

ORIGINAL RESEARCH

The effect of SPARK exercises combined with pivotal response treatment on balance and executive function in children with high-functioning autism spectrum disorder: A follow-up study

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Abstract

Background: Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by impairments in social communication and interaction, repetitive behaviors, and strong genetic associations. **Objective:** This study examines the impact of SPARK exercises combined with pivotal response treatment (PRT) on enhancing executive function and balance in children with high-functioning ASD, who are faced with challenges in communication, cognition, and motor skills. **Methods:** A total of 24 boys aged 7–10 years with high-functioning ASD were randomly divided into two groups of 12. The experimental group participated in 18 sessions of SPARK exercises using child-led, interest-based PRT over a period of six weeks (3 sessions/week, 45 min/session), while the control group was provided with SPARK exercises with instructor training under the same schedule. Static balance was measured by the stork test, modified dynamic balance by the heel-to-toe walk test, cognitive flexibility by the Wisconsin Card Sorting Test, and working memory by the n-back test. Pretest, posttest, and 2-month follow-up tests were conducted. **Results:** Cognitive flexibility revealed a statistically significant improvement for the experimental group ($p = .026$, $\eta_p^2 = .15$), which was maintained at follow-up two months later. The group $\times$ time interaction for static balance, dynamic balance, and working memory were not significant for the pretest, posttest, or follow-up (all $ps > .05$). **Conclusions:** The effectiveness of the PRT intervention, when used in conjunction with SPARK-based activities, was substantial for the improvement of cognitive flexibility for children with high-functioning ASD. Such improvements could explain the enhanced behavioral adaptability of this group. However, the effectiveness of the intervention was limited for balance and working memory, suggesting specific rather than general benefits. Further studies with larger and more diverse samples are needed to increase external validity, replicate these findings, and improve the intervention protocol.

Keywords: autism spectrum disorder; SPARK; balance; pivotal response treatment; executive function

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by impairments in social communication and interaction, repetitive behaviors, and strong genetic associations (Baio et al., 2018). It affects approximately one in every thirty-six children, with boys 3.8 times more likely to be diagnosed than girls (Maenner et al., 2023). The core symptoms emerge in early childhood and disrupt daily functioning (American Psychiatric Association, 2013). In addition to social and communicative challenges, ASD often involves motor impairments (e.g., balance deficits) and executive function (McDaniel et al., 2020) difficulties, leading to problems in adaptive behavior, academics, and social participation (Lord et al., 2018). Motor skill dysfunction persists in 50–85% of high-functioning ASD (Alschuler et al., 2009), increasing injury risk (Lim et al., 2017; Travers et al., 2018). Executive function deficits primarily affect planning, working memory, and cognitive flexibility (Demetriou et al., 2019), contributing

to inflexibility and discomfort with change (Munakata et al., 2011). Early targeted interventions are essential for long-term outcomes (Corsello, 2005).

No core pharmacological treatments exist for ASD; medications address associated symptoms (e.g., irritability, attention deficit hyperactivity disorder), complementing behavioral and educational strategies (Lin et al., 2024). Physical activity interventions improve motor skills, social behaviors, and reduce stereotypies (Ruggeri et al., 2020), while fitness deficits increase obesity risk in ASD (Healy & Marchand, 2020). Motor difficulties warrant consideration in diagnostic criteria (Licari et al., 2020). The current study examines the integration of SPARK exercises with pivotal response treatment (PRT) as the independent variable to enhance physical activity and responsive learning in children with high-functioning ASD. SPARK, developed by a cross-disciplinary team for school-based physical activity promotion (Dowda et al., 2005), offers simple, reliable, everyday play suitable for children with autism (Najafabadi

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et al., 2018). Tailoring activities to children's interests supports enriching, developmentally relevant experiences (Voigt et al., 2011). PRT, a Naturalistic Developmental Behavioral Intervention, targets pivotal areas such as motivation, multi-cue responsiveness, self-management, and social initiation rather than isolated behaviors (L. K. Koegel et al., 2016). Key PRT procedures include following child interests, gaining attention, using clear prompts, providing immediate contingent reinforcement, and alternating maintenance and novel tasks, with parent training promoting generalization across settings (R. L. Koegel & Koegel, 2006). Empirical evidence shows SPARK improves balance, bilateral coordination, and social interaction in autistic children through structured, game-like activities (Najafabadi et al., 2018). PRT yields consistent gains in language and communication, with variable improvements in other domains, confirming its evidence-based status and potential synergy with movement-based programs (Hardan et al., 2015; McDaniel et al., 2020).

Current literature demonstrates that physical activity programs like SPARK enhance motor skills and social behaviors in high-functioning ASD (Najafabadi et al., 2018; Pan et al., 2017), while PRT facilitates skill acquisition across contexts (Vismara & Lyons, 2007). A study combining aquatic exercises with PRT reported improvements in motor skills and executive function in high-functioning ASD, though long-term sustainability was not explored (Faraji et al., 2023). Despite robust separate evidence for SPARK and PRT, few studies investigate their combined effects on balance and executive functions in high-functioning ASD, particularly with follow-up assessments to evaluate sustainability. SPARK primarily targets motor development and may indirectly benefit balance and executive functions through physical activity (Healy et al., 2018), whereas PRT emphasizes social and communication skills (Mohammadzahari et al., 2014). The synergistic impact of this integration remains under-researched, representing a key gap in the literature.

The aim of this study is to evaluate an integrative intervention combining SPARK exercises with child-directed PRT to improve balance and executive function in children with high-functioning ASD – an area that remains quantitatively under-investigated.

Methods

Participants

The study included 24 boys aged 7–10 years (mean age 8.5 ± 1.2 years) diagnosed with high-functioning ASD, recruited from a specialized autism school in Tehran, Iran. Inclusion criteria were operationalized as follows: confirmed ASD diagnosis via the Gilliam Autism Rating

Scale-Third Edition (GARS-3) with Autism Index scores of 70–85 (indicating high-functioning status, $IQ > 70$ from school records); no co-occurring neurological or physical disorders precluding physical activity; ability to follow basic instructions; and parental consent (Yazdani et al., 2020). Exclusion criteria included recent participation in structured physical or behavioral interventions (past 3 months), severe sensory processing issues interfering with testing (parent report), or use of medications affecting motor/cognitive function (unless stable > 6 months).

Participants were randomly assigned to experimental ($n = 12$) or control ($n = 12$) groups using simple randomization via computer-generated random numbers. Allocation concealment was achieved through sequentially numbered, opaque sealed envelopes prepared by an independent assistant. Groups were matched on age and ASD severity. Demographic characteristics are presented in Table 1. The study was approved by the University of Tehran Ethics Committee (IR.UT.SPORT.REC.1404.099), and written informed consent was obtained from parents or guardians.

Measures

Standardized tests of balance and executive functions were selected for their established reliability and validity in children with autism, particularly in Iranian contexts where applicable. The assessor was trained for about 3 months in all assessments and had specialized expertise in working with children diagnosed with ASD. For screening, the Gilliam Autism Rating Scale-Third Edition (GARS-3; Gilliam, 2014) was used to assess ASD likelihood across six subscales (Restricted/Repetitive Behaviors, Social Interaction, Social Communication, Emotional Responses, Cognitive Style, Maladaptive Speech) based on behavior frequency. It demonstrates high validity, reliability, and sensitivity ($r = .89$ in Iranian samples), see Minaei and Nazeri (2018). In this study, static balance was measured using the Modified Stork test in which participants stood on one leg, keeping the other leg bent at the ankle and arms placed at their sides, while the duration of maintaining balance without falling was recorded. The best performance of the two trials per leg was used for analysis. The test demonstrates a validity ranging from 64% to 79%, and a reliability between 93% and 99% (Lahtinen et al., 2007).

Dynamic balance was assessed with the heel-to-toe test, where participants walked 15 steps along a straight line. The best score of the two attempts was considered. The test has been shown to have a validity of 91% and a reliability coefficient of .94 in ASD populations (Pan et al., 2017). Cognitive flexibility was evaluated using the Wisconsin Card Sorting Test (WCST), with the primary indicator being the number of correct answers and secondary measures including perseverative errors and completed

Table 1 Demographic characteristics (mean $\pm$ SD) of participants

Variable	Experimental group	Control group	<i>p</i>
Body height (cm)	149 $\pm$ 12.80	143 $\pm$ 11.70	.233
Body mass (kg)	46.00 $\pm$ 10.15	49.33 $\pm$ 12.47	.611
Body mass index (kg/m ²)	22.44 $\pm$ 2.19	22.05 $\pm$ 1.83	.403

categories. The WCST assesses the ability to shift cognitive sets, particularly relevant for high-functioning ASD, and has a reported validity of over 86% for assessing cognitive impairments (Lezak et al., 2004). Working memory was measured using a computer-based n-back task in which participants were asked to identify whether the current stimulus matched one presented previously. Task performance was calculated as the percentage of accurate responses for matching stimuli (visual/auditory). This measure has demonstrated high reliability ($r = .91$) in Iranian samples (Taghizade et al., 2014).

Intervention

Participants were randomly assigned to experimental (SPARK + PRT) or control (SPARK alone) conditions. Height and weight were measured at baseline with standardized equipment. Data were collected in three phases: (1) pretest (baseline), (2) posttest (2 days after the final intervention session), and (Dowda et al., 2005) follow-up (2 months post-intervention). All sessions and assessments occurred in the school's naturalistic playroom, equipped with toys (e.g., ball pits, sand pits) to support a child-centered approach.

The intervention consisted of 18 sessions over 6 weeks (3 sessions/week, 45 min each). Each session followed a structured format: 10-min warm-up (e.g., light stretching, marching in place, arm circles); 25-min main activities; and 10-min cool-down (e.g., relaxation breathing, group review of achievements). Concrete examples of SPARK activities included ball-tossing games, jumping jacks, obstacle courses with cones, and balance drills (e.g., standing on one foot while catching/throwing a ball). For the experimental group, key PRT components were integrated:

Children were afforded opportunities to select their preferred equipment, game rules, and activities. This autonomy-promoting approach fostered greater perceived autonomy and intrinsic motivation. Activities were individualized and carefully aligned with each child's perseverative interests, thereby enhancing intrinsic motivation and active participation. Contingent and immediate reinforcement was delivered following appropriate responses or sincere attempts, which served to encourage participation and further strengthen intrinsic motivation. The interventionist delivered contingent attention, followed the child's lead in activities, and provided positive reinforcement for high-quality attempts, including partial or approximate successes. This approach enhanced intrinsic motivation and helped reduce performance-related anxiety in the children (Chiva-Bartoll et al., 2021; Najafabadi et al., 2018).

The control group received identical SPARK activities delivered via traditional instructor-led training without PRT elements (Chiva-Bartoll et al., 2021; Najafabadi et al., 2018). Interventions were delivered by certified physical education instructors with specialized training in ASD interventions, including a PRT certification workshop and prior experience in adapted physical activity. All intervention sessions were directly supervised by a senior, highly experienced research team member with extensive

specialized expertise in working with children diagnosed with ASD.

Statistical analysis

Sample size was determined a priori using G*Power software based on an expected large effect size (Cohen's $d \approx 1.2$ for balance outcomes, which provided the minimum required sample for conservative powering). This estimate was derived from a recent meta-analysis showing standardized mean difference (SMD) = 1.19 (95% confidence interval [0.79, 1.58]) for balance improvement in exercise interventions lasting > 8 weeks in children with ASD (Li & Zhang, 2025). For the primary outcome (cognitive flexibility), expected effect sizes from related meta-analyses range from medium ($g \approx 0.3$ – 0.5 ; Hou et al., 2024; Liang et al., 2022) to large in combined interventions; thus, the calculated sample ($n = 12$ per group, total 24) ensured adequate power (>.80) for large effects across domains. With $\alpha = .05$ and a repeated-measures design, this total sample was required. Although this provides adequate power to detect large effects, the study may have limited power to detect smaller effects; this is acknowledged as a limitation.

All statistical analyses were carried out using IBM SPSS Statistics (Version 27; IBM). Cognitive flexibility (number of correct answers on the WCST, with perseverative errors and completed categories as secondary measures) was predetermined as the primary outcome measure because it is considered particularly sensitive to the child-centered, motivational, and naturalistic components of PRT. Static balance (Stork test), dynamic balance (heel-to-toe walking test), and working memory (n-back accuracy) were predetermined as secondary outcome measures.

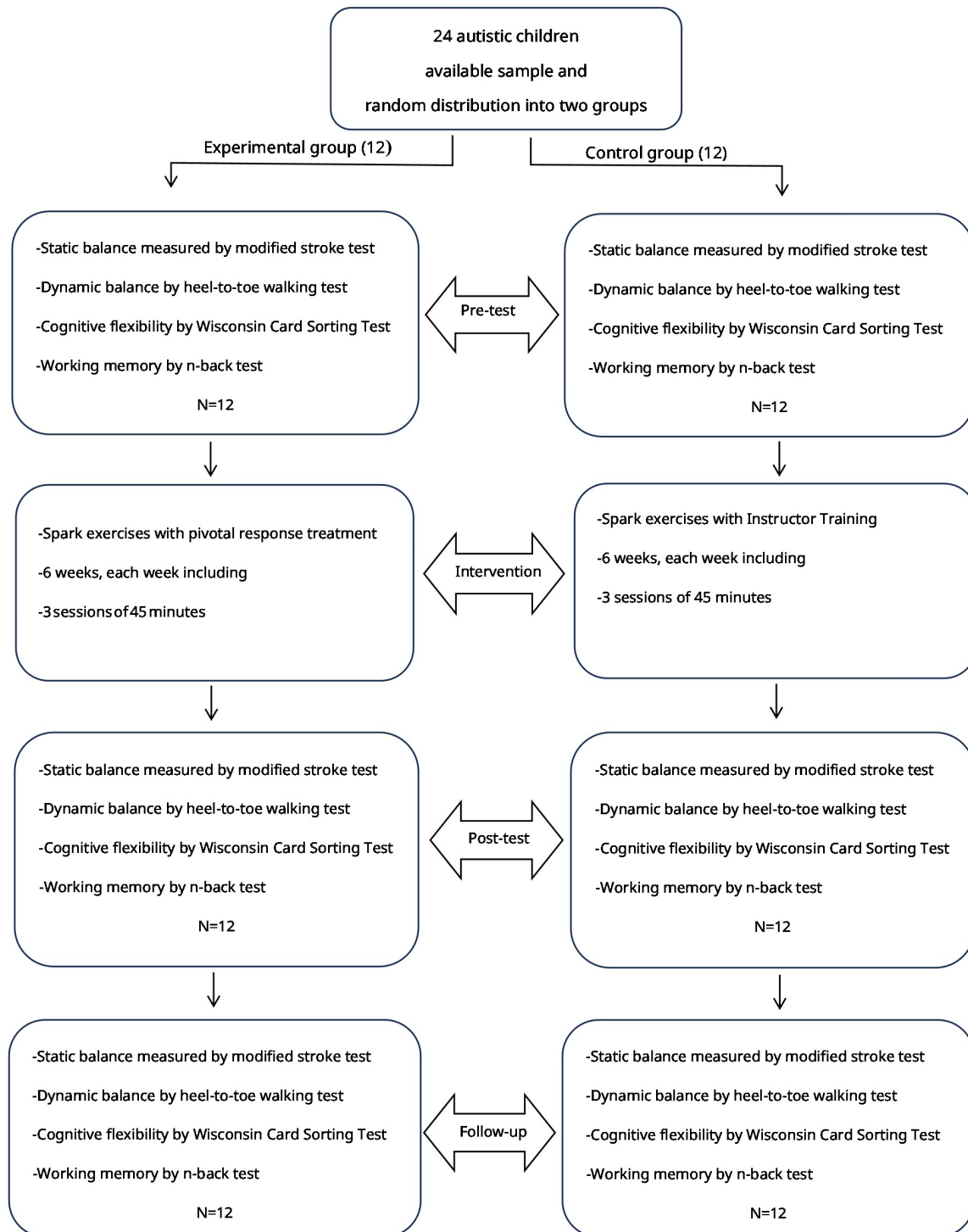
Data were tested for normality (Shapiro-Wilk) and homogeneity of variances (Levene's). These tests showed normal data distribution and homogeneity of variances for all variables. The primary approach was a 2 (group: experimental vs. control) $\times$ 3 (time: pretest, posttest, follow-up) repeated-measures analysis of variance (ANOVA), chosen because it accounts for within-subject correlations, providing greater power than separate tests – especially advantageous with modest sample sizes ($n = 12$ per group). Mauchly's test assessed sphericity; violations prompted Greenhouse-Geisser correction. Partial eta squared (η_p^2) reported effect sizes. Significant group $\times$ time interactions or time main effects were followed by Bonferroni-corrected post-hoc pairwise comparisons to control family-wise error rate for multiple comparisons. All tests two-tailed, $\alpha = .05$.

Results

Twenty-four participants completed the study with no dropouts (flow diagram in Figure 1). Demographic characteristics showed no significant between-group differences at baseline (Table 1).

For static and dynamic balance (Table 2), repeated-measures ANOVA indicated no significant group $\times$ time interactions or main effects of group (all $ps > .05$, η_p^2 s ranging from .03 to .17). For the primary outcome – cognitive

Figure 1 Flow diagram of the study



flexibility (number of correct answers on WCST) – repeated-measures ANOVA (Table 2) revealed a significant main effect of time ($F(2, 44) = 5.97, p = .005, \eta_p^2 = .21$) and a significant group $\times$ time interaction ($F(2, 44) = 3.99, p = .026, \eta_p^2 = .15$). The interaction effect size ($\eta_p^2 = .15$) is large, indicating that 15% of the variance in cognitive flexibility improvements over time is attributable to the intervention. Post-hoc Bonferroni comparisons (Table 3) indicated significant improvements from pretest to post-test ($p = .031$) and pretest to follow-up ($p = .024$) in the

experimental group, with no significant change from post-test to follow-up ($p = .648$). The control group showed no significant changes over time.

Secondary outcomes for perseverative errors and completed categories on WCST showed significant time effects (errors: $F(2, 44) = 6.39, p = .004$; categories: $F(2, 44) = 4.17, p = .022$), but non-significant group effects (errors: $p = .136$; categories: $p = .315$). The time effects for errors ($\eta_p^2 = .22$) and completed categories ($\eta_p^2 = .15$) represent moderate effect sizes, reflecting

improvements in both groups over time regardless of intervention. Detailed post-hoc results are in Table 3.

Working memory showed significant time ($F(2, 44) = 10.92$, $p < .001$, $\eta_p^2 = .33$) and group ($F(1, 22) = 7.74$, $p = .011$, $\eta_p^2 = .26$) effects, but no group $\times$ time interaction beyond baseline differences (Table 2).

The time effect size ($\eta_p^2 = .33$) was large, indicating substantial improvements in working memory performance across both groups over time.

Overall, the integrative SPARK + PRT intervention produced significant and sustained improvements in the primary outcome (cognitive flexibility), while secondary

Table 2 Means, standard deviations, and ANOVA results for study variables

Variable	Experimental group		Control group		ANOVA				
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	Effect	<i>F</i> ratio	<i>df</i>	<i>p</i>	η_p^2
Static balance									
Pretest	5.00	1.69	7.00	1.66	T	11.90	2, 44	.001	.35
Posttest	17.70	6.99	10.58	6.32	G	0.72	1, 22	.404	.03
Follow-up	16.58	5.73	11.08	1.47	G $\times$ T	2.94	2, 44	.063	.11
Dynamic balance									
Pretest	20.42	5.48	20.00	8.72	T	7.85	2, 44	.001	.26
Posttest	23.75	4.73	23.58	5.21	G	0.39	1, 22	.530	.17
Follow-up	25.67	4.12	22.50	5.11	G $\times$ T	1.20	2, 44	.310	.05
Cognitive flexibility									
Pretest	21.33	7.39	22.17	5.25	T	5.97	2, 44	.005	.21
Posttest	29.33	8.46	24.50	9.40	G	3.71	1, 22	.067	.14
Follow-up	33.59	9.73	23.08	9.09	G $\times$ T	3.99	2, 44	.026	.15
Error response in cognitive flexibility									
Pretest	38.67	7.39	37.83	0.25	T	6.39	2, 44	.004	.22
Posttest	30.67	8.46	34.93	10.65	G	2.13	1, 22	.136	.09
Follow-up	25.67	10.65	35.50	12.11	G $\times$ T	2.92	2, 44	.064	.11
Completed categories in cognitive flexibility									
Pretest	1.25	0.97	1.58	0.79	T	4.17	2, 44	.022	.15
Posttest	2.33	1.23	2.00	1.86	G	1.05	1, 22	.315	.04
Follow-up	3.08	1.83	1.75	1.76	G $\times$ T	2.71	2, 44	.078	.11
Working memory									
Pretest	53.43	15.39	40.25	8.97	T	10.92	2, 44	< .001	.33
Posttest	65.25	13.14	54.50	13.34	G	7.74	1, 22	.011	.26
Follow-up	75.00	22.49	62.58	23.91	G $\times$ T	0.03	2, 44	.966	.00

Note. ANOVA = analysis of variance; T = time; G = group.

Table 3 Bonferroni post-hoc tests results for the experimental group

Variable	Mean difference	SE	95% confidence interval	<i>p</i>
Static balance				
Pretest vs. Posttest	-7.87	2.13	[-13.40, -2.35]	.004
Pretest vs. Follow-up	-7.83	2.14	[-13.38, -2.29]	.004
Posttest vs. Follow-up	0.04	1.42	[-3.63, 3.71]	> .99
Dynamic balance				
Pretest vs. Posttest	-3.46	1.15	[-6.45, -0.47]	.020
Pretest vs. Follow-up	-3.88	1.21	[-7.00, -0.75]	.012
Posttest vs. Follow-up	-0.42	0.82	[-2.54, 1.70]	> .99
Cognitive flexibility				
Pretest vs. Posttest	-8.00	2.99	[-16.44, 0.44]	.031
Pretest vs. Follow-up	-12.25	4.06	[-23.69, -0.81]	.024
Posttest vs. Follow-up	-4.35	2.77	[-12.07, 3.57]	.648
Error responses in cognitive flexibility				
Pretest vs. Posttest	5.46	1.93	[0.46, 10.46]	.029
Pretest vs. Follow-up	7.67	2.63	[0.86, 14.47]	.024
Posttest vs. Follow-up	2.21	1.99	[-2.96, 7.38]	.841
Completed categories in cognitive flexibility				
Pretest vs. Posttest	-0.75	0.33	[-1.42, -0.08]	.031
Pretest vs. Follow-up	-1.00	0.41	[-1.85, -0.15]	.024
Posttest vs. Follow-up	-0.25	0.34	[-0.95, 0.45]	.468
Working memory				
Pretest vs. Posttest	-11.83	10.35	[-26.93, 3.27]	.014
Pretest vs. Follow-up	-21.58	9.84	[-46.54, 3.34]	.049
Posttest vs. Follow-up	-9.75	6.70	[-28.67, 9.17]	.522

outcomes (balance and working memory) showed improvements over time in both groups without differential intervention effects.

Discussion

The study demonstrated significant and sustained improvements in cognitive flexibility (primary outcome) in the experimental group, which was maintained at the 2-month follow-up. These behavioral changes provide direct empirical support for the motivational and naturalistic mechanisms of PRT, which appear to enhance adaptive cognitive processes in high-functioning ASD. The findings align closely with Diamond's executive function framework (2013), which positions cognitive flexibility as a core higher-order process enabling goal-directed behavior, inhibitory control, and set-shifting in novel contexts. Similarly, they are consistent with Cognitive Complexity and Control Theory (Zelazo & Müller, 2011), which emphasizes hierarchical prefrontal-mediated control over thought and action, particularly in response to changing demands. By embedding PRT's child-centered elements (choice, motivation, contingent reinforcement) within structured SPARK activities, the intervention likely facilitated neuroplastic changes at the functional level, supporting experience-dependent restructuring of neural pathways in ASD (Dawson & Bernier, 2013). However, without neuroimaging, these interpretations remain at the behavioral level and do not extend to direct claims of structural brain changes.

This pattern of improvement shows clear similarities with prior research on combined interventions. For example, Faraji et al. (2023) reported enhanced executive function when combining aquatic exercises with PRT in high-functioning ASD, although long-term sustainability was not assessed. Likewise, network meta-analyses indicate that multi-component physical activities (including SPARK-like programs) produce moderate to large effects on cognitive flexibility ($SMD \approx 0.79\text{--}0.94$; Hou et al., 2024), which parallels the sustained gains observed here. The addition of PRT's naturalistic and motivational components may explain the domain-specific advantage over standalone SPARK studies, which often show variable or smaller cognitive effects in children (Najafabadi et al., 2018). In contrast, broader executive improvements have been reported with exergaming or mind-body exercises (e.g., $SMD = 0.92\text{--}1.91$ for overall executive function (Tao et al., 2025), suggesting that the child-led nature of PRT may be particularly effective for flexibility but less so for other executive function subdomains.

Although significant main effects of time and group were observed for working memory ($p < .001$ and $p = .011$, respectively), the non-significant group $\times$ time interaction ($p = .966$) suggests that these overall effects do not indicate a specific intervention benefit. It should also be noted that the significant time effects observed across both groups may reflect practice effects or natural maturation, which were not controlled for in this design. This pattern is consistent with several lines of evidence. Network meta-analyses show

that SPARK or similar fixed-exercise programs frequently fail to yield robust working memory gains, often due to insufficient targeting of visuospatial or verbal components and short intervention durations (Hou et al., 2024; Liang et al., 2022). Similar null results have been reported in reviews where exercise protocols ≤ 8 weeks limit cognitive consolidation (Li & Zhang, 2025), which aligns with our 6-week timeline. Positive effects on working memory are more commonly seen with martial arts, Neiyang Gong, or rhythmic/sensory-integrated exercises (Heidari et al., 2024; Hou et al., 2024), which involve greater repetition and memory-specific demands. The lack of effect in the present study may be attributed to several factors: individual variability in ASD cognitive profiles, co-occurring conditions such as attention deficit hyperactivity disorder that moderate outcomes (Rabiee et al., 2020; Schuh & Eigsti, 2012), the n-back task's limited sensitivity to subtle naturalistic changes, and PRT's primary focus on motivation and flexibility rather than repetitive memory training. These null findings underscore that while physical activity can support executive function broadly, domain-specific tailoring is necessary for working memory gains.

Similarly, static and dynamic balance showed no significant group differences, despite meta-analytic evidence of large effects from exercise interventions ($SMD = 0.86$ overall; 1.19 for protocols > 8 weeks; Li & Zhang, 2025). Similarities exist with SPARK-specific literature, where many studies report balance improvements (Najafabadi et al., 2018), but differences emerge in our null results, likely due to PRT's cognitive emphasis diluting motor-specific training intensity. Comparable non-significant findings appear in aquatic or exergaming studies (Faraji et al., 2023; Hou et al., 2024), often attributed to insufficient duration or specificity for postural stability ($SMD = 0.72$ in motor meta-analyses; Ji et al., 2023). Possible explanations include the short 6-week intervention (versus 12–16 weeks in positive SPARK trials (Najafabadi et al., 2018), sample homogeneity (urban, male-only participants), unaccounted environmental or cultural factors affecting measurement in Iran (Samadi & McConkey, 2015), and potential ceiling effects in baseline balance among high-functioning children. Overall, these secondary null outcomes highlight the domain-specific nature of the intervention: PRT integration appears to preferentially benefit cognitive flexibility over motor or memory domains, suggesting that longer durations or more targeted motor components may be required for broader effects.

Limitations of the study include the small sample size ($N = 24$, male-only) from a single urban school, which limits statistical power for smaller effects and generalizability; lack of trial registration, increasing risk of selective reporting bias; reliance on behavioral measures without neuroimaging or cultural adaptations for Iranian children (Samadi & McConkey, 2015); and the relatively short 6-week duration, which may have been insufficient for motor consolidation or working memory transfer.

Future research should recruit larger, more diverse samples, extend intervention periods, incorporate neuroimaging to clarify underlying mechanisms, and compare

different motivational variants to refine ASD intervention protocols. Combining motivational behavioral strategies with structured physical activity holds strong promise for targeted cognitive enhancements in children with high-functioning ASD.

Conclusions

The research findings confirmed the primary hypothesis that the integrated treatment approach produces lasting improvements in cognitive flexibility for children between 7 and 10 years old who have high-functioning ASD. However, for static balance, dynamic balance, and working memory, the absence of significant group×time interactions, combined with uncontrolled learning effects, prevents any strong claims of intervention efficacy. The study answers its research questions through evidence that shows that personalized interventions combining structured physical activities with motivational approaches lead to specific executive function improvements in high-functioning ASD.

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Conflict of interest

The authors report no conflict of interest.

References

- Alschuler, K. N., Neblett, R., Wiggert, E., Haig, A. J., & Geisser, M. E. (2009). Flexion-relaxation and clinical features associated with chronic low back pain: A comparison of different methods of quantifying flexion-relaxation. *Clinical Journal of Pain*, 25(9), 760–766. <https://doi.org/10.1097/AJP.0b013e3181b56db6>
- American Psychiatric Association, DSM-5 Task Force. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5™* (5th ed.). American Psychiatric Publishing, Inc. <https://doi.org/10.1176/appi.books.9780890425596>
- Baio, J., Wiggins, L., Christensen, D. L., Maenner, M. J., Daniels, J., Warren, Z., Kurzius-Spencer, M., Zahorodny, W., Robinson Rosenberg, C., White, T., Durkin, M. S., Imm, P., Nikolaou, L., Yeargin-Allsopp, M., Lee, L. C., Harrington, R., Lopez, M., Fitzgerald, R. T., Hewitt, A., Pettygrove, S., ... Dowling, N. F. (2018). Prevalence of autism spectrum disorder among children aged 8 years – Autism and Developmental Disabilities Monitoring Network, 11 sites, United States, 2014. *Morbidity and Mortality Weekly Report*, 67(6), 1–23. <https://doi.org/10.15585/mmwr.mm6706a1>
- Chiva-Bartoll, O., Maravé-Vivas, M., Salvador-García, C., & Valverde-Esteve, T. (2021). Impact of a physical education service-learning programme on ASD children: A mixed-methods approach. *Children and Youth Services Review*, 126, Article 106008. <https://doi.org/10.1016/j.childyouth.2021.106008>
- Corseello, C. M. (2005). Early intervention in autism. *Infants & Young Children*, 18(2), 74–85.
- Dawson, G., & Bernier, R. (2013). A quarter century of progress on the early detection and treatment of autism spectrum disorder. *Development and Psychopathology*, 25(4 Pt 2), 1455–1472. <https://doi.org/10.1017/S0954579413000710>
- Demetriou, E. A., DeMayo, M. M., & Guastella, A. J. (2019). Executive function in autism spectrum disorder: History, theoretical models, empirical findings, and potential as an endophenotype. *Frontiers in Psychiatry*, 10, Article 467109. <https://doi.org/10.3389/fpsy.2019.00753>
- Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, 64, 135–168. <https://doi.org/10.1146/annurev-psych-113011-143750>
- Dowda, M., James, F., Sallis, J. F., McKenzie, T. L., Rosengard, P., & Kohl, H. W., III. (2005). Evaluating the sustainability of SPARK physical education: A case study of translating research into practice. *Research Quarterly for Exercise and Sport*, 76(1), 11–19. <https://doi.org/10.1080/02701367.2005.10599257>
- Faraji, S., Najafabadi, M. G., Zandi, H. G., & Shaw, I. (2023). Effect of aquatic therapy on motor skill and executive function in children with Autism Spectrum Disorder. *South African Journal for Research in Sport, Physical Education and Recreation*, 45, 17–27. <https://doi.org/10.36386/sajrsper.v45i2.101>
- Gilliam, J. E. (2014). *Gilliam Autism Rating Scale – Third Edition*. PRO-ED.
- Hardan, A. Y., Gengoux, G. W., Berquist, K. L., Libove, R. A., Ardel, C. M., Phillips, J., Frazier, T. W., & Minjarez, M. B. (2015). A randomized controlled trial of Pivotal Response Treatment Group for parents of children with autism. *Journal of Child Psychology and Psychiatry*, 56(8), 884–892. <https://doi.org/10.1111/jcpp.12354>
- Healy, S., & Marchand, G. (2020). The feasibility of Project CHASE: A Facebook-delivered, parent-mediated physical activity intervention for children with autism. *International Journal of Disability, Development and Education*, 67(2), 225–242. <https://doi.org/10.1080/1034912X.2019.1597968>
- Healy, S., Nacario, A., Braithwaite, R. E., & Hopper, C. (2018). The effect of physical activity interventions on youth with autism spectrum disorder: A meta-analysis. *Autism Research*, 11(6), 818–833. <https://doi.org/10.1002/aur.1955>
- Heidari, S. F., Ayatizadeh Tafti, F., Sadeghian Shahi, M. R., & Aria, B. (2024). The effect of rhythmic movement exercises on visual-spatial memory, cognitive flexibility and balance of children with autism spectrum disorder. *Journal of Paramedical Sciences & Rehabilitation*, 12(4), 79–92. <https://doi.org/10.22038/jpsr.2024.72588.2505>
- Hou, Y., Wang, Y., Deng, J., & Song, X. (2024). Effects of different exercise interventions on executive function in children with autism spectrum disorder: A network meta-analysis. *Frontiers in Psychiatry*, 15, Article 1440123. <https://doi.org/10.3389/fpsy.2024.1440123>
- Ji, Y.-Q., Tian, H., Zheng, Z.-Y., Ye, Z.-Y., & Ye, Q. (2023). Effectiveness of exercise intervention on improving fundamental motor skills in children with autism spectrum disorder: A systematic review and meta-analysis. *Frontiers in Psychiatry*, 14, Article 1132074. <https://doi.org/10.3389/fpsy.2023.1132074>
- Koegel, L. K., Ashbaugh, K., & Koegel, R. L. (2016). Pivotal Response Treatment. In R. Lang, T. Hancock, & N. Singh (Eds.), *Early intervention for young children with autism spectrum disorder* (pp. 85–112). Springer. https://doi.org/10.1007/978-3-319-30925-5_4
- Koegel, R. L., & Koegel, L. K. (2006). *Pivotal response treatments for autism: Communication, social, & academic development*. Paul H. Brookes Publishing Co.
- Lahtinen, U., Rintala, P., & Malin, A. (2007). Physical performance of individuals with intellectual disability: A 30 year follow up. *Adapted Physical Activity Quarterly*, 24(2), 125–143. <https://doi.org/10.1123/apaq.24.2.125>
- Lezak, M. D., Howieson, D. B., Loring, D. W., Hannay, H. J., & Fischer, J. S. (2004). *Neuropsychological assessment* (4th ed.). Oxford University Press.
- Li, H., & Zhang, R. (2025). The effect of exercise intervention on balance and executive function in children with autism spectrum disorder: A meta-analysis. *BMC Sports Science, Medicine and Rehabilitation*, 17(1), Article 80. <https://doi.org/10.1186/s13102-025-01142-1>
- Liang, X., Li, R., Wong, S. H. S., Sum, R. K. W., Wang, P., Yang, B., & Sit, C. H. P. (2022). The effects of exercise interventions on executive functions in children and adolescents with autism spectrum disorder: A systematic review and meta-analysis. *Sports Medicine*, 52(1), 75–88. <https://doi.org/10.1007/s40279-021-01545-3>
- Licari, M. K., Alvares, G. A., Varcin, K., Evans, K. L., Cleary, D., Reid, S. L., Glasson, E. J., Bebbington, K., Reynolds, J. E., & Wray, J. (2020). Prevalence of motor difficulties in autism spectrum disorder: Analysis of a population-based cohort. *Autism Research*, 13(2), 298–306. <https://doi.org/10.1002/aur.2230>
- Lim, Y. H., Partridge, K., Girdler, S., & Morris, S. L. (2017). Standing postural control in individuals with autism spectrum disorder: Systematic review and meta-analysis. *Journal of Autism and Developmental Disorders*, 47, 2238–2253. <https://doi.org/10.1007/s10803-017-3144-y>
- Lin, X., Wang, G., Shen, S., & Zhan, J. (2024). Advances in the diagnosis and treatment of autism spectrum disorders in children. *Alternative Therapies in Health and Medicine*, 30(3), 170–175.
- Lord, C., Elsabbagh, M., Baird, G., & Veenstra-Vanderweele, J. (2018). Autism spectrum disorder. *Lancet*, 392(10146), 508–520. [https://doi.org/10.1016/S0140-6736\(18\)31129-2](https://doi.org/10.1016/S0140-6736(18)31129-2)
- Maenner, M. J., Warren, Z., Williams, A. R., Amoakohene, E., Bakian, A. V., Bilder, D. A., Durkin, M. S., Fitzgerald, R. T., Fournier, S. M., Hughes, M. M., Ladd-Acosta, C. M., McArthur, D., Pas, E. T., Salinas, A., Vehorn, A., Williams, S., Esler, A., Grzybowski, A., Hall-Lande, J., Nguyen, R. H. N., ... Shaw, K. A. (2023). Prevalence and characteristics of autism spectrum disorder among children aged 8 years – Autism and Developmental Disabilities Monitoring Network, 11 sites, United States, 2020. *Morbidity and Mortality Weekly Report*, 72(2), 1–14. <https://doi.org/10.15585/mmwr.mm7202a1>
- McDaniel, J., Yoder, P., Crandall, M., Millan, M. E., Ardel, C. M., Gengoux, G. W., & Hardan, A. Y. (2020). Effects of pivotal response treatment on reciprocal vocal contingency in a randomized controlled trial of children with autism spectrum disorder. *Autism*, 24(6), 1566–1571. <https://doi.org/10.1177/1362361320903138>
- Minai, A., & Nazeri, S. (2018). Psychometric properties of the Gilliam Autism Rating Scale – Third Edition (GARS-3) in individuals with autism: A pilot study. *Journal of Exceptional Children*, 18(2), 113–122. <http://joec.ir/article-1-847-en.html>
- Mohammadzadeh, F., Koegel, L. K., Rezaee, M., & Rafiee, S. M. (2014). A randomized clinical trial comparison between Pivotal Response Treatment (PRT) and structured Applied Behavior Analysis (ABA) intervention for children with autism. *Journal of Autism and Developmental Disorders*, 44(11), 2769–2777. <https://doi.org/10.1007/s10803-014-2137-3>

- Munakata, Y., Herd, S. A., Chatham, C. H., Depue, B. E., Banich, M. T., & O'Reilly, R. C. (2011). A unified framework for inhibitory control. *Trends in Cognitive Sciences*, 15(10), 453–459. <https://doi.org/10.1016/j.tics.2011.07.011>
- Najafabadi, M. G., Sheikh, M., Hemayatlab, R., Memari, A.-H., Aderyani, M. R., & Hafizi, S. (2018). The effect of SPARK on social and motor skills of children with autism. *Pediatrics & Neonatology*, 59(5), 481–487. <https://doi.org/10.1016/j.pedneo.2017.12.005>
- Pan, C. Y., Chu, C. H., Tsai, C. L., Sung, M. C., Huang, C. Y., & Ma, W. Y. (2017). The impacts of physical activity intervention on physical and cognitive outcomes in children with autism spectrum disorder. *Autism*, 21(2), 190–202. <https://doi.org/10.1177/1362361316633562>
- Rabiee, A., Vasaghi-Gharamaleki, B., Samadi, S. A., Amiri-Shavaki, Y., & Alagband-Rad, J. (2020). Working memory deficits and its relationship to autism spectrum disorders. *Iranian Journal of Medical Sciences*, 45(2), 100–109. <https://doi.org/10.30476/ijms.2019.45315>
- Ruggeri, A., Dancel, A., Johnson, R., & Sargent, B. (2020). The effect of motor and physical activity intervention on motor outcomes of children with autism spectrum disorder: A systematic review. *Autism*, 24(3), 544–568. <https://doi.org/10.1177/1362361319885215>
- Samadi, S. A., & McConkey, R. (2015). Screening for autism in Iranian preschoolers: Contrasting M-CHAT and a scale developed in Iran. *Journal of Autism and Developmental Disorders*, 45(9), 2908–2916. <https://doi.org/10.1007/s10803-015-2454-1>
- Schuh, J. M., & Eigsti, I. M. (2012). Working memory, language skills, and autism symptomatology. *Behavioral Sciences*, 2(4), 207–218. <https://doi.org/10.3390/bs2040207>
- Taghizade, T., Nejati, V., Mohammadzade, A., Akbarzade Baghban, A., & Nejati, V. N. (2014). Evolution of auditory and visual working memory in primary school-aged children. *Journal of Research in Rehabilitation Sciences*, 10(2), 239–249. <https://doi.org/10.22122/jrrs.v10i2.1300>
- Tao, R., Yang, Y., Wilson, M., Chang, J. R., Liu, C., & Sit, C. H. P. (2025). Comparative effectiveness of physical activity interventions on cognitive functions in children and adolescents with neurodevelopmental disorders: A systematic review and network meta-analysis of randomized controlled trials. *International Journal of Behavioral Nutrition and Physical Activity*, 22, Article 6. <https://doi.org/10.1186/s12966-024-01702-7>
- Travers, B. G., Mason, A. H., Gruben, K. G., Dean, D. C., III, & McLaughlin, K. (2018). Standing balance on unsteady surfaces in children on the autism spectrum: The effects of IQ. *Research in Autism Spectrum Disorders*, 51, 9–17. <https://doi.org/10.1016/j.rasd.2018.03.008>
- Vismara, L. A., & Lyons, G. L. (2007). Using perseverative interests to elicit joint attention behaviors in young children with autism: Theoretical and clinical implications for understanding motivation. *Journal of Positive Behavior Interventions*, 9(4), 214–228. <https://doi.org/10.1177/109830070700900404>
- Voigt, R. G., Macias, M. M., Myers, S. M., & Tapia, C. D. (2011). *Developmental and behavioral pediatrics*. American Academy of Pediatrics.
- Yazdani, S., Capuano, A., Ghaziuddin, M., & Colombi, C. (2020). Exclusion criteria used in early behavioral intervention studies for young children with autism spectrum disorder. *Brain Sciences*, 10(2), Article 99. <https://doi.org/10.3390/brainsci10020099>
- Zelazo, P. D., & Müller, U. (2011). Executive function in typical and atypical development. In U. Goswami (Ed.), *The Wiley-Blackwell handbook of childhood cognitive development* (2nd ed., pp. 574–603). Wiley Blackwell. <https://doi.org/10.1002/9781444325485.ch22>