



The Effect of Adaptive Physical Activity on the Motor Abilities of Children with Autism Spectrum Disorder: A Systematic Review

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ABSTRACT: Motor skill deficit is prevalent among children with Autism Spectrum Disorder (ASD), yet it remains relatively neglected and is not listed as a core symptom or “specifier” in the DSM-5. Given the wide range of individual differences in symptom presentation, age, and interests among children with ASD, Adaptive Physical Activity (APA) has shown promise as a physical intervention due to its flexibility, individualization, and specificity. In view of this, this study, on the basis of identifying the motor ability problems of children with ASD and the effects of APA on movement disorders in this population, and based on the characteristic that ASD is a neurodevelopmental disorder, systematically reviewed and analysed the principles of neural control of body postures in children with ASD and the adaptive matching mechanisms of different sports with children with ASD, and proposed that in the future, APA should be intensively carried out for children with ASD intervention studies and form specific guidelines on the principles of intervention and adaptive matching mechanisms. Through these theoretical studies, our knowledge in these areas can be enhanced to provide a clearer understanding of how these interventions can be improved in order to develop more effective, individualised APA programmes that provide holistic interventions for children with ASD that are both scientifically based and practical, and ultimately lead to better outcomes for this population.

KEYWORDS: Autism Spectrum Disorder, Motor skills, Dyspraxia, Adaptive Physical Activity (APA)

1. INTRODUCTION

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by social deficits and repetitive, stereotyped behaviors (Gao & Chen, 2023). The DSM-5 further identifies additional aspects of ASD through “specifiers,” which highlight disorders in areas such as communication, language, narrow interests, and cognition (American Psychiatric Association, 2013). Typically manifesting in early childhood, ASD has seen a significant and rapid increase in prevalence over recent decades. By 2020, the average prevalence of ASD among 8-year-olds in the United States reached 27.6 per 1,000, with California reporting the highest rate at 44.9 per 1,000 (Maenner, 2023). According to the World Health Organization (WHO), the global prevalence of ASD in children was estimated to be 1 in 100 in 2023, though actual rates may be higher due to improved early screening and increased public awareness. This global rise in ASD prevalence has profound implications for individuals, families, and societies, drawing significant international and academic attention.

Impaired motor development is prevalent in children with ASD, who often exhibit lower gross and fine motor abilities compared to their typically developing peers. Common issues include difficulties with visual-motor integration, dynamic balance, multi-limb coordination, and everyday functional motor skills (Bhat, 2022). In academic contexts, these motor abilities are frequently referred to as motor skills, and deficits in these areas are often described as motor skill deficits or dyspraxia.

Physical activity is considered an effective intervention for addressing motor skill deficits in children with ASD. Studies have shown that appropriate physical activity can enhance the health and psychological functioning of these children. This improvement occurs as physical activity stimulates different areas of the brain in an interactive manner, positively influencing motor skills, social communication, stereotyped behaviors, cognition, and overall behavior (Shahane, Kilyk & Srinivasan, 2024; Ranieri et al., 2023). It is crucial to adhere to the principle of adaptability when implementing such activities. This principle involves designing individualized activity programs tailored to the unique characteristics and needs of each child with ASD, ensuring they receive optimal support to maximize the intervention's effectiveness (Bremer & Cairney, 2020).

Currently, the relationship between motor skills and ASD remains under-researched, and the DSM-5 does not include specifiers related to motor disability (American Psychiatric Association, 2013). On the basis of reviewing and sorting out the motor ability of children with ASD, adaptive physical activity (APA) and its effect on the motor impairment of children with ASD, this study systematically analyses the principles in APA intervention and the adaptive matching between different sports and children with ASD based on the characteristic that ASD is a neurodevelopmental disorder, and proposes the potential direction of future research. In order to promote the relevant research in this field for children with ASD, and to provide theoretical support and practical guidance for the clinical treatment of children with ASD, and to help them better adapt to social life.

1. Motor Skills in Children with ASD

1.1. Definition of Motor Skills

Motor ability refers to an individual's capacity to perform a variety of physical activities, encompassing both gross and fine motor skills. Gross motor development, which typically precedes fine motor development, involves the coordinated use of large muscle groups in the trunk and limbs. This includes basic movements such as walking, running, and jumping, as well as more complex actions like throwing and climbing (Newell, 2020). Fine motor skills, on the other hand, involve the precise coordination of small muscle groups, particularly in the hands, for tasks such as writing, holding, or manipulating objects (Collin & McDougle, 2021).

1.2. Motor impairment in children with ASD

Motor impairments are prevalent in children with ASD, with rates reaching 79-88%. Their severity increases with other impairments such as social communication deficits, repetitive stereotyped behaviors, language, and cognitive challenges, and these impairments can persist into adolescence and throughout life (Bhat, Boulton & Tulsy, 2022). Additionally, Kangarani-Farahani & Zwicker (2024) reported that 92.5% of relevant studies found that 50-88% of children with ASD exhibit severe motor impairments.

Motor ability deficits in these children are usually evident in early childhood (Stevenson, Lindley & Murlo, 2017; Isenhower et al., 2012). Some studies suggest that children with ASD have motor abilities equivalent to those of typically developing children only half their age (Greco, 2020). These deficits manifest as significant delays in the development of motor abilities, including gross motor skills such as body movement coordination, motor planning, and static/dynamic balance, and fine motor skills such as manual dexterity (precision/integration) (Bhat et al., 2022).

Motor deficits not only affect the physical health of these children but also lead to poor performance in social situations, severely affecting their social, cognitive, language, and emotional well-being (Bhat et al., 2022). Lidstone and Mostofsky (2021) found that motor deficits in children with ASD are closely linked to their executive functioning, favoring proprioception (internal body feedback) over vision (external feedback) during motor learning. There is growing evidence that the severity of other symptoms in children with ASD is positively correlated with the extent of motor impairment (Bhat et al., 2022). Therefore, interventions targeting dyspraxia are essential not only for improving the physical health of children with ASD but also as a crucial strategy for promoting their overall development.

2. ADAPTIVE PHYSICAL ACTIVITY (APA)

APA (Adapted Physical Activity) is an interdisciplinary term aimed at providing adaptive rehabilitation applications for individuals with impairments, broadly related to the fields of physical education, sport, and recreation (International Council of Sports Science and Education, 2002). According to Winnick and Porretta (2016), “Adaptation” refers to modifications made to meet the individual needs of specific populations. APA is a personalized physical activity program tailored to the needs of individuals, encompassing both adaptive physical education and adaptive sports.

Yang and Du (2020) further suggest that APA is a type of physical activity based on the knowledge systems of sports and other multidisciplinary fields. It is specifically designed for special populations with physical, mental, and cognitive disabilities, characterized by specificity, flexibility, and highly individualized approaches. Therefore, APA is also a strategy and principle in the practice of physical activity, emphasizing the flexible and adaptive adjustment of activity content, modes, environments, and methods according to the ability levels and specific needs of individuals. The goal is to provide effective strategies and principles to promote their athletic abilities and overall health. Additionally, APA for children with ASD should consider their age characteristics, incorporating principles of simplicity, storytelling, fun, and parent-child interaction.

Physical activity has a positive impact on children with ASD. Given the wide range of individual differences among these children, it is particularly necessary to develop and implement APA tailored to their specific symptoms and individualized needs (Di Vara et al., 2024; Gehricke et al., 2020). When implementing physical activity interventions for children with ASD, it is important to develop specific APA programs for each individual based on differences in symptoms, age, and interests. This includes considerations of activity form, participation, and exercise load, with flexible adjustments during implementation to meet their needs and ensure they engage in activities in the most appropriate state to achieve the best intervention effects (Roşca, Rusu, Marin, Ene & Ene, 2022). Attention should also be paid to the design of elements such as frequency, duration, teaching methods, and strategies (Antonio & Santillan, 2020).

3. EFFECTS OF APA ON THE MOTOR ABILITIES OF CHILDREN WITH ASD

Numerous studies have confirmed that physical activity is effective in improving motor ability and overall functioning in children with ASD. This includes a wide range of activities such as general and specialized sports games, sport-specific training (e.g., ball games, equestrian, swimming), aerobic exercises (e.g., jogging, bicycling), strength exercises, and balance and coordination training (e.g., yoga, dance, martial arts) (Pope, Fautsch, Zeng & Gao, 2019; Shahnaz, Kateb, Doyle-Baker & Hassani, 2023; Ruggeri, Dancel, Johnson & Sargent, 2020; Bremer, Crozier & Lloyd, 2016; Hyne & Block, 2022; Ludyga, Pühse, Gerber & Mücke, 2021). Given the wide range of individual differences typical of children with ASD (Di Vara et al., 2024; Gehricke et al., 2020), researchers have utilized strategies that adapt physical activities to the specific needs of these children to improve their motor abilities and overall functioning (Pan & Frey, 2006). APA interventions are not only effective for motor impairments in children with ASD but also create conditions for enhanced neurological functioning and improved behavior (Musiyenko, Chopyk & Kizlo, 2020).

APA emphasises that the content of the activity must be adapted to the age, gender, interests and physical characteristics of those for whom the activity is carried out (Gao, Hu & Wang, 2024). Ruggeri et al. (2020) suggested the need for strategic research on physical activity for children with ASD. A search of databases such as ScienceDirect, PubMed, Web of Science, and CNKI revealed that the number of studies on adaptive interventions for specific types of physical activity in children with ASD is relatively limited. However, adaptive principles and instructional strategies have been widely represented and utilized in many studies of physical education interventions for children with ASD. These studies emphasize pre-assessment of programs based on individual characteristics and needs, as well as adaptive selections and adjustments to ensure the effectiveness of the interventions. Given the age-specific characteristics of children with ASD, sports games have demonstrated good adaptability and broad application prospects due to their fun and engaging nature. Studies have shown that scientifically evaluated and carefully selected sports games not only help improve the attention of children with ASD but also effectively promote the development of their motor skills and overall functioning (Pope et al., 2019).

In addition to physical games, Hayward, Fragala-Pinkham, Johnson and Torres (2016) conducted an adaptive soccer intervention study in a community setting. The results showed significant improvements in participants' kicking accuracy and agility, suggesting that motor skill-based training is feasible and effective in enhancing motor skills and overall motor competence in children with ASD. It is also important to note that different motor environments may significantly impact intervention outcomes (Pan, 2008). Therefore, environmental factors should be considered when designing APA interventions.

4. PRINCIPLES AND MECHANISMS BY WHICH PHYSICAL ACTIVITY INFLUENCES MOTOR ABILITY IN CHILDREN WITH ASD

The exact etiology of ASD is not yet fully understood. It is widely recognized that ASD is a neurodevelopmental disorder caused by a combination of environmental and genetic factors (Genovese & Butler, 2023). The nervous system, which regulates the body's physiological and functional activities, includes the central nervous system (brain and spinal cord) and the peripheral nervous system (cerebral and spinal nerves) (Sports Anatomy, 2013).

Postural control has an important place in the development of motor abilities in children with ASD, with dynamic and static balance of the body belonging to the essential components of motor abilities (Bhat et al., 2022), both of which are maintained by postural control, which underpins the early development of motor abilities (gross motor and fine motor) (Date, Munn & Frey, 2024). Postural control is realized by the central nervous system through the complex integration of the visual, somatosensory, and vestibular systems (Latash & Hadders-Algra, 2008). Postural control deficits in children with ASD may be related to systemic deficits in the visual, somatosensory, and vestibular systems, deficits in nonspecific channel integration of multisensory systems, or deficits in cerebellar connectivity (Doumas, McKenna & Murphy, 2016; Chisari, Vitkovic, Clark & Rance, 2024). When multi-system sensory integration is limited, this can lead to deficits in information input and integration between the visual, somatosensory and vestibular systems, such as body swaying when eyes are closed or in unstable planes (Minshew, Sung, Jones & Furman, 2004). Existing research has identified developmental problems with postural control in children with ASD, which are often manifested by unsteady swaying of the body during stance, uneven distribution of body weight, and a lack of ankle adjustment strategies (Chisari et al., 2024). Developmental problems with postural control in children with ASD affect their gross and fine motor development and lead to the development of repetitive stereotypical behaviors, which can have a negative impact on a range of issues such as motor competence, social interaction, communication, and participation (Date & Frey, 2024). It is important to note that the development of postural control in children with ASD typically stagnates with age (Date & Frey, 2024), and that improvements obtained through interventions, for example, are very slow and take a long time to show significant changes (Li & Venuti, 2021), and even then, their postural control may fail to reach the normal levels of their peers in adulthood (Li & Venuti, 2021). levels of their peers (Minshew, Sung, Jones & Furman, 2004), a characteristic that is consistent with the developmental profile of ASD.

5. ADAPTIVE MECHANISMS BY WHICH PHYSICAL ACTIVITY AFFECTS MOTOR PERFORMANCE IN CHILDREN WITH ASD

For children with ASD, no research has demonstrated that there is a specific form of physical activity that is most effective (Wu et al., 2024). Ruggeri, Dancel, Johnson and Sargent (2020) conducted a meta-analysis of 41 studies from 2000-2019 and found that various forms of physical activity improved the motor abilities of children with ASD. They identified adaptive mechanisms by which different forms of physical activity enhanced motor performance, suggesting an adaptive matching mechanism between specific activities and motor improvements in children with ASD.

Specific types of physical activity can target specific impairments in children with ASD (Roşca et al., 2022), and this area of research has become a central focus in the field. Numerous studies confirm the effectiveness of these programs. For example, aquatic activities and KAKA techniques have been shown to improve balance in children with ASD (Ansari et al., 2020), dance training promotes neuromuscular coordination (Arzoglou et al., 2013), and equestrian exercises enhance balance and gross motor skills (Stergiou, 2017)

The adaptive matching of different forms of physical activity to the symptoms of children with ASD has been investigated at a theoretical level. Early studies have confirmed that strength training enhances excitability and improves neural drive in the corticospinal system by affecting intracortical inhibitory networks in the primary motor cortex and corticospinal pathways (Kidgell et al., 2017; Enoka, 1988; Hickson et al., 1994; Moritani & DeVries, 1979; Narici et al., 1989). Jensen, Marstrand and Nielsen (2005) found, through a 4-week study, that visuomotor skill

learning increases corticospinal excitability, which affects both distal and proximal finger muscle groups, and that because the proximal muscle groups, because they are more susceptible to corticospinal control, produce greater changes in motor performance. The positive effects of equestrian practice on children with ASD may be related to the rhythmic vibrations of the horse. The cyclical movements produced by horses when walking are effective in stimulating the spinal cord, which promotes the development of the rider's locomotor and balance abilities (Ohtani et al., 2017).

6. DISCUSSION

Children with ASD commonly have motor ability disorders involving both gross and fine motor skills, which are evident in early childhood. The severity of these disorders is closely related to other developmental challenges. There are extensive individual differences among children with ASD in terms of symptoms, age, and interests. Due to its core strengths of specificity, flexibility, and individualization, APA (Adapted Physical Activity) shows great promise for physical activity interventions for children with ASD.

A customized APA program for each child with ASD ensures they receive maximum support during their participation, resulting in the best intervention outcomes. APA interventions not only significantly improve motor performance but also positively impact overall functioning, including social, cognitive, and repetitive stereotypic behaviors. However, related research is still in its infancy. Future research is needed to further determine the effects of different forms of APA on children with ASD and to develop instructional APA programs based on systematic theories.

Motor behavior is dependent on the coordinated control of both the central and peripheral nervous systems. For neurodevelopmental disorders such as ASD, postural control is an important basis for the development of motor abilities in children with ASD and is realized by the central nervous system through the complex integration of the visual, somatosensory and vestibular systems. Physical activity improves postural control in children with ASD by facilitating neurological function and sensory integration abilities to achieve improvements in their motor abilities and overall function. In addition, because the development of postural control in children with ASD usually stagnates with age and the effect of intervention is slow, improvement of motor dysfunction in children with ASD requires long-term physical intervention and support.

Different forms of physical activity can positively affect specific categories of symptoms in children with ASD, and there are adaptive matching mechanisms for specific physical activities to enhance motor abilities in children with ASD. In physical activities for children with ASD, producing effective exercise stimuli by rationally designing forms of motion can help improve the motor abilities of children with ASD. Currently, the mechanisms involved in this area are unclear, the adaptive matching mechanism between specific physical activities and the motor abilities of children with ASD has not been fully investigated. Future research should build on existing studies to explore the intrinsic principles of this adaptive matching mechanism in depth, aiming to form a systematic theoretical framework.

7. CONCLUSION

In summary, Adapted Physical Activity (APA) holds significant promise for improving motor abilities and overall functioning in children with ASD. While current research has laid a foundation, it remains in its early stages, necessitating further exploration to fully understand the effects of various APA forms and to develop comprehensive,

theory-based instructional programs.

Future research should focus on elucidating the principles and mechanisms associated with APA, particularly the principles of neurological control of body posture, which could provide a clearer understanding of how to improve these interventions. In addition, investigating the adaptive matching mechanisms between specific physical activities and the motor abilities of children with ASD will be crucial.

By advancing our knowledge in these areas, we can develop more effective, individualized APA programs that not only enhance motor skills but also contribute to the overall well-being of children with ASD. This holistic approach will ensure that interventions are both scientifically grounded and practically applicable, ultimately leading to better outcomes for this population.

Ethics Statement:

In consideration of the nature of the systematic evaluation and meta-analysis, no ethical approval was deemed necessary.

Consent for Publication:

All authors have read and agreed to the published version of the manuscript.

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Author Contribution Statement

Kueifeng Gao: primary author, original draft, systematic analysis. Mahlen B. Antonio: secondary author, supervision, organization.

Statement of Competing Interests

The authors confirm that they have no competing financial interests or personal relationships that could potentially influence the results and conclusions presented in this study.

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REFERENCES

1. American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders, 5th Edition: DSM-5 (5th ed.)*. American Psychiatric Publishing.
2. Ansari, S., Hosseinkhanzadeh, A. A., AdibSaber, F., Shojaei, M., & Daneshfar, A. (2021). The effects of aquatic versus kata techniques training on static and dynamic balance in children with autism spectrum disorder. *Journal of autism and developmental disorders, 51*, 3180-3186.
3. Antonio, M. B., & Santillan, J. P. (2020). Use of Phono-Graphix™ method to improve the phonological awareness skills of a student with reading difficulty. *Universal Journal of Educational Research, 8*(12), 6706-6714.
4. Arzoglou, D., Tsimaras, V., Kotsikas, G., Fotiadou, E., Sidiropoulou, M., Proios, M., & Bassa, E. (2013). The effect of [alpha] traditional dance training program on neuromuscular coordination of individuals with autism. *Journal of Physical Education and Sport, 13*(4), 563.
5. Bhat A. (2022). Why add motor to the definition of ASD: A response to Bishop et al.'s critique of Bhat (2021). *Autism research: official journal of the International Society for Autism Research, 15*(8), 1376-1379.

- <https://doi.org/10.1002/aur.2776>
6. Bhat, A. N., Boulton, A. J., & Tulsy, D. S. (2022). A further study of relations between motor impairment and social communication, cognitive, language, functional impairments, and repetitive behavior severity in children with ASD using the SPARK study dataset. *Autism research: official journal of the International Society for Autism Research*, 15(6), 1156–1178. <https://doi.org/10.1002/aur.2711>.
 7. Bremer, E., & Cairney, J. (2020). Adaptive behavior moderate's health-related pathways in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 50(2), 491-499.
 8. Bremer, E., Crozier, M., & Lloyd, M. (2016). A Systematic Review of the Behavioural Outcomes following Exercise Interventions for Children and Youth with Autism Spectrum Disorder. *Autism: The International Journal of Research and Practice*, 20(8), 899–915. <https://doi.org/10.1177/1362361315616002>
 9. Chisari, D., Vitkovic, J., Clark, R., & Rance, G. (2024). Vestibular Function and Postural Control in Children with Autism Spectrum Disorder. *Journal of Clinical Medicine*, 13(17), 5323.
 10. Collins, A. G., & McDougle, S. D. (2021). Context is key for learning motor skills. *Nature: News and Views*. <https://www.nature.com/articles/d41586-021-03028-x>
 11. Date, S., Munn, E., & Frey, G. C. (2024). Postural balance control interventions in autism spectrum disorder (ASD): A systematic review. *Gait & Posture*.
 12. Di Vara, S., Guerrero, S., Menghini, D., Scibelli, F., Lupi, E., Valeri, G., & Vicari, S. (2024). Characterizing individual differences in children and adolescents with autism spectrum disorder: a descriptive study. *Frontiers in Psychology*, 15, 1323787.
 13. Dumas, M., McKenna, R., & Murphy, B. (2016). Postural control deficits in autism spectrum disorder: the role of sensory integration. *Journal of autism and developmental disorders*, 46, 853-861.
 14. Enoka, R. M. (1988). Muscle strength and its development: new perspectives. *Sports medicine*, 6, 146-168.
 15. Gao, K.F., & Chen, M. (2023). Research progress on physical intervention for social disorders in children with autism spectrum disorders. *Journal of Shandong Medical College*, 45(02): 97-99.
 16. Gao, K.F., Hu, G.H., & Wang, B. (2024). Innovation and reform of physical education teaching in colleges and universities. Harbin: Harbin Publishing House.
 17. Gehricke, J. G., Chan, J., Farmer, J. G., Fenning, R. M., Steinberg-Epstein, R., Misra, M., ... & Neumeyer, A. M. (2020). Physical activity rates in children and adolescents with autism spectrum disorder compared to the general population. *Research in autism spectrum disorders*, 70, 101490.
 18. Genovese, A., & Butler, M. G. (2023). The Autism Spectrum: Behavioral, Psychiatric and Genetic Associations. *Genes*, 14(3), 677. <https://doi.org/10.3390/genes14030677>
 19. Greco, G. (2020). Multilateral training using physical activity and social games improves motor skills and executive function in children with autism spectrum disorder. *European Journal of Special Education Research*.
 20. Hayward, L. M., Fragala-Pinkham, M., Johnson, K., & Torres, A. (2016). A Community-Based, Adaptive Soccer Program for Children with Autism: Design, Implementation, and Evaluation. *Palaestra*, 30(4).
 21. Hickson, R. C., Hidaka, K., Foster, C., Falduto, M. T., & Chatterton Jr, R. T. (1994). Successive time courses of strength development and steroid hormone responses to heavy-resistance training. *Journal of applied physiology*, 76(2), 663-670. <https://doi.org/10.1123/jmld.2020-0013>
 22. Hynes, J., & Block, M. (2022). Effects of Physical Activity on Social, Behavioral, and Cognitive Skills in Children and Young Adults with Autism Spectrum Disorder: A Systematic Review of the Literature. *Review Journal of Autism and Developmental Disorders*, 1-22.
 23. International Council of Sports Science and Education. (2002). *Guide to Sports Science*. Beijing: Beijing Sport University Press.
 24. Isenhower, R. W., Marsh, K. L., Richardson, M. J., Helt, M., Schmidt, R. C., & Fein, D. (2012). Rhythmic bimanual coordination is impaired in young children with autism spectrum disorder. *Research in Autism Spectrum Disorders*, 6(1), 25-31.
 25. Jensen, J. L., Marstrand, P. C., & Nielsen, J. B. (2005). Motor skill training and strength training are associated with different plastic changes in the central nervous system. *Journal of applied physiology*, 99(4), 1558-1568.
 26. Kangarani-Farahani, M., Malik, M. A., & Zwicker, J. G. (2024). Motor impairments in children with autism spectrum disorder: A systematic review and meta-analysis. *Journal of Autism and Developmental Disorders*, 54(5), 1977-1997.
 27. Kidgell, D. J., Bonanno, D. R., Frazer, A. K., Howatson, G., & Pearce, A. J. (2017). Corticospinal responses following strength training: a systematic review and meta-analysis. *European Journal of Neuroscience*, 46(11), 2648-2661.
 28. Latash, M., & Hadders-Algra, M. (2008). What is posture and how is it controlled? *Clinics in Developmental Medicine*, 3(1), 3-21.
 29. Li, Y., Liu, T., & Venuti, C. E. (2021). Development of postural stability in children with autism spectrum disorder: a cross-sectional study. *International Biomechanics*, 8(1), 54-62.
 30. Lidstone, D. E., & Mostofsky, S. H. (2021). Moving Toward Understanding Autism: Visual-Motor

- Integration, Imitation, and Social Skill Development. *Pediatric neurology*, 122, 98–105. <https://doi.org/10.1016/j.pediatrneurol.2021.06.010>
31. Ludyga, S., Pühse, U., Gerber, M., & Mücke, M. (2021). Muscle strength and executive function in children and adolescents with autism spectrum disorder. *Autism Research*, 14(12), 2555-2563
 32. Maenner, M. J. (2023). Prevalence and characteristics of autism spectrum disorder among children aged 8 years—Autism and Developmental Disabilities Monitoring Network, 11 sites, United States, 2020. *MMWR. Surveillance Summaries*, 72. <http://dx.doi.org/10.15585/mmwr.ss7202a1>
 33. Minshew, N. J., Sung, K., Jones, B. L., & Furman, J. M. (2004). Underdevelopment of the postural control system in autism. *Neurology*, 63(11), 2056-2061.
 34. Minshew, N. J., Sung, K., Jones, B. L., & Furman, J. M. (2004). Underdevelopment of the postural control system in autism. *Neurology*, 63(11), 2056-2061. doi:<https://doi.org/10.1212/01.WNL.0000145771.98657.62>.
 35. Moritani, T., & DeVries, H. A. (1979). Neural factors versus hypertrophy in the time course of muscle strength gain. *American journal of physical medicine & rehabilitation*, 58(3), 115-130.
 36. Musiyenko, O., Chopyk, R., & Kizlo, N. (2020). Influence of adaptive physical education on motor possibilities, behavior and quality of life of children with autism. *Health, Sport, Rehabilitation*, 6(2), 41–49. <https://doi.org/10.34142/HSR.2020.06.02.04>
 37. Narici, M. V., Roi, G. S., Landoni, L., Minetti, A. E., & Cerretelli, P. (1989). Changes in force, cross-sectional area and neural activation during strength training and detraining of the human quadriceps. *European journal of applied physiology and occupational physiology*, 59, 310-319.
 38. Newell, K. M. (2020). What are fundamental motor skills and what is fundamental about them? *Journal of Motor Learning and Development*, 8(2), 280-314. DOI:
 39. Ohtani, N., Kitagawa, K., Mikami, K., Kitawaki, K., Akiyama, J., Fuchikami, M., ... & Ohta, M. (2017). Horseback riding improves the ability to cause the appropriate action (go reaction) and the appropriate self-control (no-go reaction) in children. *Frontiers in Public Health*, 5, 8.
 40. Pan, C. Y. (2008). School time physical activity of students with and without autism spectrum disorders during PE and recess. *Adapted Physical Activity Quarterly*, 25(4), 308-321.
 41. Pan, C. Y., & Frey, G. C. (2006). Physical activity for children with autism spectrum disorders: A review of the literature. *Journal of Autism and Developmental Disorders*, 36(4), 549-563. <https://doi.org/10.1007/s10803-006-0150-4>
 42. Pope, Z. C., Fautsch, K., Zeng, N., & Gao, Z. (2019). Comparison of exergaming and adaptive physical education on physical activity, on-task behavior, and communication in children with autism spectrum disorder. *eJRIEPS. Ejournal de la recherche sur l'intervention en éducation physique et sport*, (Hors-série N° 3).
 43. Ranieri, A., Mennitti, C., Falcone, N., La Monica, I., Di Iorio, M. R., Tripodi, L., Gentile, A., Vitale, M., Pero, R., Pastore, L., D'Argenio, V., Scudiero, O., & Lombardo, B. (2023). Positive effects of physical activity in autism spectrum disorder: how influences behavior, metabolic disorder and gut microbiota. *Frontiers in psychiatry*, 14, 1238797. <https://doi.org/10.3389/fpsyt.2023.1238797>
 44. Roşca, A. M., Rusu, L., Marin, M. I., Ene Voiculescu, V., & Ene Voiculescu, C. (2022). Physical activity design for balance rehabilitation in children with autism spectrum disorder. *Children*, 9(8), 1152.
 45. 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.
 46. Shahane, V., Kilyk, A., & Srinivasan, S. M. (2024). Effects of physical activity and exercise-based interventions in young adults with autism spectrum disorder: A systematic review. *Autism: the international journal of research and practice*, 28(2), 276–300. <https://doi.org/10.1177/13623613231169058>
 47. Shahnaz, S., Kateb, M. Y., Doyle-Baker, P., & Hassani, F. (2023). Physical activity for children with autism spectrum disorder during COVID-19 pandemic. *International Journal of Developmental Disabilities*, 69(4), 467-471.
 48. Sports Anatomy. (2013). Editorial Group of Sports Anatomy. Beijing: Beijing Sport University Press.
 49. Stergiou, A., Tzoufi, M., Ntzani, E., Varvarousis, D., Beris, A., & Ploumis, A. (2017). Therapeutic effects of horseback riding interventions: a systematic review and meta-analysis. *American journal of physical medicine & rehabilitation*, 96(10), 717-725.
 50. Stevenson, J. L., Lindley, C. E., & Murlo, N. (2017). Retrospectively assessed early motor and current pragmatic language skills in autistic and neurotypical children. *Perceptual and motor skills*, 124(4), 777-794.
 51. Winnick, J. P., & Porretta, D. L. (2016). *Adapted physical education and sport*. Human Kinetics.
 52. Wu, Y., Ding, L., Zhang, Q., Dong, Y., Tao, C., Li, Z., ... & Lu, L. (2024). The effect of physical exercise therapy on autism spectrum disorder: a systematic review and meta-analysis. *Psychiatry Research*, 116074.
 53. Yang, Y. F., & Du, Y. S. (2020). *Guidance on Rehabilitation Training for Children with Autism Spectrum Disorder*. Beijing: People's Medical Publishing House.