Identifying Gravitational Insecurity in Children: A Pilot Study

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KEY WORDS
- GI Assessment
- gravitational insecurity
- pediatric
- sensory integration
- sensory processing

OBJECTIVE. This study developed an observational assessment of gravitational insecurity (GI), the GI Assessment, and examined its preliminary reliability and validity evidence.

METHOD. The GI Assessment consisted of 15 activities that created conditions characterized as fear-inducing for children with gravitational insecurity. Three behavioral categories—avoidance, emotional, and postural responses—were scored for each activity. Participants were 18 children with gravitational insecurity, ages 5–10 years, and a matched group of children who were typically developing. Forty-eight preschoolers who were typically developing, ages 2–4 years, were examined for developmental trends.

RESULTS. Significant differences were found between groups. Discriminant analysis classified 83% of the gravitationally insecure group and 100% of the typical group. Interrater reliability for the total test was .79. Performance of preschool children suggested a developmental age trend.

CONCLUSION. The GI Assessment is a promising clinical tool for objectively identifying children with gravitational insecurity.

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Occupational therapists using a sensory integration frame of reference frequently identify and provide intervention to children who are overresponsive to sensory experiences. However, those children who display excessive reactions to movement experiences are especially challenging for therapists to understand and treat. Ayres (1979) specifically identified a unique subgroup of children with sensory integration dysfunction who exhibit excessive emotional reactions in response to changes in movement or head position as having a condition called *gravitational insecurity*. She identified symptoms that included fear of falling, fear of inverted head positions, inability to jump or have the feet leave the ground, inability to perform a somersault, and reluctance to lie supine. Dislike of everyday activities such as walking over bumpy ground, climbing stairs, stepping over objects, leaning over backward, climbing, or riding in cars was viewed as characteristic of gravitational insecurity (Lee, 1987). Interference also was noted with children's participation in daily life occupations, such as roughhouse play, exploration of playground equipment, engagement in sports, successful navigation of the out-of-doors on foot, or use of bicycles or skates.

Ayres (1979) stated that this type of child feels "fear, anxiety, and distress whenever he is in a position to which he is not accustomed, or when he tries to assume such a position, or when someone else tries to control his movement or position" (p. 84). Further, the child with gravitational insecurity is described as feeling "a primal threat to the pull of gravity. . . . His fear is not rational; it comes from deep inside his brain where words and rewards have no effect" (Ayres, 1979). Shaffer (1979) described this concept of primal threat or fear as the emotional response experienced when one's ability to naturally maintain balance against gravity is disrupted. He stated that poor vestibular integration results in a child's life experiences informing him or her that the world is fraught with possible destruction.

Ayres (1979) conceptually differentiated gravitational insecurity from intolerance to movement and postural insecurity by associating intolerance to movement with autonomic nervous system reactions and postural insecurity with decreased postural mechanisms. *Intolerance to movement* was defined as great discomfort after nonthreatening stimulation of the semi-circular canals of the inner ear, usually accompanied by nausea, vertigo, or headache. *Postural insecurity* was defined as extreme caution experienced as a result of decreased postural ability when completing physical challenges involving postural strength and stability. This condition lacks the fear response associated with gravitational insecurity.

Gravitational insecurity is conceptualized as a subtype of sensory integration dysfunction. It is characterized by decreased vestibulocerebellar functioning (primarily difficulty in processing information from the utricle and saccule of the vestibular system) and possibly decreased vestibular–ocular integration, which results in high arousal and apparently irrational limbic system–based fear responses to sudden or disorienting movement experiences (Ayres, 1979; Fisher & Bundy, 1989). Disorienting perceptual experiences in children—particularly poor depth perception; lack of visual input during motor tasks; and difficulty integrating visual, vestibular, and proprioceptive inputs—also have been implicated as characteristic of gravitational insecurity (Bloomberg, Mulavara, & Cohen, 2001; Lee, 1987). It is proposed that these sensory inputs, which should help an individual maintain a sense of his or her position in space, are not reliably interpreted by the central nervous system. Further, this sensory conflict may result in people with gravitational insecurity having higher resting sympathetic arousal states than peers without gravitational insecurity (Weisberg, 1984). Performance of typical, everyday activities and occupations that cause changes in head position (e.g., leaning over to tie shoes or turning one's head when riding in a car) may contribute to this heightened arousal state in people with gravitational insecurity.

A number of researchers have supported the relationship of vestibulocerebellar dysfunction to increased arousal state, anxiety, and fear responses characteristic of gravitational insecurity. Steinberg and Rendle-Short (1977) found extreme fear responses during nystagmus testing in a subgroup of children with hyponystagmus. Koomar (1995) found a strong relationship between anxiety and gravitational insecurity in a group of teens with dyspraxia. In adults, Levinson (1989a) found that nearly all adults with anxiety disorder exhibited vestibulocerebellar dysfunction and, conversely, that more than half of adults with vestibular dysfunction exhibited fears and phobias (Levinson, 1989b). He concluded that vestibulocerebellar system dysfunction was a major contributing factor to fear responses—particularly fear of heights, elevators, crowds, amusement park rides, escalators, and planes—that are commonly found in persons with gravitational insecurity (Levinson, 1989a, 1989b).

Method

The purpose of this study was to develop an assessment to identify children with gravitational insecurity, to examine preliminary reliability and validity evidence for the GI Assessment, and to examine developmental age trends. This study examined gravitational insecurity as a valid dysfunction and operationally defined it as an abnormal, excessive display of emotion characterized by fear or anxiety when engaged in an activity involving (a) a change in head position; (b) movement onto a raised or unstable surface; (c) movement through space; or (d) disorienting, or lack of, visual stimuli.

Phase 1: Initial Planning and Construct Specification

Phase 1 of this study defined the construct and characteristics of gravitational insecurity and developed an operational definition of gravitational insecurity. Domain specification of gravitational insecurity was based on constructs proposed by Ayres (1979), Fisher & Bundy (1989), and Lee (1987), review of the literature; and survey of a panel of master occupational therapists experienced with working with children with sensory integration dysfunction. These sources confirmed that children with gravitational insecurity, as defined by the operational definition, may be identified clinically by observing responses to activities that expose them to one or more conditions that challenge their vestibular system.

Phase 2: Test Construction and Pretesting

In Phase 2, we developed the assessment through interrater reliability and internal consistency of the instrument. Preliminary test activities, item format, and scoring criteria were developed for the GI Assessment, resulting in 15 tasks (see Table 1) and three categories of behavioral responses to be rated for each task (see Table 2). Items and behavioral categories were developed from literature review, feedback from expert occupational therapists, and clinical observations of people with suspected gravitational insecurity. For initial interrater reliability, the first author trained two

Table 1. Test Items on the Pilot Study GI Assessment

Item	Description
1. Jumping*	Participant jumps up and down with both feet together
2. Broad jump	Participant broad-jumps forward as far as possible
3. Stick jump	Participant jumps over stick on ground
4. Height jump*	Participant jumps over stick raised 10 cm (4 in) off ground
5. Stand on chair*	Participant steps up on seat of chair
6. Jump off chair—eyes open	Participant hops off chair with eyes open
7. Jump off chair—eyes closed*	Participant hops off chair with eyes closed
8. Forward roll*	Participant does a forward somersault
9. Backward roll*	Participant attempts a backward somersault
10. Tiltboard step*	Participant steps on tiltboard, then steps off backward
11. Prone on ball	Participant lies prone on large therapy ball and rocks from hands to feet
12. Supine on ball—active*	Participant lies back on ball, then stands up
13. Supine on ball—passive*	Participant lies supine on therapy ball as rater quickly tips it backward
14. Swinging ball	Rater swings ball toward participant's face
15. Bounced ball catch	Rater bounces large therapy ball to participant

Note. GI = gravitational insecurity. *Items used for preschool study.

therapists to administer a preliminary form of the GI Assessment to 7 children who were typically developing and 1 child with gravitational insecurity. The items and scoring of the GI Assessment were refined and a final standardized test protocol was developed.

Twelve children identified by their occupational therapists as demonstrating behaviors characteristic of gravitational insecurity were tested by the first author and another therapist to obtain interrater reliability data for this finalized scale. Intraclass correlation coefficients (ICC), (2,1) (Shrout & Fleiss, 1979) were calculated and yielded values of .79 for the total test score, .91 for the Postural subscore, .71 for the Emotional subscore, and .23 for the Avoidance subscore. Item values ranged from .49 to .97. The resultant scores were considered adequate for research purposes.

Phase 3: Pilot Testing for Discriminative Ability

Phase 3 involved pilot testing to determine initial discriminative ability of the GI Assessment and established preliminary construct validity for gravitational insecurity.

Table 2. Scoring Criteria of the Pilot GI Assessment's Behavioral Category

Behavioral Category	Level 1 Typical Responses	Level 2 Mild to Moderate GI	Level 3 Definite GI
Avoidance behaviors	No hesitation, or from 1 to 5 seconds of hesitation Readily attempts or repeats activity May require 1 verbal prompt to begin	Definite hesitation; significant delay in initiating task (6+ seconds) Attempts task with modifications "Works up" courage to attempt task	Refuses to attempt activity Stops task or refuses to complete it Physically withdraws from activity
Emotional behaviors	Apparent enjoyment of activity "Neutral" affect; no overt fear	"Nervous" talk, smile, or laughter Makes 1+ statements of worry, concern, strong dislike, or mild fear (e.g., "Is this safe?" "This is scary." "I don't like this.") Grimaces or makes faces Mild autonomic responses (e.g., sweaty palms, dilation of pupils, increased breathing, flushed face, repeated blinking)	Makes 1+ statements of fear of task or anger toward therapist (e.g., "I don't want to do it! I hate this.") Shows evidence of fear or anger (e.g., tone of voice, change of inflection) Demonstrates "panic" reactions, cries, yells, or hyperventilates
Postural responses	"Normal" equilibrium responses May reach for support but no contact Both feet leave the ground No stiffness or rigidity	May grab or hold support, then release May show mild to moderate guard or startle reactions May take 1 step back from task Body may stiffen then relax Noticeably awkward or stiff responses One extremity remains in contact with ground Both feet never leave ground at same time Steps (doesn't jump) off chair Needs any verbal prompt to release grasp from support	Tight or frantic grasp at support Refusal to release grasp Stiff or rigid body or movements Does not relax with verbal prompt High guard responses Both feet or 2 extremities remain in contact with supports Needs any second verbal prompt to release grasp

Note. GI = gravitational insecurity.

Hypotheses. The following hypotheses were tested:

• Children identified by experienced occupational therapists as demonstrating behaviors characteristic of gravitational insecurity will have significantly lower mean scores on an observational test of gravitational insecurity (the GI Assessment) than children who are typically developing.

• The GI Assessment will demonstrate at a significant level the ability to discriminate children with gravitational insecurity from peers who are typically developing.

• The GI Assessment will demonstrate adequate internal consistency.

Secondary questions included the following:

• Which test items best differentiate children with gravitational insecurity from children who are typically developing?

• Which response category or combination of categories (i.e., Avoidance Behaviors, Emotional Responses, Postural Responses) best differentiates children with gravitational insecurity from children who are typically developing?

Participants. Two groups of children ages 5–10 years participated. The first clinical group (n = 18, 13 boys, 5 girls) consisted of children identified as having sensory integrative dysfunction with gravitational insecurity. Children were referred by experienced occupational therapists on the basis of behaviors observed during testing of clinical observations and ongoing treatment sessions. Each of them had demonstrated fearful responses to two or more of the following situations: (a) movement on an unstable surface; (b) unexpected or quick movement by another person; (c) change of head position; (d) change of head position with feet moved off a stable surface; (e) static position or movement on a high surface; or (f) disorienting, or lack of, visual input. Participants in this group additionally met the criteria of average intelligence, no physical handicaps, typical hearing, normal or corrected vision, and presence of sensory integrative dysfunction as determined by an occupational therapist certified in the evaluation of sensory integration dysfunction. Although not a requirement for inclusion, most participants in this group were receiving direct occupational therapy services with a sensory integrative treatment emphasis and were receiving some form of educational remediation.

The children who were typically developing (n = 18) were selected from local elementary schools and matched by age and gender to the clinical group. Typical participants met the criteria of average intelligence, no history of physical handicaps, no language problems, no history of educational remediation, normal hearing, normal or corrected vision, and no past or present occupational or physical therapy services based on parent and teacher reports. Further, they did not demonstrate any behaviors characteristic of gravitational insecurity.

Procedures. Parents were contacted, informed consent was obtained, and testing was conducted by the first author either in the child's home or at a private occupational therapy clinic. The examiner was aware of the participant's group status but was not aware of severity level of gravitational insecurity identified by the referring occupational therapist. After the assessment was explained to the child, the GI Assessment was conducted in a standardized format according to the test protocol, which is available from the first author.

Results. To address the first hypothesis, a one-way analysis of variance found the total scores of the participants with gravitational insecurity to be significantly lower than those of the children who were typically developing, $F(1, 34) = 38.035$, $p < .000$; typical M = 132.6, SD = 1.33; GI M = 123.9, SD = 5.87.

To answer the second hypothesis, discriminant analysis of the total score of the GI Assessment found that 83% of the children with gravitational insecurity and 100% of the children who were typically developing were correctly classified into their groups at a level significantly higher than chance.

A stepwise discriminant analysis further showed that the following tasks discriminated between groups at a significant level: backward roll, $F(1, 34) = 18.85$, $p < .01$; jump off chair—eyes closed, $F(1, 32) = 9.24$, $p < .02$; supine on ball—active, $F(1, 32) = 4.83$, $p < .15$; and tiltboard step, $F(1, 31) = .2.83$, $p < .15$. These four items correctly classified 89% of children with gravitational insecurity and 94% of the children who were typically developing. Supine on ball—passive, jumping, height jump, stand on chair, and forward roll also contributed to the group discrimination. Their inclusion in the final analysis did not add significant discriminative power; however, discriminative accuracy increased to 100% in classifying children who were typically developing. These results indicated that four items were sufficient to accurately identify children with gravitational insecurity but that the additional five items contributed somewhat to the reduction of false positives.

Internal consistency of total test score to the behavioral subscores for the GI Assessment had a Cronbach's alpha coefficient of .820 for the combined group, .806 for the group with gravitational insecurity, and .688 for the typical group. Internal consistency for the total test score to items scores was .741 for the total group, .717 for the group with gravitational insecurity, and .479 for the typical group. The lower internal consistency coefficients for the typical group were due to a lack of variability in the data.

A stepwise discriminant analysis conducted on the subscores of all three behavioral categories with an entry level of .15 addressed the question of which behavioral category best discriminated between the two groups. The analysis found that the combined categories of Emotional Responses, $F(1, 34) = 31.746$, $p = .0001$, and Postural Responses, $F(1, 33) = 3.950$, $p = .0552$, were able to discriminate between the two groups with statistically significant accuracy. Avoidance Behaviors were able to discriminate between the two groups, $F(1, 34) = 12.227$, $p = .0013$, based on the entry level of .15. This category, however, did not contribute additional significant discriminant power, $F(1, 32) = .085$, $p = .7720$. A classification analysis of the combined Emotional and Postural responses subscores accurately classified 83.3% of the participants with gravitational insecurity and 100% of the participants who were typically developing. Results of this phase indicated that the GI Assessment is reliable and able to adequately discriminate children with gravitational insecurity from peers who are typically developing.

Phase 4: Preliminary Validation of Developmental Trends

Phase 4 provided additional preliminary validation of the GI Assessment through examination of developmental trends in performance. Pilot testing demonstrated that children who were typically developing, ages 5–10 years, completed the GI Assessment with nearly 100% accuracy, reflecting a plateau effect on the test by age 5 years. To determine whether there was a developmental trend to gravitational security in younger children, a preliminary validation study was completed with preschool children ages 2–4 years.

Research questions. The research questions examined were

- What is the typical performance of children ages 2–4.11 years on the GI Assessment?
- Is there a significant difference in performance by age among 2- to 4.11-year-old children on the GI Assessment?

Instrumentation. A revised version of the GI Assessment was used. The 9 discriminatory items identified in Phase 3 were retained for use, and the remaining 6 items were discarded. The 9 items retained included jumping, height jump, stand on chair, jump off chair—eyes closed, forward somersault, backward somersault, tiltboard step, supine on ball—active, and supine on ball—passive. Behaviors associated with the Emotional and Avoidance rating categories were collapsed into one Emotional Category, the Postural Category was retained, and the 3-point scoring system remained unchanged.

Participants. Forty-eight children who were typically developing, ages 2–4.11 years, were recruited as a sample of convenience. Participants had no known developmental, psychological, or physical difficulties and demonstrated no behaviors characteristic of gravitational insecurity by parent report.

Procedures. Informed consent was obtained, and children were tested at each child's home or day care facility or at the first author's workplace. Ten raters who were entry-level master's-degree occupational therapy students established interrater reliability. Raters trained to administer the revised GI Assessment by the first author using verbal instruction, videotape observations, and demonstrations were divided into pairs, with each pair testing 2 children for interrater reliability. Each student acted as the primary rater of 1 participant and as an observer of the second child. Intraclass correlation coefficient (Shrout & Fleiss, 1979) for the rater pool was .959.

Results. t tests on the total score determined interage differences for each 6-month age group (see Table 3). Significant differences were found between the 2-year-old group and the 3.0-, 4.0-, and 4.6-year-old groups as well as between the 3.6-year-old group and the 4.0- and 4.6-year-old groups. These findings supported differences in performance among younger and older children, reflecting a developmental trend. However, large standard deviations across groups and a small sample size make this a preliminary conclusion and limit generalization of these findings.

Discussion

In conclusion, the GI Assessment is a reliable and accurate means of identifying children with gravitational insecurity. The small sample sizes of this study, however, are a limitation. Further studies are needed to refine this tool and to

Table 3. Comparison of One-Tailed *t*-Test Scores Between Age Groups

				t values				
Age	*N*	*M*	*SD*	2.6–2.11	3.0–3.5	3.6–3.11	4.0–4.5	4.6–4.11
2.0–2.5	7	33.57	5.34	–1.55	–2.91**	–0.008	–3.78**	–2.86**
2.6–2.11	7	41.42	8.81	—	–0.67	1.108	–1.37	–0.94
3.0–3.5	11	44.63	7.12	—	—	1.77	–0.97	–0.44
3.6–3.11	8	33.62	14.37	—	—	—	–2.31*	–1.93*
4.0–4.5	9	48.00	4.66	—	—	—	—	0.35
4.6–4.11	6	46.50	6.8	—	—	—	—	—

*$p < .05$. **$p < .01$. — = Not applicable.

establish the reliability and validity of the revised version before it may be routinely used. The GI Assessment's ability to discriminate between groups even when the participants have a minimal degree of gravitational insecurity is a strength. This sensitivity may allow the tool to be used for test–retest purposes. Preliminary results on the GI Assessment represent a promising first step toward a more objective method of identifying and assessing gravitational insecurity. Collaboration with professionals—such as physical therapists using vestibular rehabilitation and psychologists—may facilitate development of the most effective assessments and interventions for gravitational insecurity.

Content of the 9 significant tasks validated the 3 different movement components of the operational definition of gravitational insecurity. Although tasks that assessed responses to direct visual stimuli were not found to contribute strongly to the total score, other significant tasks did incorporate visual components; therefore, visual perception should not be excluded from the construct of gravitational insecurity. Further item development in the visual–vestibular domain would be recommended (Kawar, 2005). Examination of the GI Assessment to a self-report scale of gravitational insecurity—as well as a comparison of motor performance of children with gravitational insecurity and children with sensory integrative dysfunction without gravitational insecurity—would be helpful to specify gravitational insecurity's relationship to dyspraxia and poor postural mechanisms. Examination of the GI Assessment and measures of anxiety, other emotional indicators, physiological responses, and involvement in daily occupations would help identify the relationship of gravitational insecurity to emotional difficulties, arousal state, chronic stress, and occupational performance. Frequent interpretation of behaviors characteristic of gravitational insecurity as emotional problems (e.g., anxiety) indicates the importance of educating psychologists, psychiatrists, and other mental health workers to the signs and symptoms of gravitational insecurity. ▲

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