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Is Gravitational Insecurity a Unicorn?

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Editorial

"Gravitational insecurity" refers to a consequential set of problems with balance and movement that have been identified by occupational therapists (OTs), following the lead of Jean Ayres [1]. It is one of a number of conditions identified in the context of sensory processing theory and practice, but here we consider it by itself. What follows is based on the original descriptions, the relatively sparse literature including case reports [2,3], and discussions with a number of practicing pediatric OTs who have identified and treated children with this condition.

Children with gravitational insecurity have difficulty walking on uneven or unstable surfaces such as rocky ground, beaches and even gym mats. They do not like bending over backwards or forwards, being picked up, or being upside down. These children fear and avoid moving platforms like skates, cars, and escalators. Their fears are clearly displayed on playgrounds where they stay to the perimeter and refuse to rock on seesaws, swing on swings, or climb ladders and climbing frames (aka monkey bars, [4]). Children with gravitational insecurity fear falling and are afraid of heights; according to some pediatric OTs they can be identified early by their emotional upset and refusal to sleep in high cribs, beds or top bunks. Their condition can be summarized as always wanting their feet on the ground; any threat to this stance elicits intense fear.

Detailed narratives published on the internet by adults self-identified with gravitational insecurity present a consistent picture of an early-starting, life-long condition [webblogs 1-3].

Unicorns: This wealth of detail brings us to the unicorn problem. We know many details about unicorns, too. They come in white and a range of pastel shades, they have a horn growing out of their forehead, their natural habitats are medieval tapestries and magical forests, they like girls and girls like them. We also know that unicorns don't exist. Gravitational insecurity is identified by OTs, but recognized by no other health profession. Is gravitational insecurity a unicorn?

Gravitational insecurity is not a unicorn: Criteria for the valid identification of gravitational insecurity in children have been published [5] and replicated [6]: An emotional response and/or refusal to do a backward roll, jump off a chair with eyes closed, get up after lying supine on an exercise ball, and step on and off a tilt board distinguishes 87% of children pre-classified as having gravitational insecurity from 94% of those classified as typically developing. Analysis of a very large dataset from a single OT clinic specializing in sensory processing disorders found that 3.7% of 832 child pts and 2.2% of 1832 adolescent and adults pts had definite gravitational insecurity (larger percentages had mild or partial gravitational insecurity, [7]).

When "craving" is a good treatment outcome: OTs treat gravitational insecurity by graded exposure to changes in head position and movement, which might start with having children walk down a ramp and then transition to more vigorous activity involving higher linear and rotational accelerations, such as bouncing on a trampoline and swinging on a parallel and then a rotational swing [8]. These procedures resemble the systematic desensitization clinical psychologists use to treat phobias. One distinctive result is reports of some children who develop a "craving" for this kind of stimulation. Children who refused to be rotated in a swing, or who were terrified of bouncing in a suspended hammock before treatment (either refusing to climb in or immediately showing great distress when inside), eventually request that particular activity, giggling while the therapist spins or bounces them. This is notably unlike results of phobia treatment where the aversive stimulus comes to be better tolerated, but is not especially desired.

Nosology: One diagnostic/nosological complication is the reportedly frequent co-morbidity with various other conditions such as developmental coordination disorder, tactile oversensitivity and autism [3]. Thus, gravitational insecurity could be the net consequence of muscle tone abnormalities, general clumsiness, somatosensory pathologies and so forth. However, some OTs report that gravitational insecurity sometimes presents by itself as the child's major problem, more or less [9].

A major point of similarity between gravitational insecurity and frank vestibular disease or damage is the associated intense anxiety. People with the usual well-known vestibular pathologies are highly anxious; people with clinical levels of anxiety are significantly more likely to have signs of vestibular dysfunction, e.g., vertigo [10,11]. The strong link between anxiety and vestibular dysfunction may have a neuroanatomical basis in the parabrachial nuclei of the dorsolateral pons, which receive vestibular input and have been implicated in the pathogenesis of anxiety.

The classic vertigo experienced by individuals with peripheral vestibular damage has not been reported in gravitational insecurity. Ocular nystagmus also has not been reported (one might think that nystagmus would be obvious, but perhaps not). Of course, absence of evidence is not evidence of absence. Children with gravitational insecurity have been noted to have some difficulty in gaze shifting and visual tracking (T. Nichols-personal communication). Taken together, these observations suggest that gravitational insecurity is more like central than peripheral vestibular dysfunction.

Pathophysiology: There are claims that post rotary nystagmus (PRN) is prolonged in gravitational insecurity [4] although quantitative data have not been published, to the best of my knowledge. Cupula deflection in semicircular canal only accounts for 5-6 sec of PRN. The normal continuation of PRN to 10-30 sec is due

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to vestibular "velocity storage" that results from the operation of a GABAergic neural integrator circuit distributed among the anterior aspect of the medial vestibular nucleus, the vestibular commissure and the nodules and uvula of the cerebellum [12]. This neural integrator normally functions to increase the gain and adjust the phase of the vestibulo-ocular reflex at low frequencies of head movement for which the direct signal from semicircular canals is inadequate. The neural integrator also helps the vestibular system distinguish tilt from linear acceleration, for which the otolith organs generate identical signals. (An alternative model postulates two neural integrators, [13]). To function properly the neural integrator is "leaky", meaning that its signal decays over time. The rate of decay is governed by the integrator time constant. The value of the time constant is crucial; too short and the direct signal from vestibular endorgans is insufficiently amplified to maintain function across the full range of naturally occurring movement, too long and vestibular function becomes unstable [14]. Shortened integrator time constants have been implicated in motion sickness [15]. If the claims about increased PRN duration are true, it would suggest that an over-amplified and prolonged signal from the neural integrator might play a role in the pathogenesis of gravitational insecurity.

Cortical projections: Above the brainstem neural integrator there are vestibular projections to as many as 6 different areas of cortex [16,17]. Projections to the ventral peri-Sylvian area mediate conscious experiences of movement evoked by vestibular input (Okada et al 1999). Projections to parietal cortex are likely to be involved in vestibular contributions to spatial orientation [18], cognition [19,20] and navigation [21]. The latter includes "path integration", a form of vestibularly-guided spatial navigation that involves integration of the vestibular velocity signal generated while following a path, often tested with blindfolded subjects passively moved in a wheelchair [22,23]. Alternatively or additionally to neural integrator dysfunction, gravitational insecurity might result from problems in one or more of these pathways. Behavioral tests of this hypothesis would include testing people with gravitational insecurity for post-rotary sensations of movement in the dark as well as for path integration performance. Physiological tests involving fMRI or other neuroimaging techniques could reveal weaker or shifted patterns of cortical activation in response to, e.g., caloric or galvanic vestibular stimulation. Finally, gravitational insecurity may be a general problem in balance to which vestibular input is just one contributor along with vision and proprioception.

Working hypothesis: At this point the working hypothesis is that gravitational insecurity is not a unicorn. It may reflect a real, independent nosological entity; or be another name for some condition that is assessed, labeled and treated differently in OT vs. neuro-otology clinics; some combination of these or something else entirely. To begin sorting through these possibilities, we have launched a multi-clinic survey to organize pediatric OTs observations of children identified as having gravitational insecurity with regard to its prevalence in clinic populations, diagnostic signs, demographic characteristics, typically comorbid conditions, overlap with the effects of damage to the labyrinth or cranial nerve VIII, and outcomes of treatment. This work will be augmented in the next step, which is to characterize vestibular function in people with gravitational insecurity using the standard clinical battery of vestibular function tests [24]. Deficits in pursuit tracking and saccadic eye movements, e.g., would indicate dysfunction above the brain stem. Rotational chair testing of the vestibulo-ocular reflex permits a calculation of velocity storage parameters and therefore a direct test of the neural integrator hypothesis.

Clinical implications: If gravitational insecurity is a distinct, identifiable condition, then children and adults with gravitational insecurity symptoms constitute a population that is undetected and underserved by the larger health-provider community. The established techniques of vestibular rehabilitation that are well known to physical therapists might prove to be an important alternative approach to their treatment.

Webblogs

1. Julie H Rose (2010 Nov 14) Everything is interesting.
2. Karen C's story.
3. Whoa…Put me Down.

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