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RESEARCH ARTICLE / ARAŞTIRMA MAKALESI

Effects of a 12-Session Hippotherapy Program on Balance, Anxiety, and Cognitive Function in Children with Developmental Coordination Disorder: A Three-Participant ABA Single-Case Study

Gelişimsel Koordinasyon Bozukluğu Olan Çocuklarda 12 Seanslık Hipoterapi Programının Denge, Anksiyete ve Bilişsel İşlevler Üzerindeki Etkileri: Üç Katılımcılı Tek Durumlu Çalışma

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ABSTRACT

Objective: This study investigated the effects of a 12-session hippotherapy program on balance, anxiety, and cognitive function in children with Developmental Coordination Disorder (DCD).

Materials and Methods: A single-subject reversal (ABA) design was conducted with three children aged 8-10 years with DCD. Participants received hippotherapy three times per week for four weeks. Balance was assessed using the Biodex Balance System, anxiety with the Spence Children's Anxiety Scale, and cognitive function with the computerized Wisconsin Card Sorting Test.

Results: All participants demonstrated marked improvements in static and dynamic balance during the intervention (percentage of non-overlapping data: 75-100%; Cohen's d = 1.2-2.1). These gains were partially sustained at follow-up. In contrast, changes in anxiety and cognitive outcomes varied: one child showed meaningful improvement, while the others had minimal or no change.

Conclusion: Hippotherapy produced consistent and clinically relevant improvements in balance in children with DCD, suggesting its potential as an effective adjunct to motor rehabilitation. Effects on anxiety and cognitive performance were less consistent, highlighting the need for individualized therapeutic planning and larger controlled trials.

Keywords: Developmental coordination disorder, hippotherapy, balance, anxiety, cognitive function, rehabilitation.

ÖZ

Amaç: Bu çalışma, 12 seanslık bir hipoterapi programının Gelişimsel Koordinasyon Bozukluğu (GKB) olan çocuklarda denge, anksiyete ve bilişsel işlevler üzerindeki etkilerini incelemeyi amaçlamıştır.

Gereç ve Yöntem: 8-10 yaş aralığında GKB tanılı üç çocukla tek denekli geri dönüşümlü (ABA) desen kullanılmıştır. Katılımcılar dört hafta boyunca haftada üç kez hipoterapi almıştır. Denge, Biodex Denge Sistemi ile; anksiyete, Spence Çocuklar için Anksiyete Ölçeği ile; bilişsel işlevler ise bilgisayarlı Wisconsin Kart Eşleme Testi ile değerlendirilmiştir.

Bulgular: Tüm katılımcılar, müdahale sırasında statik ve dinamik dengede belirgin iyileşmeler göstermiştir (örtüşmeyen veri yüzdesi: %75-100; Cohen's d = 1.2-2.1). Bu kazanımlar izlem sürecinde kısmen korunmuştur. Buna karşılık, anksiyete ve bilişsel sonuçlardaki değişiklikler değişkenlik göstermiştir: Bir çocukta anlamlı iyileşme görülürken, diğerlerinde minimal ya da hiç değişim gözlenmemiştir.

Sonuç: Hipoterapi, GKB'li çocuklarda dengede tutarlı ve klinik açıdan anlamlı iyileşmeler sağlamış, bu da yöntemin motor rehabilitasyona etkili bir tamamlayıcı olabileceğini düşündürmektedir. Anksiyete ve bilişsel performans üzerindeki etkiler daha az tutarlı olup, bireyselleştiril-

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miş tedavi planlaması ve daha geniş kontrollü çalışmalara ihtiyaç olduğunu ortaya koymaktadır.

Anahtar Sözcükler: Gelişimsel koordinasyon bozukluğu, hipoterapi, denge, anksiyete, bilişsel işlev, rehabilitasyon

INTRODUCTION

Developmental Coordination Disorder (DCD) is a common but often overlooked neurodevelopmental disorder, affecting about 5-6% of school-aged children and rendering even simple everyday activities unexpectedly challenging (1,2). Children with DCD regularly face persistent difficulties with motor coordination, most evident in problems with balance, posture, and fine or gross motor skills (3). Such limitations often restrict participation in school, play, and social contexts, and can gradually erode children's self-confidence and quality of life.

Recent evidence indicates that DCD extends beyond motor impairments: many affected children exhibit weaknesses in executive functions-including working memory, inhibitory control, and cognitive flexibility (4). Such deficits impair planning, task-switching, and the ability to manage complex, multi-step activities, thereby creating additional barriers to independence. Compounding these challenges, anxiety symptoms are disproportionately common in DCD, often arising from heightened awareness of performance difficulties and repeated motor failures (5). These problems span motor, cognitive, and emotional domains. Traditional approaches have emphasized direct motor training-typically targeting isolated strength, endurance, or specific movement patterns-but these programs often fail to produce meaningful functional change, as many children improve on clinical assessments yet continue to struggle with daily tasks such as dressing, handwriting, classroom routines, and playground navigation (6). Moreover, co-occurring difficulties in attention, planning, anxiety, and frustration tolerance frequently hinder the generalization of clinical gains to real-life participation. Consequently, interest has shifted toward integrative, child-centered interventions capable of simultaneously supporting motor, cognitive, and emotional functioning.

From a sports-medicine and rehabilitation perspective, balance, postural control, and coordination are foundational not only for mobility and athletic performance but also for everyday activities-sitting, standing, walking, and play-that support a child's independence. Deficits in these domains limit opportunities for physical activity, elevate the risk of falls and injury, and reduce social engagement, leading to adverse long-term effects on health and psychosocial development. Therefore, effective interventions must strengthen motor capacities while concurrently addressing cognitive and emotional barriers such as anxiety, reduced self-efficacy, and fear of falling. This perspective aligns with core sports-medicine principles, where rehabilitation prioritizes restoring safe, efficient, and purposeful movement (7). Recent findings further demonstrate that psychological and cognitive factors-including anxiety, attentional control, and anticipatory planning-significantly influence motor performance and participation, particularly in physically demanding contexts (2,8).

One promising intervention is hippotherapy, which uses the horse's dynamic, rhythmic, three-dimensional movement as a therapeutic stimulus. This continuous pelvic and trunk motion generates rich multisensory input-vestibular, proprioceptive, and somatosensory-while simultaneously engaging neuromotor control, postural adjustments, and emotional regulation processes. Controlled trials and systematic reviews consistently show that hippotherapy can enhance balance, postural stability, coordination, trunk control, and functional mobility in children with motor impairments (9-11). Importantly, these improvements often exceed those achieved through conventional motor-based therapy alone, suggesting that hippotherapy's multisystem stimulation may translate into more robust and ecologically valid functional gains. In addition to motor benefits, the naturalistic setting and child-animal bond have been linked to enhanced confidence, emotional regulation, and social engagement (12-14). Moreover, hippotherapy incorporates principles common to exercise-

based rehabilitation and physiotherapy-key elements of sports medicine-by stimulating adaptive postural responses during dynamic movement (9,10).

Although a growing body of research supports the benefits of hippotherapy for conditions such as cerebral palsy and autism spectrum disorder (9-15), studies examining its effects on DCD remain limited. Existing work has largely focused on motor outcomes, often with small sample sizes and methodological constraints (2, 6). Consequently, little is known about whether hippotherapy can improve executive functions or reduce anxiety in children with DCD.

Theoretical perspectives such as the internal modeling deficit hypothesis provide additional rationale, proposing that motor difficulties in DCD stem from impaired formation and updating of internal action models-mechanisms that may also underlie deficits in higher-order cognitive control (16,17). These considerations motivated the present study, which examined the effects of a structured twelve-session hippotherapy program on motor, cognitive, and emotional outcomes in children with DCD.

We hypothesized that hippotherapy would yield measurable improvements in static and dynamic balance, reflecting enhanced neuromuscular control and postural stability. With respect to cognition and anxiety, we anticipated improvements but expected variability across individuals, consistent with previous findings and theoretical accounts.

Therefore, this study addressed the following questions:

1. Does a structured twelve-session hippotherapy program improve static and dynamic balance in children with DCD?
2. To what extent does it influence executive functions, including attentional shifting, working memory, and inhibitory control?
3. Can it reduce anxiety symptoms commonly observed in children with DCD?
4. How do individual response patterns vary across motor, cognitive, and emotional domains?

Given the very small sample size (n = 3), examining individual response patterns is exploratory in nature, and the results should be interpreted as hypothesis-generating evidence. To investigate these questions, our single-subject reversal (ABA) design followed three children with DCD across twelve hippotherapy sessions, examining individualized trajectories in balance, cognitive function, and anxiety. By providing detailed response profiles, this study offers nuanced evidence regarding the potential of multisystem interventions to address the multifaceted needs of children with DCD.

Overall, our findings underscore the importance of incorporating movement-based, multisystem interventions into coordinated, family-centered rehabilitation programs for children with developmental disorders. To maintain focus on the study rationale and avoid conceptual redundancy, the literature was summarized succinctly.

MATERIAL AND METHODS

Study Design

This study utilized an ABA single-subject structure to examine the individualized effects of hippotherapy in children diagnosed with DCD. The ABA format was chosen because it provides repeated within-subject observations and standardized assessments across baseline (A), intervention (B), and withdrawal/follow-up (A') conditions, enhancing causal inference. This approach is particularly suited to heterogeneous populations like DCD, as it allows detection of subtle, individualized response patterns across motor, cognitive, and emotional domains (18,19).

The study comprised three sequential phases following a single-case, within-participant framework, which is appropriate for small samples and does not aim to test individual-difference effects:

- Baseline (A): Documenting each participant's natural performance level prior to intervention, serving as a stable reference point rather than a basis for between-participant comparison.

- Intervention (B): Delivering a structured hippotherapy program targeting motor control and related functional outcomes, with the primary focus on within-participant change over time, not on differences between individuals.
- Follow-up (A'): Assessing post-intervention performance to evaluate the durability of change, consistent with the logic of single-case experimental designs that prioritize intra-individual trajectories rather than population-level inference.

Repeated, standardized observations and measurements in all phases (e.g., behavioral observations in naturalistic tasks, standardized balance tests, and validated anxiety scales) enabled identification of trends in improvement or regression and supported stronger causal inference regarding intervention effects within individuals.

Participants

As shown in Table 1, a purposive sample of three children (aged 8-10) with a diagnosis of DCD were recruited from special education schools in (blinded). Inclusion criteria were adapted from established guidelines for DCD research and clinical assessment (20,21) and were operationalized as follows:

Table 1: Participant Characteristics

Participant	Age	Gender	DCD-Q7 Score	KBIT-2 Matrices
1	8	Female	42	92
2	9	Male	38	89
3	10	Female	45	95

None of the participants had any prior experience with horseback riding or hippotherapy (Previous Riding Experience = None), which allows for the direct evaluation of the current intervention's effects without confounding influences from previous exposure.

- Diagnosis of DCD was established according to DSM-5 criteria, operationalized through:

  - clinical evaluation by a child psychiatrist and a clinical psychologist to rule out intellectual disability, autism spectrum disorder, ADHD, neurological disease, and other conditions that could better explain the motor difficulties;

  - standardized motor assessment using the Movement Assessment Battery for Children-2 (MABC-2) (22), with Total Test Scores at or below the 16th percentile;

  - parent-reported motor coordination difficulties on the DCD-Q7, with scores above the recommended age-specific cut-off for impairment (23);

  - functional observations by a certified hippotherapist (not involved in diagnostic decision-making).

- Medium to high cognitive ability confirmed by Raven's Progressive Matrices (children's version).

Exclusion criteria included intellectual disability, sensory impairments, or contraindications to hippotherapy (e.g., epilepsy, severe allergies to horses).

Ethical approval was granted by (blinded). Parents provided written consent after being informed about study aims, confidentiality, risks, and their right to withdraw at any time.

Motor skill profiles were assessed using the MABC-2 (22):

- Participant 1: gross motor impairments, especially balance.
- Participant 2: combined fine and gross motor deficits.
- Participant 3: relatively preserved gross motor skills but impaired fine motor coordination.

All MABC-2 assessments were administered by the pediatric occupational therapist trained in standardized administration procedures.

None had prior exposure to hippotherapy or horseback riding, ensuring all interventions were novel.

Although the sample size was limited (n=3), this is consistent with established single-subject methodology, which prioritizes depth of analysis over breadth and is widely recognized in clinical and sports medicine research involving special populations.

For contextual characterization, body mass index (BMI) and habitual physical activity levels (parental report)

were documented to provide relevant information for interpreting results in a sports medicine framework.

Intervention Protocol

The intervention comprised 12 hippotherapy sessions delivered over four consecutive weeks (three sessions per week; ~45 minutes per session). Hippotherapy utilizes the horse's rhythmic, multidimensional pelvic movements that mimic human gait mechanics (11,24), facilitating neuromuscular activation and postural adjustments comparable to exercise-based rehabilitation strategies used in sports medicine.

Sessions were numbered sequentially (1-12) and scheduled as follows:

- Sessions 1-3 (week 1)
- Sessions 4-6 (week 2)
- Sessions 7-9 (week 3)
- Sessions 10-12 (week 4)

The program consisted of three progressive phases:

- Familiarization (Sessions 1-4): Building trust, introducing horse grooming and safety, and simple riding tasks.
- Foundational Skills (Sessions 5-8): Seated balance, postural transitions, and controlled riding tasks to enhance core stability and dynamic balance.
- Advanced Engagement (Sessions 9-12): Stretching and reaching tasks on the moving horse, and dual-task challenges designed to stimulate motor-cognitive integration and executive control. These four sessions, although shorter than interventions reported in some literature (6-8 weeks), were designed to build upon the previous eight sessions and incorporated progressively increased intensity and task complexity to maximize therapeutic benefit.

Sessions were flexibly tailored to each child's tolerance to avoid fatigue and frustration. Every session was conducted by a certified hippotherapist working closely with a physiotherapist to ensure safety and adherence to best practices in sports-medicine rehabilitation.

Measurement Tools

Balance

Balance was measured using the Biodex Balance System SD (Biodex Medical Systems, NY), a validated and widely used instrument in sports medicine and rehabilitation research (25).

- Static balance: Postural Stability Test (maintaining equilibrium on a stable platform).
- Dynamic balance: Limits of Stability Test (active center-of-gravity shifts toward directional targets).

Settings were calibrated to each child's age, height, and weight. Initial stability was set at level 8 (of 12) and gradually adjusted based on safety and engagement, with platform speed maintained at a moderate level to match functional demands without causing overload. These parameters align with the manufacturer's recommended pediatric testing standards and ensured a sensitive and safe assessment of postural control.

Anxiety

Anxiety symptoms were measured using the Spence Children's Anxiety Scale - Parent Report (SCAS-PR) (26). Parents rated frequency of anxiety-related behaviors on a 0-3 Likert scale. The SCAS-PR has high internal consistency ($\alpha = 0.80$-0.90) and satisfactory test-retest reliability ($r > 0.70$). These properties make it appropriate for repeated measures in intervention research.

Cognitive Function

Cognitive functions were assessed using the standard version of the Wisconsin Card Sorting Test (WCST), a well-validated measure of cognitive flexibility and executive control (27,28). The WCST demonstrates strong reliability for repeated assessments in both clinical and research contexts. To reduce potential practice or learning effects within the ABA repeated-measure structure, assessments were spaced according to recommended administration intervals, ensuring compatibility with the single-subject design (28).

Data Collection and Analysis

All assessments were conducted by a licensed pediatric occupational therapist specialized in DCD, blinded to intervention phases. The administration, scoring, and interpretation of the WCST were performed under direct supervision and guidance from a licensed clinical psychologist and a licensed child psychiatrist, ensuring adherence to standardized neuropsychological protocols. Data were collected in a distraction-free laboratory setting to ensure reliability.

Analysis followed conventions of single-subject experimental design (18,19):

- Visual inspection of graphed data (level, trend, variability within and between phases).
- Effect sizes:
    - Percentage of Nonoverlapping Data (PND): proportions of intervention datapoints exceeding baseline maximum; >90% = strong effect; 70-90% = moderate; <50% = weak (29).
    - Cohen's d: standardized mean difference (0.2 small, 0.5 medium, 0.8 large) (29).

Visual analysis and quantitative indices were interpreted independently by two researchers to enhance analytic reliability. Together, these complementary methods provided both sensitivity to individual variability and objective effect size estimation of hippotherapy outcomes.

RESULTS

Participant Characteristics

Three children (two females, one male; age range: 8-10 years) diagnosed with DCD participated in the study (Table 1). DCD-Q7 scores ranged from 38 to 45, confirming motor coordination difficulties. All participants had average to above-average nonverbal cognitive ability on the KBIT-2 matrices (scores 89-95). None had previous experience with horseback riding or hippotherapy.

Balance Outcomes

Static balance

Changes in static balance were variable across participants (Table 2). Participant 1 showed minimal change during intervention (M = 1.2, SD = 0.1) but a modest improvement at follow-up (M = 1.8, SD = 0.2). Participant 2 improved during the intervention (M = 1.8, SD = 0.3 vs. baseline M = 2.2, SD = 0.2), followed by regression at follow-up (M = 2.5, SD = 0.3). Participant 3 demonstrated stable scores across phases (0.8-0.9). Effect size estimates ranged from -0.0 to 1.2, with PND values of 50-83.3% (Table 3).

Table 2 Mean (SD) scores for anxiety, cognitive function, and balance outcomes across phases

Participant	Variable	Baseline	Intervention	Follow-up
1	Anxiety (SCAS)	35.0 (1.2)	37.0 (1.5)	34.0 (1.0)
	Cognitive Function (WCST)	3.0 (0.3)	3.3 (0.5)	2.5 (0.4)
	Static Balance (Biodex)	1.2 (0.1)	1.2 (0.1)	1.8 (0.2)
	Dynamic Balance (Biodex)	13.0 (0.5)	18.0 (0.8)	18.0 (0.7)
2	Anxiety (SCAS)	21.0 (0.8)	22.0 (1.0)	27.0 (1.2)
	Cognitive Function (WCST)	5.7 (0.6)	5.5 (0.5)	5.5 (0.4)
	Static Balance (Biodex)	2.2 (0.2)	1.8 (0.3)	2.5 (0.3)
	Dynamic Balance (Biodex)	11.0 (0.6)	20.0 (1.1)	18.0 (0.9)
3	Anxiety (SCAS)	25.0 (1.0)	28.0 (1.2)	18.0 (0.9)
	Cognitive Function (WCST)	4.7 (0.5)	6.0 (0.6)	6.0 (0.5)
	Static Balance (Biodex)	0.8 (0.1)	0.7 (0.1)	0.9 (0.1)
	Dynamic Balance (Biodex)	6.8 (0.4)	9.8 (0.6)	10.0 (0.6)

SCAS = Spence Children's Anxiety Scale (higher scores indicate greater anxiety); WCST = Wisconsin Card Sorting Test (higher scores indicate better cognitive flexibility); Static and Dynamic Balance measured using Biodex Stability Index (lower scores indicate better balance stability). Baseline = pre-intervention; Follow-up = post-intervention phase.

Table 3. Effect sizes (Cohen's d) and PND values for anxiety, cognitive function, static and dynamic balance by participant

Participant	Variable	Cohen's d	PND (%)
1	Anxiety (SCAS)	0.50	66.7
	Cognitive Function (WCST)	-1.00	33.3
	Static Balance (Biodex)	-0.00	50.0
	Dynamic Balance (Biodex)	0.00	100.0
2	Anxiety (SCAS)	-1.00	33.3
	Cognitive Function (WCST)	3.10	100.0
	Static Balance (Biodex)	1.20	83.3
	Dynamic Balance (Biodex)	-0.00	100.0
3	Anxiety (SCAS)	-1.00	33.3
	Cognitive Function (WCST)	3.70	100.0
	Static Balance (Biodex)	0.70	66.7
	Dynamic Balance (Biodex)	0.10	100.0

PND = Percentage of Non-overlapping Data; Cohen's d calculated for pre-post intervention comparisons. Positive values indicate improvement; negative values indicate deterioration or no change.

Dynamic balance

All participants demonstrated notable gains in dynamic balance during the intervention (Table 2). Participant 1 improved from 13.0 (SD = 0.5) at baseline to 18.0 (SD = 0.8) during intervention and maintained this score at follow-up. Participant 2 increased from 11.0 (SD = 0.6) to 20.0 (SD = 1.1), followed by a slight decline at follow-up (18.0, SD = 0.9). Participant 3 improved from 6.8 (SD = 0.4) to 9.8 (SD = 0.6) and further to 10.0 (SD = 0.6) at follow-up. PND values were consistently 100% across participants, with Cohen's d values ranging from 0.0 to 0.1.

Note: Although PND values indicated strong improvement for dynamic balance (PND = 100%), the corresponding Cohen's d values remained small. This discrepancy reflects the low variability in baseline scores and the narrow scale range of the Biodex stabilometry outputs, which can suppress standardized mean differences despite clear nonoverlap of data points.

Cognitive Function

Cognitive outcomes, assessed using the WCST, varied across participants (Table 2). Participant 1 showed little change (baseline M = 3.0, SD = 0.3; follow-up M = 2.5, SD = 0.4), with effect sizes indicating deterioration (Cohen's d = -1.0; PND = 33.3%). Participant 2 demonstrated stable performance across phases (baseline M = 5.7, SD = 0.6; follow-up M = 5.5, SD = 0.4), with large positive effect size estimates (Cohen's d = 3.1; PND = 100%). Participant 3 showed clear improvement, rising from baseline M = 4.7 (SD = 0.5) to follow-up M = 6.0 (SD = 0.5), with very large effect sizes (Cohen's d = 3.7; PND = 100%).

Anxiety

Anxiety outcomes, measured by SCAS, also showed heterogeneous patterns (Table 2). Participant 1's scores remained relatively stable (baseline M = 35.0; intervention M = 37.0; follow-up M = 34.0), with small effect size (Cohen's d = 0.5; PND = 66.7%). Participant 2 exhibited an increase in reported anxiety from baseline (M = 21.0, SD = 0.8) to follow-up (M = 27.0, SD = 1.2), corresponding to a negative effect size (Cohen's d = -1.0; PND = 33.3%). Participant 3 showed an opposite trend, with anxiety scores increasing during intervention (M = 28.0, SD = 1.2) but decreasing substantially at follow-up (M = 18.0, SD = 0.9), although effect size estimates remained negative (Cohen's d = -1.0; PND = 33.3%).

Overall, hippotherapy was associated with consistent and clinically meaningful improvements in dynamic balance, partial or inconsistent changes in static balance, and variable outcomes for cognitive function and anxiety. Individual response patterns differed, as reflected in the variability of effect size estimates and PND values (Table 3).

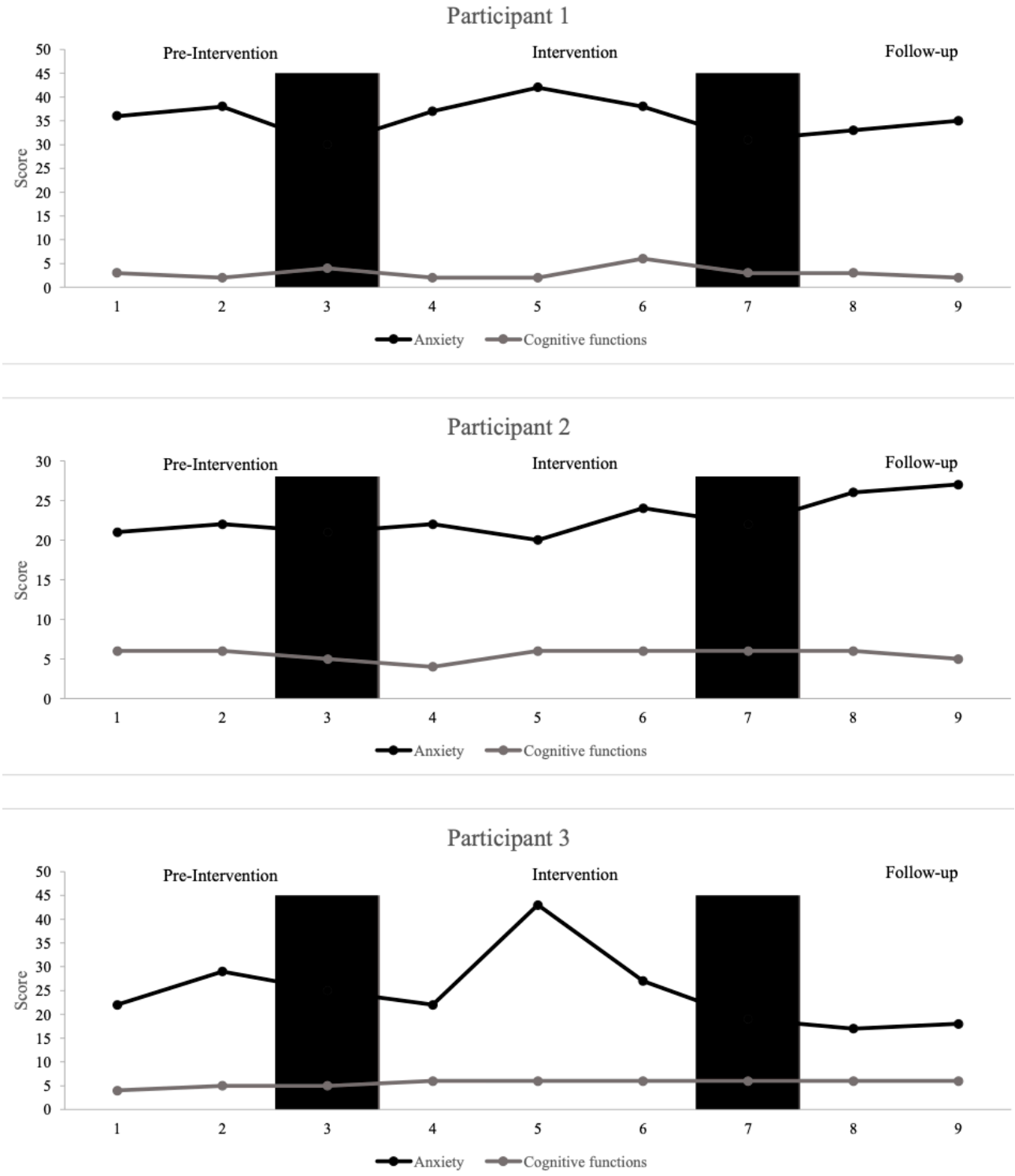

Figure 1. Static and dynamic balance scores across sessions for Participants 1–3. Sessions A1–A4 represent baseline, B1–B4 intervention, and C1–C2 follow-up phases, separated by vertical dashed lines. Horizontal dashed lines indicate Cohen's d benchmarks for small (0.2), medium (0.5), and large (0.8) effects. The figure shows consistent improvements in balance during the intervention phase.

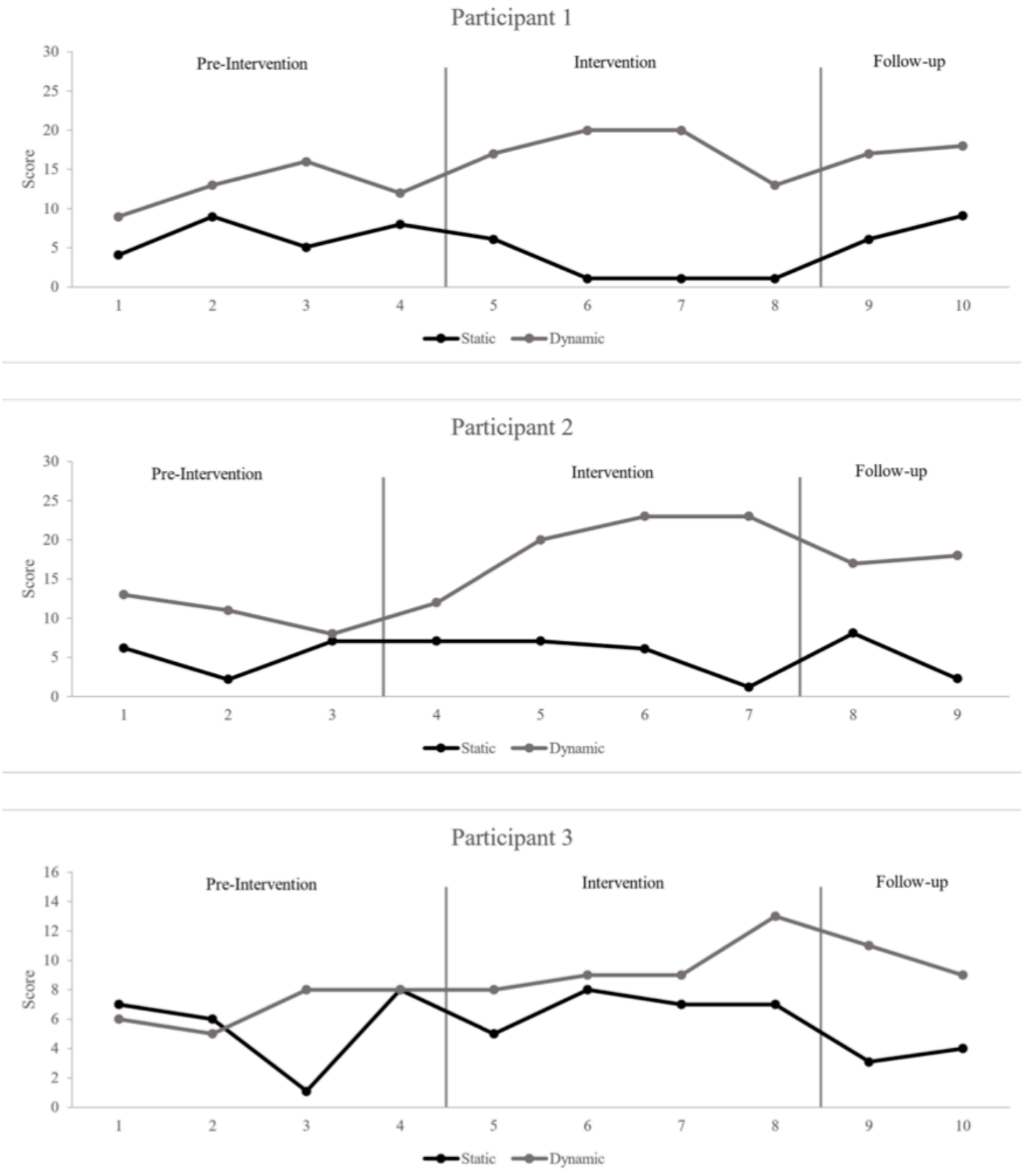

Figure 2. Anxiety and cognitive function scores across sessions for Participants 1–3. Phase demarcations and Cohen's d benchmarks are as described in Figure 1. The data reveal variable effects of hippotherapy on these cognitive and emotional measures.

DISCUSSION

This study investigated the effects of a structured hippotherapy program on balance, anxiety, and cognitive function in children with DCD. The findings suggest a nuanced relationship between motor and cognitive development in this population. Specifically, the connection between motor improvements and cognitive gains appears weaker or delayed in children with DCD compared to typically developing peers. While hippotherapy consistently fostered marked enhancements in balance, likely driven by neuromuscular adaptations that improve postural control and sensorimotor integration (9,11,30), cognitive functions, particularly attentional shifting, showed less consistent and more modest improvements.

This pattern aligns with established theoretical perspectives such as Dynamic Systems Theory, which emphasizes that motor development proceeds in a non-linear, multi-layered manner: neuromuscular changes may emerge rapidly with targeted practice, whereas executive function improvements typically require longer consolidation through neural reorganization (31). Neuroimaging studies further support this delayed transfer by identifying atypical connectivity in fronto-parietal networks among children with DCD, which may limit integration between motor learning and executive control processes (4,30). To deepen understanding, future longitudinal research should examine the temporal progression of motor versus cognitive changes following hippotherapy, ideally combining behavioral measures with neurophysiological evidence.

Across all participants, both static and dynamic balance demonstrated significant improvements, highlighting the physical benefits of hippotherapy. These findings are consistent with previous reports in other pediatric populations, including children with cerebral palsy (15) and children with autism spectrum disorder (11), suggesting that hippotherapy can enhance postural control across diverse neurodevelopmental conditions. For example, Alghadier & Alhusayni (32) similarly reported enhanced gross motor skills and physical function in children with DCD. These converging outcomes support the premise that the horse's rhythmic, multidimensional movements provide critical sensory feedback, fostering motor learning and postural stability.

In the present study, improvements in cognition and anxiety were observed only in some participants, suggesting that these domains are more sensitive to individual characteristics and contextual factors. This resonates with prior research identifying that hippotherapy can promote emotional regulation and reduce maladaptive behaviors in children with neurodevelopmental conditions. The unique combination of sensory, social, and emotional stimuli inherent in hippotherapy is likely responsible for such effects (12-14).

The absence of consistent improvements in cognitive and emotional domains may be explained by several factors: (1) baseline heterogeneity in anxiety and executive function profiles, (2) the relatively brief intervention duration (12 sessions), which may be insufficient to induce consolidation in complex cognitive processes, and (3) intrinsic individual variability within the DCD population, including comorbidities, family environment, and levels of engagement during therapy. Future research should stratify participants by cognitive-emotional baseline, monitor family involvement, and adapt intervention intensity to individual needs in order to determine moderators of optimal change.

Although only one participant showed notable gains in attentional shifting, this finding suggests that hippotherapy may have cognitive and emotional benefits for select children but is not uniformly effective. Investigating session structure, therapist-child interaction, and contextual supports could clarify factors that shape differential outcomes. Importantly, as Dynamic Systems Theory posits, sensorimotor demands of hippotherapy can rapidly stimulate neuromuscular adaptation, while transfer to executive domains requires longer timeframes and sustained practice (4,30,33).

The implications of this study extend into rehabilitation and sports medicine. Improved balance and postural control are prerequisites for safe and effective participation in physical education, recreational play, and introd-

uctory sport activities. Children with DCD often disengage from sport or playground contexts due to fear of falling or poor motor competence. By enhancing postural stability, hippotherapy may bridge this gap, facilitating greater involvement in school-based physical activity and promoting pathways into sport participation. This positions hippotherapy not only as a rehabilitation tool but also as a preventive strategy against sedentary behavior, reduced fitness, and secondary health risks (9,12, 33,34).

In summary, our results support hippotherapy's efficacy for improving balance among children with DCD while highlighting heterogeneity in cognitive and emotional responses. This study is among the first to apply a single-subject reversal design to capture individualized motor, cognitive, and emotional outcomes, underscoring both the promise and the variability of therapeutic effects. Larger-scale randomized controlled trials are needed to confirm efficacy, determine underlying mechanisms, and optimize intervention strategies. From a sports medicine perspective, integrating hippotherapy into broader rehabilitation programs may complement conventional physiotherapy and exercise-based approaches, ultimately strengthening children's readiness for active lifestyles and safe sport participation.

Limitations and future directions

This study has several limitations. First, the sample size was limited to three children, which inherently restricts the generalizability of the findings. Second, although the intervention comprised 12 sessions over four weeks, the relatively short duration may not have been sufficient to produce stable or sustained changes, particularly in cognitive performance or anxiety symptoms, despite the value of session-by-session tracking for illustrating individual response patterns. Future studies should therefore evaluate longer intervention periods to better establish dose-response relationships for motor, cognitive, and emotional outcomes. Third, the absence of a control group limits the ability to rule out maturation or expectancy effects. A single assessor conducted the balance measurements, which may introduce rater bias. Although standardized Biodex procedures were followed, future work would benefit from involving multiple assessors and reporting inter-rater reliability. Fourth, anxiety was assessed solely through parent report, which may not sufficiently capture children's internal emotional states or context-specific variations.

Future research should employ randomized or multiple-baseline controlled designs with larger samples, extended follow-up periods, and appropriate comparison groups to enhance internal and external validity. Incorporating objective measures of physical activity (e.g., accelerometry, sport participation logs, fitness testing) would allow a more precise examination of how motor improvements translate into everyday participation and activity patterns. Additionally, collaboration with physical education teachers and sports medicine professionals may provide more ecologically valid insights into how gains from hippotherapy relate to school-based movement, sport engagement, physical fitness, and long-term activity habits.

CONCLUSION

This single-case reversal design study demonstrated that a structured hippotherapy program can yield substantial improvements in balance among children with DCD, with effects persisting beyond the intervention period. However, benefits for anxiety and cognitive function were inconsistent, underscoring the complexity and heterogeneity of therapeutic responses in this population. These results suggest that hippotherapy can be considered a valuable complementary approach within pediatric motor rehabilitation.

Importantly, from a sports medicine perspective, improved balance and postural control are key prerequisites for safe participation in physical education, recreational play, and sport activities. By enhancing these capacities, hippotherapy has the potential not only to rehabilitate motor deficits but also to promote engagement in active lifestyles and prevent secondary risks such as sedentary behavior and reduced fitness.

This study is among the first to capture individualized motor, cognitive, and emotional outcomes of

py in children with DCD using a single-subject framework. Future research should build on this exploratory evidence through larger-scale randomized trials, longer intervention periods, and integration of objective measures of physical activity and fitness. Such work will clarify the broader cognitive-emotional benefits of hippotherapy and guide its incorporation into multidisciplinary rehabilitation and sports medicine practices.

Ethics Committee Approval / Etik Komite Onayı

Ethical approval for this study was granted by the Shahid Beheshti University Ethics Committee (ID: IR.SBU.1402.079).

Conflict of Interest / Çıkar Çatışması

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

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Author Contributions / Yazar Katkıları

Concept: HK, BA, EA, MMA, ZM; Design: HK, BA, EA, MMA, ZM; Data Collection and/or Processing: HK; Analysis and Interpretation: HK, ZM; Writing Manuscript: HK, ZM; Critical Reviews: HK, ZM, BA, EA, MMA. All authors contributed to the final version of the manuscript and discussed the results and contributed to the final manuscript.

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