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Technical Note

The Scope for Audiologists and Speech-Language Pathologists in Space Research: Views and Perspectives

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ABSTRACT

Introduction: This technical note highlights the significant advancements in space exploration by the Indian Space Research Organization, China National Space Administration and National Aeronautics and Space Administration. It delves into the challenges astronauts face in space, particularly regarding hearing, speech, language, communication, and swallowing, due to microgravity and other unique space environment factors. The crucial role of speech-language pathologists (SLPs) and audiologists in addressing these issues is underscored, emphasizing their involvement in astronaut training and the development of specialized protocols and communication methods suited for space conditions.

Conclusion: The interdisciplinary collaboration among various professionals to support astronaut health and ensure mission success is discussed. As space missions extend in duration and ambition, the increasingly vital role of Audiologists and SLPs in overcoming the complex challenges of space travel is highlighted, marking an essential contribution to the safety and success of future explorations.

Keywords: *Audiologists, Indian Space Research Organization, Microgravity, National Aeronautics and Space Administration, Speech and Language Pathologists, Speech and Language Problem.*

Uzay Araştırmalarında Odyologlar ve Dil ve Konuşma Terapistlerinin Yeri: Görüşler ve Perspektifler

ÖZET

Giriş: Bu teknik notta Hindistan Uzay Araştırma Organizasyonu, Çin Ulusal Uzay İdaresi ve Ulusal Havacılık ve Uzay Dairesi tarafından uzay araştırmalarında kaydedilen önemli ilerlemeler vurgulanmaktadır. Astronotların mikro yerçekimi ve diğer benzersiz uzay ortamı faktörleri nedeniyle uzayda özellikle işitme, konuşma, dil, iletişim ve yutma konularında karşılaştıkları zorluklar ele alınmaktadır. Dil ve konuşma terapistlerinin (DKT) ve odyologların bu sorunların ele alınmasındaki hayati rolü vurgulanmakta, astronot eğitimine katılımları ve uzay koşullarına uygun özel protokollerin ve iletişim yöntemlerinin geliştirilmesi üzerinde durulmaktadır.

Uzay uçuşuna çıkmadan önce astronotların birçok eğitim ve testten geçmesi gerekmektedir. Araştırmalar, astronotların işitme seviyelerinin uzaydaki performansları ve sağlıkları için çok önemli olduğunu göstermiştir (NASA, 2024). Uzaya gitmek ve mikro yerçekiminde (çok düşük yerçekimi) yaşamak astronotların işitme duyularının değişmesine ve denge sorunları yaşamalarına neden olabilir. Dünya'daki yaşam, Dünya'nın yerçekimi sınırlarında evrimleşmiştir. Bu nedenle, yerçekimi olmadığında, insan vücudunun tüm bölümleri etkilenebilir. Vücut yeni yerçekimi seviyelerine uyum sağlayabilse de bu uyum sağlık sorunlarına neden olabilir veya fiziksel sağlığı olumsuz yönde etkileyebilir. Bu durum, astronotların Dünya'ya döndüklerinde görevlerini etkili bir şekilde yerine getirmelerini zorlaştırabilir. Yerçekimsiz bir ortamda dengeden sorumlu olan vestibüler sistem bozulabilir. Bu bozulma astronotların uzamsal yönelim bozukluğu, mide bulantısı ve kusma yaşamasına neden olabilir. Ayrıca, mikro yerçekimi ortamı orta kulağı da etkileyerek işitme ve kulak basıncında değişikliklere yol açabilir. Mikro yerçekimine uzun süre maruz kalmak da vücutta sıvı değişimlerine neden olarak kulaklarda ve sinüslerde basıncın artmasına yol açabilir. Bu etkiler bir astronotun etkili iletişim kurma ve uzay görevleri sırasında kritik görevleri yerine getirme becerisini etkileyebilir.

Astronotlar ayrıca mikro yerçekimi, izolasyon ve uzaya özgü diğer koşullar gibi faktörler nedeniyle uzayda iletişim, dil, konuşma ve yutma ile ilgili benzersiz zorluklarla karşılaşabilir (Buckey, 2006). Bu zorluklar, mikro yerçekimine karşı sağlanan postüral adaptasyonun konuşma için gerekli olan ince motor becerilerini nasıl etkilediğini inceleyen yakın tarihli bir araştırmada gösterilmiştir (Shamei ve ark., 2023). Bu çalışma, astronotların çene ve dilin konumunu mikro yerçekimi ortamına uyarlamalarının Dünya'nın yerçekimine döndüklerinde ses yolunun işlerliği ile ilgili sorunlara ve konuşmada ince motor bozukluklarına yol açtığını ortaya koymaktadır. Biyomekanik simülasyonlar ayrıca, bu değişikliklerin yerçekiminin dil ve çene konumlandırması üzerindeki pasif etkilerinden kaynaklandığını göstermekte ve konuşma motor kontrolünde yerçekimi karşıtı kas aktivasyonunun rolünü vurgulamaktadır. Bu bulgular, yerçekimi geçişlerini ve bunların konuşma üzerindeki etkilerini anlamanın önemini vurgulamakta ve bu alanda daha fazla araştırma yapılması gerektiğini göstermektedir (Shamei ve ark., 2023).

Sonuç: Odyologlar ve DKT'ler yutma ve beslenme zorluklarının ele alınmasında da kritik bir rol oynayacak ve astronotların uzun süreli uzay görevleri sırasında yeterli beslenme ve hidrasyon almalarını sağlayacaktır. Ayrıca, uzmanlık alanları uzay giysilerinin, uzay araçlarının ve ekipmanlarının geliştirilmesinde yardımcı olacak ve bunların iletişim ve işitsel erişilebilirlik göz önünde bulundurularak tasarlanmasını sağlayacaktır. Bu hedeflere ulaşmak için Odyologlar ve DKT'ler astronotlar için kapsamlı işitme, konuşma, dil ve yutma programları geliştirmek ve uygulamak üzere uzay ajansları, mühendisler ve diğer sağlık uzmanları ile iş birliği yapmalıdır. Ayrıca mikro yerçekiminin iletişim, işitme ve yutma üzerindeki etkileri üzerine araştırmalar yaparak kanıta dayalı müdahalelerin geliştirilmesi konusunda öncü olmalıdırlar.

Anahtar Sözcükler: *Dil ve Konuşma Problemleri, Dil ve Konuşma Terapistleri, Hindistan Uzay Araştırma Organizasyonu, Mikro Yerçekimi, Odyologlar, Ulusal Havacılık ve Uzay Dairesi.*

Introduction

The Indian Space Research Organization (ISRO) successfully landed the Chandrayaan-3 mission on the moon's south pole on August 23, 2023. There's a strategic plan for the upcoming Chandrayaan-4 mission. Another exciting project on the horizon is the Gaganyaan missions, which ISRO and Hindustan Aeronautics Ltd (HAL) are working on together. The collaborative program includes an uncrewed first mission by the end of the year 2024, followed by three more missions before the manned space flight, aiming to send three astronauts to low Earth orbit by 2025 (Jacob, 2023; Sharmila, 2023; Somanath, 2024). The long-term goals include a space station by 2035 and an Indian moon landing by 2040 (Somanath, 2024). China National Space Administration's (CNSA) lunar exploration project has achieved six successful missions since 2007, from Chang'E-1 to Chang'E-6 in 2024, including the return of lunar samples. China's Chang'E-6 mission made history on June 24, 2024, successfully returning moon samples from the far side, a groundbreaking achievement in the nation's space exploration program (Huaxia, 2024). To enhance its space science capabilities, the Chinese Academy of Sciences has developed an ambitious medium- and long-term roadmap, outlining strategic objectives and future mission priorities. China and India are not alone in this race to the moon. The United States is planning to send astronauts to the moon by late 2025 with its Artemis 3 mission, which would be the first manned lunar landing since the Apollo missions 50 years ago (Sharmila, 2023). This progress will fuel further advancements in the space industry, promoting collaborative innovation and healthy competition.

As astronauts play a crucial role in these missions, their responsibilities extend beyond space exploration [National Aeronautics and Space Administration (NASA, 2015)]. An astronaut is someone who is specially trained and skilled to go into space. On a spacecraft, each astronaut has different roles and responsibilities. Usually, there is a commander who leads the mission and a pilot.

Other roles might include flight engineer, payload commander, mission specialist, and science pilot (NASA, 2024).

Audiology and Hearing Conservation in Space

Before going on a spaceflight, astronauts need to go through a lot of training and tests. Studies have shown that the hearing level of astronauts who are to protect this level is crucial for their performance and health in space (NASA, 2024). Going to space and living in microgravity (very low gravity) might cause astronauts to alter their hearing and have balance problems. Life on Earth has evolved under Earth's gravity. Therefore, when there's no gravity, it could affect all parts of human body. Although the body can adjust to new gravity levels, this adjustment might cause health problems or reduce physical fitness, which could make it hard for astronauts to perform their duties effectively when they come back to Earth. In a gravity-free environment, the vestibular system, which is responsible for balance and equilibrium, can be disrupted. This disruption can cause astronauts to experience spatial disorientation, nausea, and vomiting. Furthermore, the microgravity environment can also affect the middle ear, leading to changes in hearing and ear pressure. Prolonged exposure to microgravity can also cause fluid shifts in the body, leading to increased pressure in the ears and sinuses. These effects can impact an astronaut's ability to communicate effectively and perform critical tasks during space missions. National Aeronautics and Space Administration’s (NASA) Johnson Space Center (JSC) in Houston, Texas, houses a specialized audiology and hearing conservation clinic dedicated to assessing, monitoring and protecting the hearing of astronauts through both baseline and on-orbit hearing evaluations (Dicken, 2012).

The JSC has established a comprehensive Hearing Conservation Program that not only meets but also exceeds federal regulatory safety and health standards including personal hearing conservation, noise monitoring and control, health education, audiometric monitoring for early hearing loss detection, and follow-up care (Alford et al., 2013). The JSC audiologist collaborates with the Acoustics Working Group and Crew Surgeons to minimize noise exposure for crew members on the International Space Station (ISS) through engineering controls and medical monitoring. This team also evaluates, recommends, and custom-fits hearing protectors for NASA training flights and space missions. Regarding long-term spaceflight, the Audiology and Hearing Conservation department conducts critical research on microgravity's effects on human health when crew members spend extended periods of time in microgravity. Additionally, their expertise contributes to informing safety standards and space vehicle design for future NASA missions (Dicken, 2012). NASA also offers externship opportunities to Doctor of Audiology (AuD) students at their space centers, allowing them to work alongside a multidisciplinary team, from acoustic engineers to healthcare professionals, to study and apply hearing conservation methods (Umashankar & Prabhu, 2022). Audiologists (hearing specialists) look after balance problems astronauts might face because there's no gravity in space. Transitioning from the auditory to the communication challenges faced in space, it becomes evident that the microgravity environment that potentially alters hearing and balance can also extend its influence on speech and language functions.

Speech, Language, Communication and Swallowing Problems in Space

Astronauts encounter unique challenges with speech, language, communication, and swallowing in space due to factors such as microgravity, isolation, and other space-specific conditions (Buckey, 2006). These challenges are further explored in recent research, which examines how postural adaptation to microgravity affects fine motor skills essential for speech (Shamei et al., 2023). This study reveals that astronauts adapt their jaw and tongue postures to the microgravity environment, leading to altered vocal tract configurations and fine motor impairments in speech upon returning to Earth's gravity. Biomechanical simulations further demonstrate that these changes result from the passive effects of gravity on tongue and jaw positioning, emphasizing the role of anti-gravity muscle activation in speech motor control. These findings highlight the importance of understanding gravitational transitions and their impact on speech, suggesting the need for further research in this area (Shamei et al., 2023).

In addition to speech-specific studies, research on microbial behavior in microgravity has shown that microgravity can influence biological systems, potentially affecting human physiological responses. The study discusses how fluid dynamics and cellular behavior are altered in space, providing insights into broader physiological changes (Williamson Smith, 2017). Similarly, head-down-tilted bed rest studies, which simulate the effects of microgravity, have been utilized to investigate its impact on human physiology. These studies suggest that simulated microgravity can induce symptoms such as headaches, particularly on the first day, while countermeasures help mitigate these effects (van Oosterhout et al., 2015). Although primarily focused on headaches, such studies indicate that microgravity may influence other physiological functions, including those involved in speech mechanisms.

Furthermore, studies have explored how microgravity affects the human brain and vestibular function. For example, Van Ombergen et al. (2017) discuss the effects of spaceflight and microgravity on the human brain, particularly the vestibular system, which is responsible for balance and spatial orientation. The findings suggest that disruptions in the vestibular system may influence broader physiological and motor functions, including communication. Additionally, the influence of isolation and confinement during space missions has been examined in the context of communication styles. Kanki's work on *Crew Resource Management* provides insights into how these unique conditions lead to changes in communication patterns, such as increased directness or reduced social cues, and highlights the importance of effective communication strategies in high-stress and isolated environments (Kanki et al., 2010). These findings highlight the complex interactions between microgravity, biological systems, and human physiology, emphasizing the importance of ongoing research to better understand the diverse effects of space environments on astronauts' speech, communication, and overall health.

Space exploration requires specialized nutrition and swallowing mechanisms. To keep astronauts healthy in microgravity, space food is carefully designed. Space exploration demands unique food solutions. Space food differs significantly from Earthly cuisine, requiring lightweight, compact, and easy-to-store designs. Additionally, it must withstand extreme temperatures and microgravity environments. Different types of space food have been developed, including rehydratable, thermostabilized, frozen, fresh, irradiated, and refrigerated options (Bourland, 1993). In recent years, the ISS has revolutionized food options for astronauts. The ISS galley allows for meal preparation using a variety of ingredients sent from Earth, including rehydratable, heated, and ready-to-eat meals. Additionally, fresh produce such as lettuce, zinnias, and red romaine lettuce is now grown on the ISS (Douglas et al., 2020, Gary et al., 1996). Continuous innovation helps overcome the unique nutrition challenges of space. Research indicates that microgravity in space significantly impairs gastrointestinal function, compromising digestion and absorption. The absence of gravitational forces alters gastrointestinal motility patterns, peristaltic movement efficacy, and food transit times. As a result, digestive disturbances arise, highlighting the need for targeted countermeasures to mitigate these effects in microgravity environments (Yang et al., 2020).

Typically, Earth’s gravity assists in the swallowing process by aiding food movement down the esophagus. However, in microgravity conditions of the space, astronauts may need to rely more on muscular control to swallow effectively. While the human body can adapt to microgravity over time, astronauts may initially experience discomfort or difficulty adjusting to this altered swallowing mechanism. Moreover, the behavior of liquids and foods differs in space, which can further complicate the swallowing process. To address these challenges, speech-language pathologists (SLPs), who specialize in treating swallowing difficulties (dysphagia) play a crucial role. They can devise strategies in conjunction with space agencies, food science technologies and nutritionists to ensure astronauts can safely consume food and liquids in space, reducing the risk of choking or related issues. Consequently, space agencies and food science technologies may need to develop special food formulations specifically designed for microgravity conditions. These foods are engineered to minimize the risk of choking and facilitate easier swallowing, featuring varying textures and moisture levels tailored to the unique demands of space travel.

Furthermore, astronauts may encounter communication challenges because of their altered hearing abilities or the unique space environment. As a result, they may need to utilize specialized communication methods and tools to address potential hearing issues. These solutions range from basic communication boards to advanced high-tech devices designed to assist with speech, proving particularly valuable during emergencies.

To mitigate these speech, language, communication and swallowing issues, it is crucial for astronauts to undergo extensive training prior to their mission, which includes practicing in environments that simulate the conditions of microgravity. SLPs should collaborate with professionals from various disciplines, such as neurologists, otorhinolaryngologists, audiologists, psychologists, occupational therapists, and nutritionists to conduct research on the impact of space travel on speech, language, cognition, and swallowing. This interdisciplinary research can pave the way for innovative strategies to support astronaut health and mission success. Training is not only essential for astronauts but also for the team working alongside them, ensuring they possess the necessary expertise to provide astronauts with the support they need during their space expeditions.

In the future, as space missions become longer and go further, such as trips to Mars or prolonged stays on space stations, the role and knowledge of Audiologists and SLPs will become increasingly vital. They will be at the forefront of addressing and resolving the complex issues related to hearing, speech, language, communication, and swallowing in the unique environment of space.

The involvement of Audiologists and SLPs in space exploration will offer numerous social, economic, and professional contributions. For instance, their expertise will help to develop and implement effective communication strategies for astronauts, enhancing their ability to work together as a team and respond to emergencies. Additionally, they will design and implement hearing conservation programs, reducing the risk of noise-induced hearing loss and protecting the auditory health of astronauts.

Conclusion

Audiologists and SLPs will also play a critical role in addressing swallowing and feeding difficulties, ensuring that astronauts receive adequate nutrition and hydration during long-duration space missions. Furthermore, their expertise will inform the development of space suits, spacecraft, and equipment, ensuring that they are designed with communication and auditory accessibility in mind. To achieve these goals, Audiologists and SLPs should collaborate with space agencies, engineers, and other healthcare professionals to develop and implement comprehensive hearing, speech, language, and swallowing programs for astronauts. They should also conduct research on the effects of microgravity on communication, hearing, and swallowing, informing the development of evidence-based interventions and treatments. Ultimately, the success and safety of future space missions will depend on the expertise and contributions of Audiologists and SLPs. As such, it is essential that they are integrated into all aspects of space mission planning and development, and that their expertise is valued and recognized as a critical component of space exploration.

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