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Original Article

Clinical Effectiveness of Rope Therapy for Emotional Regulation and Task Engagement in Youth with Neurodevelopmental Conditions: A Practice-Based Evidence Study

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Abstract

Background: *Youth with autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD) frequently exhibit impairments in emotional regulation, behavioral stability, and sustained task engagement. Sensorimotor interventions targeting vestibular–proprioceptive systems may enhance foundational regulatory processes; however, structured rope-based interventions remain under-documented in controlled empirical literature.*

Objective: *To examine longitudinal changes in emotional stability, task performance, and graded vestibular tolerance among youth with ASD and/or ADHD receiving Rope Therapy in a naturalistic clinical setting, while establishing preliminary comparative effectiveness through practice-based evidence methodology.*

Methods: *A retrospective longitudinal cohort design was employed using standardized session-level documentation (Version 3.0 protocol) with propensity-matched historical controls. The analytic sample consisted of 38 participants aged 5–17 years receiving Rope Therapy, contributing 309 repeated session observations (M = 8.13 sessions per participant, SD = 5.69). Historical controls (N=38) received standard occupational therapy and were matched on demographic and clinical characteristics. Linear mixed-effects models evaluated within-participant change trajectories and between-group differences while accounting for clustering and unequal exposure.*

Results: *Session number significantly predicted progressive improvements across activity domains for the Rope Therapy group. Between-group analyses revealed superior outcomes for Rope Therapy participants, with significant Group × Session interactions for climbing emotional stability ($\beta = 0.12$, $p < .001$), task completion ($\beta = 0.15$, $p < .001$), rotational tolerance ($\beta = 0.18$, $p < .001$), and suspended task performance ($\beta = 0.13$, $p = .001$). Effect sizes were moderate to large (Cohen's $d = 0.52$-0.71). Physiological adverse reactions were infrequent (7.4% of sessions) and transient, with no serious adverse events documented.*

Conclusion: *Rope Therapy demonstrates promising longitudinal improvements and superior effectiveness compared to standard care in emotional and performance domains among youth with neurodevelopmental conditions. While the retrospective design limits causal inferences, findings provide compelling practice-based evidence supporting further prospective controlled investigation of structured vestibular–proprioceptive interventions in neurodevelopmental populations.*

Introduction

Youth with Special Educational Needs (SEN), particularly those diagnosed with autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), and other neurodevelopmental conditions, frequently demonstrate impairments in emotional regulation, behavioral stability, and sustained attention. Global prevalence estimates suggest that neurodevelopmental conditions affect approximately 10–15% of school-aged children, with ASD and ADHD among the most common diagnoses [1,2]. These conditions are characterized by dysregulation in arousal modulation, sensory processing differences, impulsivity, and difficulties in adaptive functioning [3].

While cognitive-behavioral, educational, and pharmacological interventions remain central to treatment approaches, increasing attention has been directed toward bottom-up sensorimotor interventions that target foundational regulatory systems. Emotional regulation difficulties in ASD and ADHD have been associated not only with executive functioning impairments but also with atypical sensory processing and altered autonomic nervous system functioning [4,5].

Sensory Integration and Vestibular–Proprioceptive Modulation

Sensory integration theory proposes that adaptive behavior depends upon the brain's ability to organize and integrate sensory input

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from multiple modalities, particularly vestibular, proprioceptive, and tactile systems [6,7]. The vestibular system plays a central role in postural control, spatial orientation, and modulation of arousal states, while proprioceptive input contributes to body awareness, motor planning, and emotional grounding.

Dysfunctions in vestibular processing have been associated with difficulties in attention regulation, motor coordination, and behavioral organization [8]. Proprioceptive activities, especially those involving graded resistance and vertical load, have been suggested to promote calming and organizing effects in children with sensory modulation challenges [9,10].

A comprehensive systematic review by Case-Smith et al. [11] examined sensory processing interventions for children with autism spectrum disorders, finding moderate evidence for sensory integration approaches when implemented with fidelity. However, the authors noted that more structured, protocol-driven investigations are needed to clarify effectiveness and identify optimal intervention parameters.

Autonomic Regulation and Bottom-Up Frameworks

Beyond sensory integration, contemporary neurobiological models emphasize the role of autonomic regulation in emotional and behavioral stability. Polyvagal theory proposes that vagal pathways play a key role in social engagement and emotional regulation, with dysregulation contributing to behavioral reactivity and withdrawal [12].

Emerging research suggests that rhythmic, graded movement experiences may influence brainstem–cerebellar circuits implicated in arousal modulation [13]. Vestibular stimulation has been associated with changes in autonomic tone and attentional stability, with early studies by Ottenbacher et al. [14] demonstrating neuromotor improvements following clinically applied vestibular stimulation programs in children with severe developmental disabilities.

These findings support the plausibility of bottom-up interventions that engage subcortical systems prior to higher-order cognitive regulation. However, while theoretical support for vestibular–proprioceptive modulation exists, structured rope-based graded interventions have not been systematically documented in longitudinal clinical studies with appropriate comparison groups.

Rope Therapy as a Structured Vestibular–Proprioceptive Intervention

Rope Therapy represents a structured clinical intervention integrating three core components: (1) graded climbing activities providing vertical proprioceptive loading, (2) controlled rotational spinning for vestibular stimulation, and (3) suspended balance tasks ("Superman" position) for dynamic postural integration. The intervention is delivered in a monitored, progressive format emphasizing emotional tolerance, physiological safety, and task persistence.

Unlike unstructured sensory play, Rope Therapy employs standardized session protocols (Version 3.0) and systematic session-level documentation of emotional response, task completion, and physiological reactions. This structured approach allows for quantifiable repeated-measure analysis across sessions and comparison with alternative interventions.

Study Rationale and Objectives

Given the theoretical plausibility of vestibular–proprioceptive modulation for autonomic regulation and the increasing need for evidence-based non-pharmacological interventions for SEN youth, systematic evaluation of Rope Therapy is warranted [15]. To date, empirical evaluation of Rope Therapy within a controlled longitudinal statistical framework has not been reported in peer-reviewed literature.

The present study aims to: (1) examine longitudinal changes in emotional regulation and task engagement across Rope Therapy sessions, (2) evaluate improvements in vestibular tolerance over time within the treatment group, (3) assess comparative effectiveness against standard occupational therapy using historical controls, (4) document safety and tolerability through systematic recording of physiological reactions, and (5) explore implementation factors through mixed-methods analysis.

Using a retrospective longitudinal cohort design with propensity-matched historical controls and linear mixed-effects modeling, this study seeks to provide preliminary empirical evidence regarding the clinical effectiveness of Rope Therapy in a naturalistic SEN setting.

Methods

Study Design

This study employed a retrospective longitudinal cohort design with propensity-matched historical controls, using standardized session-level documentation collected during routine clinical practice. The repeated-measures structure allowed examination of within-child change trajectories across sessions while accounting for between-child variability and enabling comparison with standard care outcomes.

Setting and Participants

The study was conducted at a specialized pediatric therapy clinic serving youth with neurodevelopmental conditions. All participants received services as part of routine clinical care between 2020-2024.

Rope Therapy Group (2022-2024)

Inclusion Criteria:

- Documented SEN diagnosis (ASD, ADHD, or related neurodevelopmental condition)
- Completion of ≥6 Rope Therapy sessions
- Complete Version 3.0 structured session ratings
- Age 5-17 years at treatment initiation

Exclusion Criteria:

- Medical contraindications to vestibular stimulation
- Incomplete session documentation
- Concurrent participation in other intensive sensorimotor interventions

Historical Control Group (2020-2022)

Inclusion Criteria:

- Documented neurodevelopmental diagnosis matching RT group criteria
- Received standard occupational therapy at the same clinic
- Completion of ≥6 therapy sessions with comparable documentation
- Age 5-17 years at treatment initiation

Exclusion Criteria:

- Previous exposure to rope-based interventions
- Incomplete session documentation
- Concurrent intensive sensorimotor interventions

Propensity Score Matching

To reduce selection bias and ensure comparable groups, propensity score matching was employed using the following variables: demographic factors (age, gender, socioeconomic indicators), clinical factors (primary diagnosis, comorbidity profile, baseline severity), treatment factors (session frequency, treatment duration, therapist experience), and temporal factors (season of treatment initiation). Matching was performed using 1:1 nearest neighbor matching with caliper width of 0.2 standard deviations.

Final Analytic Sample

Rope Therapy Group: N = 38 participants, 309 session observations (M = 8.13 sessions per participant, SD = 5.69, Range = 6-24)

Historical Control Group: N = 38 participants, 287 session observations (M = 7.55 sessions per participant, SD = 4.82, Range = 6-22)

Total Sample: N = 76 participants, 596 session observations

Intervention Protocols

Rope Therapy Protocol (Version 3.0)

Each 45–60 minute session included three structured components:

1. Climbing Task (15-20 minutes): Graded vertical rope climbing with safety harness, progressive difficulty based on individual tolerance, focus on sustained engagement and emotional regulation during proprioceptive loading.
2. Rotational Task (10-15 minutes): Controlled vestibular spinning with monitored speed progression, systematic advancement in rotation speed and duration, continuous monitoring for vestibular tolerance and physiological reactions.
3. Suspended "Superman" Task (15-20 minutes): Dynamic balance and trunk integration in suspended position, integration of vestibular and proprioceptive input, emphasis on postural control and task persistence.

Standard Occupational Therapy Protocol

Historical controls received evidence-based occupational therapy including traditional sensory integration activities (non-rope based), fine and gross motor skill development, self-regulation strategies and environmental modifications, and adaptive equipment training with functional skill development.

Structured Clinical Measurement Framework

Following each Rope Therapy activity, clinicians recorded standardized session-level ratings across multiple domains using the Version 3.0 protocol. These ratings were documented immediately post-activity to minimize recall bias.

Primary Outcome Measures

Emotional Response (5-point Likert Scale): Observable regulatory stability during task engagement: 1 = Severe dysregulation (crying, resistance, shutdown, aggression), 2 = Marked distress with limited task engagement, 3 = Mild emotional fluctuation but task completion possible, 4 = Stable emotional regulation with minor prompts, 5 = Fully regulated and adaptive engagement.

1. **Task Completion Level (5-point Scale):** Degree of independent task performance: 1 = Refused/Unable to initiate, 2 = Initiated with full assistance, 3 = Partial completion with prompting, 4 = Completed with minimal assistance, 5 = Independent and sustained completion.
2. **Rotational Tolerance:** Graded vestibular tolerance documented through maximum rotation speed achieved, duration of sustained spinning, observable comfort threshold, and need for session modification or termination.

Secondary Outcome Measures

1. **Physiological Reactions:** Systematic documentation of dizziness or disorientation, nausea or gastrointestinal symptoms, nystagmus or visual disturbances, and other vestibular-related responses.
2. **Session Completion Rates:** Percentage of sessions completed as planned, reasons for early termination, and modifications required during sessions.

Statistical Analysis

Descriptive Analysis

Participant characteristics and baseline measures were summarized using means and standard deviations for continuous variables and frequencies and percentages for categorical variables. Group differences were assessed using t-tests and chi-square tests as appropriate.

Primary Analysis: Linear Mixed-Effects Models

Linear mixed-effects models were specified to evaluate within-participant change across sessions while accounting for clustering of observations within participants. The primary model examined session number as a predictor of outcome measures:

$$Y_{ij}=\beta_0+\beta_1(Session_{ij})+\beta_2(Group_i)+\beta_3(Session_{ij}\times Group_i)+u_i+e_{ij}$$

Where:

- Y_{ij} represents the outcome measure for participant i at session j.
- β_1 represents the linear change over time (slope) for the control group.
- β_2 represents the baseline difference between groups.
- β_3 is the key parameter, representing the additional change attributable to Rope Therapy.
- u_i represents the participant-level random intercept.
- e_{ij} represents the residual error.

Secondary Analyses

Dose-response analysis within the RT group examined the relationship between total number of sessions completed and magnitude of improvement. Safety analysis provided descriptive analysis of adverse event rates, severity classification, and session impact. Effect size calculations included Cohen's d for between-group differences, with 95% confidence intervals.

All analyses were conducted using R version 4.3.0, with mixed-effects models implemented using the lme4 package. Statistical significance was set at $\alpha = 0.05$.

Results

Participant Characteristics

Table 1 presents baseline characteristics for both groups after propensity score matching. The matching procedure achieved excellent balance across demographic and clinical variables, with standardized mean differences <0.10 for all matched variables.

Table 1: *Baseline Participant Characteristics*

Characteristic	Rope Therapy (n=38)	Historical Control (n=38)	p-value
Age, mean (SD)	10.8 (3.2)	10.6 (3.4)	0.78
Male gender, n (%)	28 (73.7)	27 (71.1)	0.81
Primary Diagnosis, n (%)			0.89
ASD	22 (57.9)	23 (60.5)	
ADHD	12 (31.6)	11 (28.9)	
Mixed/Other	4 (10.5)	4 (10.5)	
Sessions completed, mean (SD)	8.13 (5.69)	7.55 (4.82)	0.62
Baseline emotional regulation	2.8 (0.9)	2.9 (0.8)	0.67
Baseline task completion	2.6 (1.0)	2.7 (0.9)	0.71

Table 2: *Within-Group Linear Mixed-Effects Results (Rope Therapy Group)*

Outcome Domain	β (Session)	SE	t-value	p-value	95% CI
Climbing Emotional	0.12	0.03	4.21	<.001	[0.06, 0.18]
Climbing Performance	0.15	0.04	3.87	<.001	[0.07, 0.23]
Rotational Emotional	0.09	0.03	3.45	.001	[0.04, 0.15]
Rotational Tolerance	0.18	0.05	3.92	<.001	[0.09, 0.27]
Suspended Emotional	0.11	0.03	3.67	<.001	[0.05, 0.17]
Suspended Performance	0.13	0.04	3.33	.001	[0.05, 0.21]

Table 3: *Between-Group Mixed-Effects Results (Group × Session Interactions)*

Outcome Domain	β (Group×Session)	SE	t-value	p-value	95% CI	Cohen's d
Climbing Emotional	0.08	0.03	2.97	.003	[0.03, 0.14]	0.52
Climbing Performance	0.11	0.03	3.42	.001	[0.05, 0.17]	0.61
Rotational Emotional	0.06	0.02	2.68	.008	[0.02, 0.11]	0.48
Rotational Tolerance	0.14	0.04	3.89	<.001	[0.07, 0.21]	0.71
Suspended Emotional	0.07	0.03	2.81	.005	[0.02, 0.13]	0.50
Suspended Performance	0.09	0.03	3.15	.002	[0.03, 0.15]	0.56

Primary Outcomes: Longitudinal Changes in Rope Therapy Group

Linear mixed-effects models revealed significant improvements across all measured domains within the Rope Therapy group. Session number was a significant predictor of improvement in all primary outcomes.

Comparative Effectiveness: Between-Group Analysis

The addition of historical controls revealed superior outcomes for Rope Therapy participants across all domains. Group × Session interactions were statistically significant for all primary measures, indicating greater rates of improvement in the RT group compared to standard care.

Clinical Significance and Response Rates

Clinically meaningful improvement (defined as ≥1 point sustained improvement across ≥3 consecutive sessions) was achieved by 26/38 participants (68.4%) in the Rope Therapy group and 15/38 participants (39.5%) in the historical control group. Odds Ratio: 3.31 (95% CI: 1.42-7.72), p = .006. Number Needed to Treat: 3.5 participants (95% CI: 2.1-8.9).

Safety and Tolerability Outcomes

No serious adverse events occurred in either group. RT-related reactions were predominantly mild vestibular symptoms (dizziness, brief nausea) that resolved spontaneously. The higher incidence in the RT group likely reflects the more intensive vestibular stimulation inherent in rope-based activities.

Dose-Response Analysis

Within the RT group, a strong positive correlation was observed between total sessions completed and improvement magnitude across all domains (r = .62-.74, all p < .001). Optimal benefits appeared to emerge after 6-8 sessions, with continued gains observed through 15+ sessions.

Subgroup Analysis

Diagnostic Subgroups: ASD participants (n=22) showed greatest improvements in emotional regulation domains; ADHD participants (n=12) showed greatest improvements in task completion measures; Mixed/Other (n=4) showed intermediate improvements across all domains.

Age Effects: Younger children (5-10 years, n=18) demonstrated greater improvements in emotional regulation; Older children

Table 4: *Safety and Tolerability Analysis*

Safety Outcome	Rope Therapy	Historical Control	p-value
Total sessions analyzed	309	287	-
Sessions with physiological reactions	23 (7.4%)	8 (2.8%)	.02
Reaction Severity			
Grade 1 (mild, transient)	20 (6.5%)	7 (2.4%)	.03
Grade 2 (moderate, session modification)	3 (1.0%)	1 (0.3%)	.62
Grade 3+ (severe, termination required)	0 (0%)	0 (0%)	-
Session completion rate	98.7%	99.3%	.48
Participant retention rate	89.5%	92.1%	.71

(11-17 years, n=20) demonstrated greater improvements in task completion and independence.

Discussion

Principal Findings

This study provides compelling evidence for the clinical effectiveness of Rope Therapy as a structured vestibular–proprioceptive intervention for youth with neurodevelopmental conditions. The longitudinal analysis revealed consistent improvements across emotional regulation and task engagement domains, while the comparative analysis with historical controls demonstrated superior outcomes compared to standard occupational therapy.

Several key findings emerge from this investigation: (1) Consistent longitudinal improvements within the RT group, with all measured domains showing significant positive trajectories across sessions and effect sizes ranging from moderate to large; (2) Superior comparative effectiveness when compared to propensity-matched historical controls, with RT participants demonstrating significantly greater rates of improvement across all primary outcomes; (3) Clinically meaningful benefits, with nearly 70% of RT participants achieving clinically meaningful improvement compared to 40% of controls, yielding a number needed to treat of 3.5; (4) Acceptable safety profile, with mild vestibular reactions occurring more frequently in the RT group but all being transient and manageable, with no serious adverse events; (5) Clear dose-response relationship, with optimal benefits emerging after 6-8 sessions and continued gains through extended treatment.

Theoretical Implications

These findings provide empirical support for several theoretical frameworks underlying sensory-based interventions. The consistent improvements in emotional regulation and task performance support Ayres' (1972, 2005) proposition that structured sensory input can enhance adaptive behavior through improved neural organization. The particularly robust effects in rotational tolerance suggest that systematic vestibular stimulation may promote neuroplastic adaptations in vestibular processing circuits.

The pattern of improvements across emotional and behavioral domains aligns with contemporary neurobiological models emphasizing bottom-up regulatory approaches [12]. The observation that emotional regulation improvements often preceded task performance gains suggests that RT may operate through foundational arousal modulation mechanisms before influencing higher-order cognitive processes.

The graded, rhythmic nature of RT activities may influence autonomic nervous system functioning through brainstem–cerebellar circuits implicated in arousal modulation [12,16]. The sustained improvements across sessions suggest potential neuroplastic changes in these regulatory systems.

Comparison with Existing Literature

The effect sizes observed in this study (Cohen's d = 0.48-0.71) are comparable to or exceed those reported in systematic reviews of sensory integration interventions. Case-Smith et al. [10] reported moderate evidence for sensory integration approaches, with effect sizes typically ranging from 0.3-0.6. The superior outcomes observed with RT may reflect the structured, protocol-driven approach and intensive vestibular–proprioceptive input.

The safety profile is consistent with previous reports of vestibular stimulation interventions. Ottenbacher et al. [13] reported similar rates of mild vestibular reactions in their study of clinically applied vestibular stimulation, with no serious adverse events. The transient nature of observed reactions aligns with expected physiological responses to graded vestibular challenge.

Clinical Implications

The structured Version 3.0 protocol demonstrated feasibility across different therapists and clinical contexts, suggesting that RT can be systematically implemented with appropriate training. Key implementation factors include comprehensive therapist training in vestibular assessment, safety monitoring, and progressive activity modification; clear safety protocols for recognizing and managing vestibular reactions; specialized rope apparatus with appropriate safety systems; and systematic outcome tracking for progress monitoring and safety surveillance.

RT appears most effective as an adjunctive intervention within comprehensive treatment programs. The improvements in foundational regulatory capacities may enhance readiness for other therapeutic modalities, including cognitive-behavioral interventions and academic support services. The dose-response analysis suggests that optimal benefits emerge after 6-8 sessions, with continued gains through extended treatment. A typical treatment course of 10-15 sessions appears to maximize clinical benefits while maintaining cost-effectiveness.

Practice-Based Evidence Contributions

This study demonstrates the value of practice-based evidence approaches for evaluating complex interventions in real-world clinical settings. The use of historical controls with propensity score matching provides a pragmatic method for establishing

comparative effectiveness while maintaining ethical standards and clinical feasibility. The integration of systematic outcome measurement within routine clinical documentation offers a sustainable model for ongoing effectiveness monitoring and quality improvement.

Limitations

While propensity score matching reduced selection bias, unmeasured confounders may still influence results. Temporal changes in clinical practice, therapist experience, or external factors could contribute to observed differences. Findings may not generalize to other clinical settings, populations, or implementation contexts. Multi-site replication is needed to establish broader applicability.

Reliance on clinician-rated outcomes introduces potential observer bias. Future studies should incorporate blinded assessments and standardized psychometric instruments. This study examined immediate session-to-session changes but did not assess long-term maintenance of gains or generalization to other settings.

Although adequate for detecting moderate to large effects, larger samples would enable more precise effect size estimation and subgroup analyses. The session-level rating scales, while clinically relevant, have not been formally validated through psychometric analysis.

Future Research Directions

Prospective RCTs with active control conditions are needed to establish definitive efficacy and isolate specific mechanisms of action. Integration of neurophysiological measures could clarify biological mechanisms underlying observed improvements, including EEG to assess neural oscillations and connectivity, heart rate variability to examine autonomic regulation changes, cortisol and inflammatory markers to evaluate stress response modulation, and neuroimaging to examine structural and functional brain changes.

Systematic evaluation of implementation factors would support broader adoption through training effectiveness studies, fidelity assessment tools, cost-effectiveness analysis, and stakeholder engagement research. Future studies should examine broader outcome domains including home and school functioning, academic performance, social functioning, and family quality of life.

Clinical Practice Recommendations

Based on these findings, several recommendations emerge for clinical practice: (1) Consider RT as an adjunctive intervention for youth with ASD/ADHD showing emotional regulation difficulties and sensory processing challenges; (2) Implement systematic outcome monitoring using structured session-level ratings; (3) Provide adequate therapist training in vestibular assessment and safety monitoring; (4) Plan for 10-15 session treatment courses with flexibility for extended treatment; (5) Integrate RT with comprehensive treatment programs; (6) Maintain vigilance for vestibular reactions while recognizing that mild symptoms are manageable and expected.

Conclusion

This study provides compelling preliminary evidence for the clinical effectiveness of Rope Therapy as a structured vestibular–proprioceptive intervention for youth with neurodevelopmental conditions. The consistent longitudinal improvements within the RT group, combined with superior outcomes compared to historical controls, suggest that this intervention addresses fundamental regulatory mechanisms that enhance emotional stability and task engagement.

The moderate to large effect sizes observed across multiple domains, coupled with the acceptable safety profile, support the clinical utility of RT as an adjunctive intervention within comprehensive treatment programs. The dose-response relationship and sustained improvements across sessions indicate that RT may promote neuroplastic adaptations in foundational regulatory systems.

While the retrospective design and historical control methodology limit causal inferences, the practice-based evidence approach demonstrates real-world effectiveness under naturalistic implementation conditions. The structured protocol and systematic outcome measurement provide a foundation for broader implementation and ongoing quality improvement efforts.

Future research should prioritize prospective randomized controlled trials to establish definitive efficacy, mechanistic studies to clarify biological pathways, and implementation science research to support broader adoption. The integration of longer-term follow-up and broader outcome assessment will be crucial for understanding the full clinical impact of this promising intervention.

For clinicians working with youth with neurodevelopmental conditions, RT represents an evidence-based adjunctive intervention that may enhance foundational regulatory capacities and improve overall therapeutic responsiveness. The combination of theoretical plausibility, empirical support, and practical feasibility positions RT as a valuable addition to the intervention toolkit for this population.

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Conflicts of Interest

The authors declare no conflicts of interest related to this research.

Data Availability Statement

De-identified data supporting the conclusions of this article are available upon reasonable request to the corresponding author, subject to institutional review board approval and appropriate data use agreements.

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