



ADAPTATION AND SENSORIMOTOR PROCESSING DURING INCREASED GRAVITY GRADIENTS

Project code: J7-4601

Principal investigator: Uroš Marušič, PhD

Duration: 1 October 2022–30 September 2026

Scientific background

Gravity is a relatively constant physical factor that has guided evolution and sustains the health of organisms on Earth. Some consider it as fundamental a precondition for life as oxygen, nutrients, and a suitable temperature, arguing that, for ethical reasons, artificial gravity should be an integral component of space stations (van Loon, 2020). The idea of generating artificial gravity in space is not new: it dates back to 1883, when Tsiolkovsky discussed the rotation of a spacecraft, an idea later developed by Oberth (1923) and Potočnik/Noordung (1928). Owing to technical, financial and operational constraints, as well as certain adverse effects on the human body, the concept of rotating an entire vehicle was superseded by the short-arm human centrifuge (SAHC).

The physiological deconditioning of the human body in microgravity and its analogues (bed rest, dry immersion) is now well studied. Artificial gravity generated by rotation on a short-arm centrifuge is regarded as one of the most promising countermeasures, as it addresses the fundamental cause of deconditioning—the absence of gravity—and may simultaneously benefit multiple body systems (Hargens et al., 2013). Centrifugation has been shown to improve orthostatic tolerance, better preserve plasma volume and enhance exercise capacity (Clément et al., 2015). The central nervous system is increasingly highlighted as a key driver of these adaptive processes, since its plastic mechanisms substantially influence spatial orientation, sensorimotor control and cardiovascular dynamics (Clément et al., 2020).

A deeper understanding of these mechanisms has implications not only for the development of effective and user-friendly centrifugation protocols, but also for aviation. Reducing sensorimotor disturbances during increased exposure to g-force can improve vehicle-control skills and contribute to lowering the number of fatal aviation accidents (Paloski et al., 2008; Gibb et al., 2011). It is precisely at this intersection of neuroscience, physiology and increased gravity gradients that the present project operates.

Current project status

Experimental measurements were fully completed in April and May 2026. This concludes the central data-collection phase, to be followed by data processing, analysis and the preparation of scientific publications. In parallel with the measurements, two systematic literature reviews are in preparation, which will establish the conceptual and methodological framework for interpreting the collected data:

Review 1 summarises the evidence to date on sensorimotor processing under higher gravity gradients.

Review 2, titled “Exercise during Centrifugation: Biomechanical Feasibility, Physiological Efficacy, and Modality Comparison for Artificial Gravity Countermeasures”, compares different exercise modalities during centrifugation and evaluates their biomechanical feasibility and physiological efficacy as an artificial-gravity countermeasure.



*Figure 1: Conducting measurements in the human centrifuge in Planica.
Slika 1: Izvajanje meritev v človeški centrifugi v Planici.*

Both reviews are expected to be submitted for publication in the final year of the project, while the findings of the measurements will be presented in separate original research articles.

This work was supported by the Slovenian Research and Innovation Agency (ARIS) under research project J7-4601, “Adaptation and Sensorimotor Processing During Increased Gravity Gradients”.

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PRILAGODITEV IN SENZOMOTORIČNO PROCESIRANJE MED POVEČANIMI GRAVITACIJSKIMI GRADIENTI

Šifra projekta: J7-4601

Vodja projekta: dr. Uroš Marušič

Trajanje: 1. 10. 2022–30. 9. 2026

Znanstveno ozadje

Gravitacija je razmeroma stalen fizikalni dejavnik, ki je usmerjal evolucijo in vzdržuje zdravje organizmov na Zemlji. Nekateri jo uvrščajo med enako temeljne pogoje za življenje, kot so kisik, hranila in primerna temperatura, ter zagovarjajo, da bi morala umetna gravitacija iz etičnih razlogov postati sestavni del vesoljskih postaj (van Loon, 2020). Zamisel o ustvarjanju umetne gravitacije v vesolju ni nova: sega vse do leta 1883, ko je Ciolkovski razpravljal o vrtenju vesoljskega plovila, pozneje pa sta jo razvijala Oberth (1923) in Potočnik/Noordung (1928). Zaradi tehničnih, finančnih in operativnih omejitev ter nekaterih neželenih učinkov na človeško telo je koncept vrtenja celotnega plovila nadomestila centrifuga s kratkimi rokami (short-arm human centrifuge, SAHC).

Fiziološko dekonicioniranje človeškega telesa v mikrogravitaciji in njenih analogih (počitek v postelji, suha potopitev) je danes dobro raziskano. Umetna gravitacija, ustvarjena z vrtenjem na centrifugi s kratkimi rokami, velja za enega najobetavnejših protiukrepov, saj odpravlja temeljni vzrok dekonicioniranja – odsotnost gravitacije – in lahko hkrati koristi več telesnim sistemom (Hargens idr., 2013). Centrifugiranje je pokazalo izboljšanje ortostatske tolerance, boljše ohranjanje volumna plazme in večjo telesno zmogljivost (Clément idr., 2015). Vse bolj se kot ključni dejavnik teh prilagoditvenih procesov poudarja osrednje živčevje, plastični mehanizmi katerega pomembno vplivajo na prostorsko orientacijo, senzomotorični nadzor in srčno-žilno dinamiko (Clément idr., 2020).

Poglobljeno razumevanje teh mehanizmov nima posledic le za razvoj učinkovitih in uporabniku prijaznih protokolov centrifugiranja, temveč tudi za letalstvo. Zmanjšanje senzomotoričnih motenj med povečano silo g lahko izboljša veščine nadzora nad vozilom in prispeva k zmanjšanju števila letalskih nesreč s smrtnim izidom (Paloski idr., 2008; Gibb idr., 2011). Prav na tem presečišču nevroznanosti, fiziologije in povečanih gravitacijskih gradientov deluje ta projekt.



Trenutno stanje projekta

Eksperimentalne meritve smo v celoti zaključili aprila in maja 2026. S tem je končana osrednja faza zbiranja podatkov, sledijo pa obdelava, analiza in priprava znanstvenih objav. Sočasno z meritvami se pripravljata sistematična pregleda literature, ki bosta konceptualni in metodološki okvir za interpretacijo zbranih podatkov:

Pregled 1 povzema do zdaj znane dokaze o senzomotoričnem procesiranju v višjih gravitacijskih gradientih.

Pregled 2 primerja različne načine vadbe med centrifugiranjem ter ocenjuje njihovo biomehansko izvedljivost in fiziološko učinkovitost kot protiukrep za umetno gravitacijo.

Oba pregleda bosta predvidoma oddana v objavo v zadnjem letu projekta, izsledki meritev pa bodo predstavljeni v ločenih izvirnih znanstvenih prispevkih.

To delo je podprla Javna agencija za znanstvenoraziskovalno in inovacijsko dejavnost Republike Slovenije (ARIS) v okviru raziskovalnega projekta J7-4601 »Prilagoditev in senzomotorično procesiranje med povečanimi gravitacijskimi gradienti«.

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