. These results demonstrate how important head stability is for maintaining eye stability when moving. Guitton et al. [29] examined the visual, vestibular, and voluntary control of head movement in healthy subjects and patients with bilateral vestibular deficits during passive whole body rotation on a vertical axis. Subjects were told to maintain a head-fixed laser focused at a stationary object with eyesight, without eyesight in the dark, and while doing a distracting job like mental arithmetic. Participants with normal vision performed the best when granted eyesight. When it comes to eyesight, persons with vestibular dysfunction performed on par with healthy people. The ill group performed worse when vision was unavailable, demonstrating the significance of vestibular information in regulating head movement. According to Guitton et al. [29], long latency voluntary activities were the source of head stabilisation. They suggested that when head frequency increased, the head-neck system's passive inertial features would dominate the response in the higher frequency range (above 2 Hz). The stability of the head during passive rotations and unrestricted movement was examined by Keshner and Peterson [30]. They discovered that head movement was mostly restricted to the 1 to 2 Hz range during free locomotion. This is between the frequency range where the vestibulocollic and cervicocollic reflexes passively rotate the head. Voluntary, reflexive, and passive processes may all have an impact on how the head moves when moving [31, 32]. In fact, angular head movements can aid in maintaining a steady gaze when moving. By compensating for the vertical trunk translation that occurs with each step during locomotion during both treadmill and free locomotion, pitch head rotations (in the sagittal plane) in humans aid with gaze stability [13, 19, 28, 33]. In a previous study, we observed that when participants were forced to fixate a target while running on a treadmill, the number of these pitch head rotations changed depending on target distance [13]. The hypothesis that rotational head movements are motivated in part by the need to assist with gaze stability is supported by pitch head movements, which increased in amplitude when an Earth-fixed visual object was positioned close to the eyes (within 30 cm). In a separate research, Paige et al. [34] shown that similar changes in target distance were the mediators of compensatory eye movements during vertical trunk translation. The goal-directed response of pitch head movements during simultaneous locomotion and target fixation suggests that these head movements were not only dependent on the passive inertial and visco-elastic properties of the head-neck system, but could also be actively modulated to respond to changed gaze control requirements. Trained monkeys have been shown to produce continuous eye and head nystagmus to maintain gaze stability while running around a circular platform [35, 36]. This means that maintaining vision during typical body motions depends on coordinated head and trunk movements, which may also have a big influence on how postural and locomotor control patterns are organised. In view of this, one of the objectives of DSO 614 was to determine if exposure to the microgravity environment encountered during spaceflight resulted in changes to post-flight locomotor skills.

## Physiological kinematics & neuromuscular activation during locomotion

According to research, perceptual motor performance changes significantly after spaceflight [10]. These changes are problematic for situations where motions must be executed regularly and correctly. When a U.S. Space Shuttle mission is over, changes in perceptual motor functioning brought on by in-flight adaptation to the microgravity environment would make it difficult to move around, whether on Earth or on the surface of a far-off planet after a long journey. Two postflight locomotor alterations of a biomechanical nature include higher vertical accelerations in the centre of mass and increased angular amplitude at the knee and ankle [37]. In addition, Chekirda et al. [6] noticed two things: (1) an apparent change in the contact phase of walking, where the foot appeared to be thrust onto the support surface with a greater force than that seen before flight; and (2) efforts to maintain stability, in which cosmonauts spread their legs widely apart, used their arms more, and took shorter steps after flight. Russian and American studies have found performance difficulties, such as deviations from a straight path [6] and a tendency to lose balance while walking around corners [1, 3], despite these compensating changes. When navigating a complex and crowded environment, perceptual demands also come into play. Maintaining a steady gaze is important for trustworthy movement. The head, neck, and ocular complex minimises angular deviations in sight during mobility, according to empirical findings [19]. The observed postflight biomechanical modifications indicate a considerable risk of injury to gaze stabilisation strategies because the head, neck, and eye complexes are piled on top of the trunk and lower limb complexes. Perceptual function changes exacerbate the issue. For instance, following spaceflight, crew members were more dependent on visual cues [38], their ability to sense accelerations changed, and their otolith organ sensitivity reduced throughout the course of a mission [128]. Changes in vestibulo-ocular reflex (VOR) gain have also been seen as a result of spaceflight [39, 40], and exposure to microgravity has had an impact on eye-head synchronisation during target acquisition [41, 42] and ocular saccade performance [43]. These biomechanical and perceptual changes put together imply that head and gaze control during locomotion will probably change after spaceflight. However, there are no known techniques for maintaining gaze stability during postflight movement. We believe that a key aspect of gaze control during locomotion is the management of energy flow through the body, particularly during high energy encounters with support surfaces like those that occur during heel strike and toe off [45, 46]. The ability to attenuate the transfer of energy through the body is directly impacted by a number of factors. Modifications to the viscoelastic properties of the joints and the features of the musculoskeletal shock absorbers are two examples of these [47]. Controlling the movement of energy through the body depends on the pattern of joint kinematics seen during locomotion. When the heel initially makes contact with the support surface, the location of the lower limb joints is crucial. As Perry and Lafortune [48] shown, excessive foot pronation can reduce the body's ability to absorb shock. Changes in foot activity were seen during the contact phase of walking following spaceflight, according to Chekirda et al. [7]. Knee flexion had a substantial effect on how much stress was transferred while walking, according to McMahon and colleagues [49]. They demonstrated that greater knee flexion exacerbated tibial shock while dramatically reducing shock wave transmission to the head. However, after a direct assessment of the influence of knee angle on lower limb axial stiffness, Lafortune et al. [50] found that increasing knee angle during foot contact was less helpful than originally thought in reducing impact stress. Despite this, Hernández-Korwo et al. [37] noted post-spaceflight locomotor changes in the knee and ankle angles. According to Grossman et al. [20], locomotion causes the trunk and the head to vibrate regularly. The main frequency of these oscillations is equal to the step frequency. Since the visual and vestibular systems are both situated in the head, any abnormalities in these step-dependent oscillations might have an impact on locomotor control. As a consequence, we got to the conclusion that in addition to the head-trunk linkage, it was required to examine each link between the head and the support surface [51]. With the adequate attenuation of the intersegmental energy flow during locomotion, which also preserves head and gaze stability, the disturbance of the visual and vestibular systems is minimised. High energy transitions between the stance and swing phases were considered to be the most likely events to illustrate changes in locomotor performance because any improper attempt to manage energy flow would result in inappropriate energy transfer among contiguous body segments and could cause disturbances in both lower limb coordination and head-eye coordination observed during walking after spaceflight. The ability to maintain balance varies after a drop landing, and astronauts also show changes in posture and locomotor control. Evidence for sensory compensation during spaceflight provided by Young et al. [79] also revealed a larger dependence on visual cues for orientation perception and the interpretation of utricular otolith signals as linear acceleration rather than head tilt. The otolith-spinal reflex, which helps the leg muscles prepare for impact in response to unexpected falls, is dramatically reduced during spaceflight [77]. However, postflight data showed no appreciable differences from preflight responses, indicating that readjustment to Earthly existence proceeded swiftly. Another study found a substantial decrease in arm pointing accuracy while wearing blindfolds both during and just after spaceflight, suggesting that spaceflight may have an effect on limb location proprioception. Additionally, Gurfinkel [83] demonstrated that during spaceflight, higher-level anticipatory postural adjustments to rapid motions took place. Because any improper attempt to manage energy flow would result in inappropriate energy transfer among contiguous body segments and could cause disturbances in both lower limb coordination and head-eye coordination observed during walking after spaceflight, high energy transitions between the stance and swing phases were considered to be the most likely events to illustrate changes in locomotor performance. After a drop landing, a person's ability to stay balanced changes, and their posture and locomotor control also shift. Young et al[79] .'s evidence for sensory compensation during spaceflight also showed a greater reliance on visual cues for orientation perception and the interpretation of utricular otolith signals as linear acceleration instead of head tilt.

## Spatial orientation

Extended stays in a microgravity setting change the vestibular and somatosensory systems [10]. Numerous ideas have been made on how changed sensory inputs are reinterpreted. For instance, the otolithic system, which on Earth evaluates a mixture of head orientation through gravity and linear translational acceleration, should reinterpret all linear acceleration in microgravity as translational [75]. This might provide the impression of a head tilt in the early hours after landing back on Earth. These changes in vestibular input perception following spaceflight might make it more difficult to maintain spatial orientation when moving about.

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