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EFFECTS OF PILATES TRAINING VERSUS BALANCE PROPRIOCEPTION EXERCISES ON LOWER EXTREMITY FUNCTION IN CHILDREN WITH HEARING IMPAIRMENT

Original Research

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ABSTRACT

Background: Hearing impairment, defined as partial or complete loss of hearing ability, affects not only auditory function but also balance and motor coordination, particularly in children. The disruption of vestibular input linked with hearing loss can compromise postural control and lower extremity function. Rehabilitation strategies such as Pilates and balance proprioception exercises have gained attention for their role in enhancing neuromuscular control and improving functional outcomes in pediatric populations with sensory deficits.

Objective: To examine and compare the effects of Pilates training and balance proprioception exercises on lower extremity function in children with hearing impairment.

Methods: This randomized clinical trial included 30 children aged 6 to 12 years diagnosed with hearing impairment. Participants were randomly assigned into two equal groups (n=15 each). Group 1 underwent Pilates training, while Group 2 received balance proprioception exercises. Both interventions were delivered over a six-week period, with three sessions per week. Outcome measures included the Pediatric Balance Scale (PBS) and the Lower Extremity Functional Scale (LEFS), recorded pre- and post-intervention. Data were analyzed using SPSS version 25, applying paired and independent sample t-tests. Statistical significance was set at $p \leq 0.05$.

Results: Group 1 (Pilates) showed significant improvement in PBS from 28.466 ± 7.347 to 39.933 ± 10.257 ($p = 0.000$), and LEFS from 37.533 ± 2.445 to 47.733 ± 5.063 ($p = 0.000$). Group 2 (Balance Proprioception) also improved in PBS from 26.933 ± 5.344 to 29.800 ± 4.813 ($p = 0.001$), and LEFS from 38.200 ± 2.210 to 47.333 ± 4.546 ($p = 0.001$). Between-group comparison showed Pilates was significantly more effective ($p < 0.001$).

Conclusion: Both interventions improved lower extremity function and balance in children with hearing impairment; however, Pilates training demonstrated superior outcomes, supporting its use as an effective rehabilitation approach in pediatric care.

Keywords: Balance training, Hearing loss, Lower extremity function, Pediatric rehabilitation, Pilates, Proprioception, Randomized controlled trial.

INTRODUCTION

Hearing impairment, whether partial or complete, presents a significant challenge in early childhood development, particularly when it results from sensorineural causes. Approximately 1 in 8 newborns are affected by permanent sensorineural hearing loss, with increased prevalence among premature and special care infants (1). Many of these cases are attributed to hereditary factors or congenital infections, most notably cytomegalovirus (CMV), which is often misdiagnosed due to its symptomatic resemblance to the common cold. CMV is widespread, with around 60% of the population estimated to be exposed to it during their lifetime (2). Among children with early-onset irreversible hearing loss, neural hearing impairment constitutes about 10% of cases, often associated with prematurity and other perinatal complications rather than inherited disorders (3). As children grow, the prevalence of persistent hearing loss doubles, rising from about 3% at birth to 6% in later childhood (4). A substantial number of children with sensorineural hearing loss (SNHL)—around 70%—experience disturbances in their vestibular system, and 20–40% suffer from severe bilateral vestibular loss (5). Such vestibular dysfunction can interfere with postural control, motor coordination, and cognitive development if left unaddressed. Balance, a crucial component of physical function, depends on the integration of multiple sensory systems including vision, somatosensory input, vestibular function, and hearing (6). Disruptions in these systems may lead to balance problems characterized by postural instability, increased risk of falling, or vestibular deficits (7). Vestibular reflexes such as the vestibulo-spinal and vestibulo-collic reflexes are essential for postural maintenance, while the vestibulo-ocular reflex (VOR) stabilizes vision during movement (5,7). Moreover, hearing loss has been associated with decreased gait speed, which may be further compromised by cognitive strain, physical dysfunction, and social isolation.

Physiotherapeutic interventions targeting balance impairments have shown promise in managing these deficits. Exercise-based rehabilitation—including Pilates and proprioceptive training—has been widely recommended for improving motor function, balance, and emotional well-being in children with disabilities. Participation in structured physical activity encourages long-term healthy lifestyles and positively affects mental health outcomes, particularly in populations vulnerable to sedentary behavior due to technological engagement or physical limitations (8). Among various rehabilitation strategies, Pilates has gained attention for its capacity to enhance core strength, joint mobility, postural control, and balance. Originating from Joseph Pilates' rehabilitation work during World War I, the method emphasizes control, precision, flow, and breath, and has evolved into both mat-based and equipment-supported formats (9). The technique is now increasingly integrated into therapeutic protocols for musculoskeletal conditions and neurodevelopmental impairments, including those associated with hearing loss (9,10). Proprioception, the body's ability to sense movement, position, and resistance, is a fundamental component of balance and motor control. It relies on input from joint receptors, muscle spindles, and Golgi tendon organs to generate sensory feedback for dynamic stabilization (11). In young children—particularly those under the age of six—proprioceptive development is rapid, and deficiencies can severely hinder motor skill acquisition (12). Proprioceptive training has demonstrated significant benefits in enhancing joint stability, postural alignment, and response timing, with some studies reporting marked improvements in as little as five weeks (13). These findings underscore the relevance of targeted interventions to support neuromuscular development and overall function in children with hearing impairment.

Given the documented interdependence of auditory, vestibular, and proprioceptive systems, there is a compelling rationale to explore integrated therapeutic approaches for children with hearing loss. This study aims to evaluate the effects of Pilates and balance proprioception exercises on postural control, motor coordination, and functional health outcomes in this population. The objective is to contribute to evidence-based practice by determining whether these interventions can enhance physical and cognitive development in children with hearing impairments, ultimately supporting more effective, holistic rehabilitation strategies.

METHODS

This study utilized a randomized comparative experimental design to investigate the effects of Pilates training and balance proprioception exercises on balance and lower extremity function in children with hearing impairment. A total of 34 pediatric participants were initially screened for eligibility based on clearly defined inclusion and exclusion criteria. The inclusion criteria encompassed children aged 6 to 12 years with a confirmed diagnosis of hearing impairment, the ability to follow simple instructions, and medical clearance to participate in physical activity. Exclusion criteria included the presence of additional neurological or orthopedic conditions,

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uncorrected visual impairments, or any contraindications to exercise. Following the screening process, four participants were excluded for not meeting the inclusion criteria, resulting in a final sample of 30 children. Participants were randomly assigned into two intervention groups using simple randomization. Group 1 received Pilates training (PT), and Group 2 received balance proprioception exercises (BPE). The intervention was delivered over a structured program lasting six weeks, with sessions conducted three times per week. Each session lasted approximately 45 minutes and was supervised by a qualified pediatric physiotherapist. The Pilates training program focused on core stability, postural alignment, controlled breathing, and muscle flexibility, whereas the balance proprioception program emphasized neuromuscular coordination, joint stabilization, and dynamic balance tasks appropriate for the age group.

Ethical approval for the study was granted by the institutional ethical review board, and informed written consent was obtained from the parents or legal guardians of all participants. Assent was also taken from the children when appropriate, in accordance with ethical standards outlined in the Declaration of Helsinki. Standardized outcome measures were used for pre- and post-intervention assessment. These included the Pediatric Balance Scale (PBS) and the Lower Extremity Functional Scale (LEFS), both of which are validated tools for assessing balance and functional mobility in pediatric populations. Data collection was conducted at baseline and immediately following the completion of the six-week intervention period. Data were analyzed using IBM SPSS Statistics version 25. Descriptive statistics were used to report demographic variables including age and gender. The Shapiro-Wilk test was applied to assess the normality of continuous variables. For variables found to be normally distributed, paired sample t-tests were used to compare pre- and post-intervention scores within each group, while independent sample t-tests were applied to evaluate post-intervention differences between the two groups. Statistical significance was set at $p \leq 0.05$ for all analyses.

RESULTS

The results revealed that each intervention group comprised 15 participants. Group 1, which underwent Pilates training, included eight males (53.33%) and seven females (46.66%). Group 2, which received balance proprioception exercises, included nine males (60%) and six females (40%). To assess the distribution of the data, the Shapiro-Wilk test for normality was conducted. The p-values for all variables—Pre-PBS ($p = 0.448$), Post-PBS ($p = 0.059$), Pre-LEFS ($p = 0.148$), and Post-LEFS ($p = 0.078$)—were greater than 0.05, indicating that the data were normally distributed. As a result, parametric tests were deemed appropriate for further statistical analysis. In the within-group analysis for the Pilates training group, the mean score on the Pediatric Balance Scale (PBS) increased from 28.466 ± 7.347 pre-intervention to 39.933 ± 10.257 post-intervention, demonstrating a statistically significant improvement ($p = 0.000$). Similarly, the Lower Extremity Functional Scale (LEFS) improved from a pre-intervention mean of 37.533 ± 2.445 to a post-intervention mean of 47.733 ± 5.063, also yielding a statistically significant result ($p = 0.000$).

In the balance proprioception exercise group, PBS scores increased from 26.933 ± 5.344 at baseline to 29.800 ± 4.813 post-intervention, with a significant p-value of 0.001. LEFS scores in this group improved from 38.200 ± 2.210 to 47.333 ± 4.546, with statistical significance achieved ($p = 0.001$). Between-group comparisons post-intervention showed that the Pilates group outperformed the balance proprioception group. The mean post-intervention PBS score was 39.933 ± 10.257 in the Pilates group versus 29.800 ± 4.813 in the balance proprioception group ($p = 0.001$). Similarly, the post-intervention LEFS score was slightly higher in the Pilates group (47.733 ± 5.063) compared to the balance proprioception group (47.333 ± 4.546), with a p-value of 0.001, indicating statistically significant differences. The gender-specific analysis revealed consistent improvements in both balance and lower extremity function across all subgroups, with notable variations in the magnitude of change. In the Pilates training group, male participants exhibited a greater increase in Pediatric Balance Scale (PBS) scores, improving from a mean of 28.36 to 39.83, while females improved from 27.94 to 38.91. Similarly, in the Lower Extremity Functional Scale (LEFS), males progressed from 37.51 to 47.75, compared to females who improved from 37.29 to 47.29. In the balance proprioception exercise group, male participants' PBS scores increased from 26.80 to 29.80 and LEFS from 38.16 to 47.33. Female participants in this group showed a comparable trend, with PBS improving from 26.52 to 29.30 and LEFS from 38.10 to 47.22. These findings suggest that while both genders benefitted from their respective interventions, male participants, particularly in the Pilates group, demonstrated slightly greater functional gains in both balance and lower limb performance.

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Table 1 Demographic Characteristics by Group and Gender

Group	Gender	Frequency	Percentage (%)	Age Mean	Age SD
Pilates (PT)	Male	8	53.33	1.6	0.507
Pilates (PT)	Female	7	46.66	1.6	0.507
BPE	Male	9	60	1.4	0.507
BPE	Female	6	40	1.4	0.507
Total	Male	15	50		
Total	Female	15	50		

Table 2 Test of Normality

	Shapiro-Wilk		
	Statistic	Df	Sig.
Pre PBS	0.966	30	0.448
Post PBS	0.921	30	0.059
Pre LEFS	0.834	30	0.148
Post LEFS	0.875	30	.0.078

Table 3 PBS and LEFS within group Comparison (Paired Sample t-test)

Pre-Post of Paired Sample t-test Values of Scales		
Group 1- PT		
	Mean ± SD	P-Value
Pre-PBS	28.466 ±7.347	0.021
Post-PBS	39.933 ± 10.257	0.000
Pre-LEFS	37.533 ± 2.445	0.031
Post-LEFS	47.733 ± 5.063	0.000

Table 4 PBS and LEFS within group Comparison (Paired Sample t-test)

Pre-Post of Paired Sample T-Test Values of Scales		
Group 2- BPE		
	Mean ± SD	P-Value
Pre-PBS	26.933 ± 5.344	0.002
Post-PBS	29.800 ± 4.813	0.001
Pre-LEFS	38.200 ± 2.210	0.003
Post-LEFS	47.333 ± 4.546	0.001

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Table 5 PBS and LEFS across groups Comparison (Independent Sample t-test)

	Mean ± S.D Group PT	Mean ± S.D Group BPE
Post PBS	39.933 ± 10.257	29.800 ± 4.813
Post LEFS	47.733 ± 5.063	47.333 ± 4.546
P-value PBS	0.000	0.001
P-value LEFS	0.000	0.001

Table 6 Gender-Specific Mean Scores for PBS and LEFS Pre- and Post-Intervention by Group

Group	Gender	Pre-PBS	Post-PBS	Pre-LEFS	Post-LEFS
BPE	Female	26.52	29.3	38.1	47.22
BPE	Male	26.8	29.8	38.16	47.33
Pilates	Female	27.94	38.91	37.29	47.29
Pilates	Male	28.36	39.83	37.51	47.75

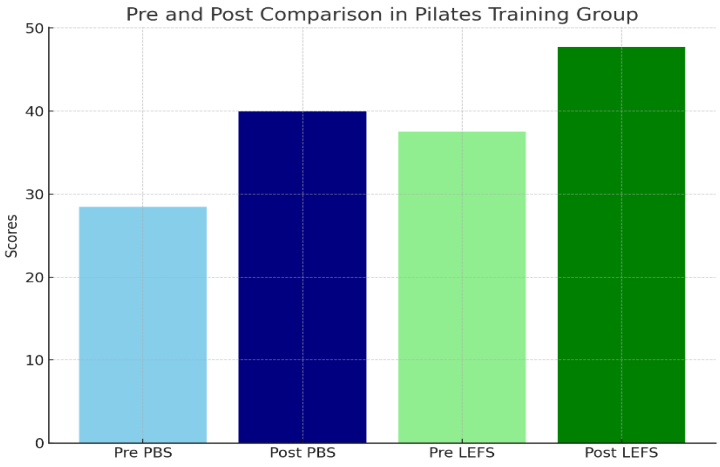

Figure 2 Pre and Post Comparison in Pilates Training Group

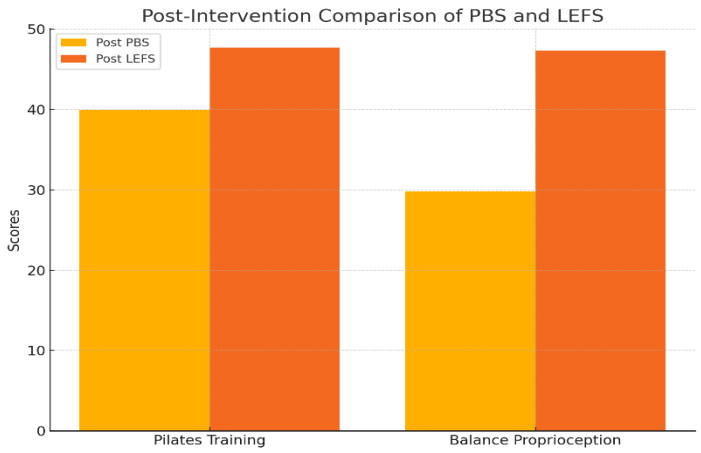

Figure 1 Post-Intervention Comparison of PBS and LEFS

DISCUSSION

The present study aimed to evaluate the comparative effectiveness of Pilates training and balance proprioception exercises in improving lower extremity function and balance among children with hearing impairment. A total of 30 participants were equally distributed into two intervention groups, and both interventions were administered over six weeks. The analysis revealed significant improvements in both groups; however, the group receiving Pilates training exhibited more pronounced functional gains, particularly in Pediatric Balance Scale (PBS) and Lower Extremity Functional Scale (LEFS) scores. Pilates, being an engaging and structured physical exercise method, appeared to offer superior benefits in enhancing balance and lower extremity strength in this population. These findings align with previous literature reporting that Pilates-based interventions significantly improve motor coordination and postural stability in children with sensorimotor deficits (14). The structured nature of Pilates, emphasizing core strength, controlled movement, and flexibility, possibly underpins its greater impact on functional outcomes compared to traditional balance proprioception exercises. Physical activity has consistently been shown to support balance development in children with hearing loss, particularly in the 5–14-year age group, with structured exercise routines facilitating greater neuromuscular adaptations (15).

The within-group improvement in the Pilates cohort was statistically significant, as evidenced by the marked increase in PBS and LEFS scores. This reinforces prior research demonstrating the sustained benefits of Pilates in pediatric rehabilitation, especially when applied in consistent sessions over several weeks. Interventions involving Pilates have been associated with improvements not only during the

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training period but also in post-detraining phases, suggesting longer-term retention of physical gains (16). Furthermore, the enjoyable and interactive nature of Pilates may have contributed to greater compliance and engagement among the children, further amplifying the treatment outcomes (17). Functional gains observed in this study are consistent with historical evidence that short-term Pilates programs can produce substantial enhancements in dynamic balance and motor control in hearing-impaired children (18). The balance proprioception group also demonstrated significant improvements in both PBS and LEFS scores, confirming the value of neuromuscular training in this population. Proprioceptive and balance-based training has been recognized for its positive influence on motor coordination, agility, and joint stability, with specific benefits in pediatric populations suffering from sensory impairments (19,20). The observed outcomes support the premise that regular proprioceptive engagement can stimulate neural pathways responsible for postural control and functional mobility.

Despite the promising findings, the study had limitations that warrant acknowledgment. The relatively small sample size may restrict the generalizability of results to broader populations. The short duration of the intervention, limited to six weeks, may not fully capture the long-term retention or sustainability of therapeutic gains. Moreover, age-specific analysis was not comprehensively integrated into the main outcomes, which may have provided additional insights into the age-related responsiveness to different interventions. Future research should consider stratifying results by age and including a follow-up phase to evaluate the persistence of functional improvements. Nonetheless, the study's strengths lie in its methodological clarity, standardized outcome measures, and comparative analysis of two widely used physiotherapeutic techniques. The integration of validated tools such as PBS and LEFS, and the use of parametric statistical methods based on confirmed data normality, added to the reliability of the findings. The outcomes reinforce the clinical value of structured physical interventions in addressing motor impairments associated with hearing loss and highlight Pilates as a promising modality in pediatric rehabilitation.

For future studies, incorporating larger, multi-centered samples, extended intervention durations, and a focus on age-specific outcomes will enhance the robustness of the evidence base. Further exploration into the neurophysiological mechanisms underpinning the effects of Pilates and balance exercises could also offer deeper insight into optimizing therapeutic strategies for children with sensory-motor deficits.

CONCLUSION

This study concluded that both Pilates training and balance proprioception exercises were effective in improving lower extremity function and balance in children with hearing impairment. However, Pilates training demonstrated greater efficacy in enhancing postural control and functional mobility. The findings highlight the practical value of integrating structured and engaging interventions like Pilates into pediatric rehabilitation programs for this population. By promoting motor development and physical independence, such interventions can significantly contribute to the overall well-being and quality of life of children with hearing loss.

Author Contribution

Author	Contribution
M Behzad Ali*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Iqra Khan	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Aqsa Lakhani	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Syeda Nayab Raza	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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Omair Khan	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Aiman Arif	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Minahil Butt	Contributed to study concept and Data collection Has given Final Approval of the version to be published
Adnan Hashim	Writing - Review & Editing, Assistance with Data Curation

REFERENCES

1. Carpenter MG, Campos JL. The Effects of Hearing Loss on Balance: A Critical Review. Ear Hear. 2020;41 Suppl 1:107s-19s.
2. Ertugrul G, Sennaroglu G, Sennaroglu L. Postural Control in Subjects with Incomplete Partition Inner Ear Malformations: A Comparison of Incomplete Partition Types. ORL J Otorhinolaryngol Relat Spec. 2022;84(1):47-54.
3. Melo RS, Lemos A, Raposo MCF, Monteiro MG, Lambertz D, Ferraz KM. Repercussions of the Degrees of Hearing Loss and Vestibular Dysfunction on the Static Balance of Children With Sensorineural Hearing Loss. Phys Ther. 2021;101(10).
4. Kamel RM, Mehrem ES, Mounir SM, Essa MM, Fergany LA, Elbedewy MA. Sensorineural hearing loss imprint on fine motor skills: A pediatric and adolescent innovative study. NeuroRehabilitation. 2021;48(3):285-92.
5. Mehrem E, Khaireldin A, Essa M, Gad Allah M, Lobbos B, Kamel R. Sensorineural hearing loss imprint on postural control: A pediatric and adolescent innovative study. NeuroRehabilitation. 2023;53(3):377-84.
6. Yigit O, Aksoy S, Akyol U, Tokatlı A, Sivri HS. Sensory, voluntary, and motor postural control in children and adolescents with mucopolysaccharidosis. J Pediatr Endocrinol Metab. 2021;34(5):583-9.
7. Singh A, Heet H, Guggenheim DS, Lim M, Garg B, Bao M, et al. A Systematic Review on the Association Between Vestibular Dysfunction and Balance Performance in Children With Hearing Loss. Ear Hear. 2022;43(3):712-21.
8. Melo RS, Lemos A, Delgado A, Raposo MCF, Ferraz KM, Belian RB. Use of Virtual Reality-Based Games to Improve Balance and Gait of Children and Adolescents with Sensorineural Hearing Loss: A Systematic Review and Meta-Analysis. Sensors (Basel). 2023;23(14).
9. Chisari D, Vitkovic J, Clark R, Rance G. Vestibular function and balance performance in children with sensorineural hearing loss. Int J Audiol. 2024;63(11):875-83.
10. Wiener-Vacher SR, Campi M, Caldani S, Thai-Van H. Vestibular Impairment and Postural Development in Children With Bilateral Profound Hearing Loss. JAMA Netw Open. 2024;7(5):e2412846.
11. Pinninti S, Christy J, Almutairi A, Cochrane G, Fowler KB, Boppana S. Vestibular, Gaze, and Balance Disorders in Asymptomatic Congenital Cytomegalovirus Infection. Pediatrics. 2021;147(2).
12. Zhou Y, Qi J. Effectiveness of Interventions on Improving Balance in Children and Adolescents With Hearing Impairment: A Systematic Review. Frontiers in Physiology. 2022;13:876974.
13. Mahafza MT, Wilson WJ, Brauer S, Timmer BH, Hickson L. A systematic review of the effect of hearing aids on static and dynamic balance in adults with hearing impairment. Trends in hearing. 2022;26:23312165221121014.
14. Sözen H, Arı E. A Study on The Visual Reaction Times of Hearing-Impaired Adolescents. International Journal of Applied Exercise Physiology. 2020;9(3):246-53.
15. Cibinello FU, de Jesus Neves JC, Valenciano PJ, Fujisawa DS, Camillo CAM. Effects of Pilates in children and adolescents–A systematic review and meta-analysis. Journal of Bodywork and Movement Therapies. 2023.
16. Hornsby E, Johnston LM. Effect of Pilates intervention on physical function of children and youth: a systematic review. Archives of physical medicine and rehabilitation. 2020;101(2):317-28.
17. Zarei H, Norasteh AA. Effects of proprioception and core stability training followed by detraining on balance performance in deaf male students: a three-arm randomized controlled trial. Somatosensory & Motor Research. 2023;40(2):47-55.
18. Ozturk N, Unver F. The effects of pilates on posture and physical fitness parameters in 5–6 years old children: A non-randomized controlled study. Journal of Bodywork and Movement Therapies. 2022;31:153-8.

19. Usama M, Abdelaziem F, Rashed WM, Maher E, El Beltagy M, Zekri W. Impact of physical activity on postural stability and coordination in children with posterior fossa tumor: randomized control phase III trial. Journal of Cancer Research and Clinical Oncology. 2022:1-8.
20. Ma Y, Wang L, Li M, Wang T. Meta-analysis of the effects of exercise programs in improving the balance ability of children with intellectual disabilities. Journal of Intellectual & Developmental Disability. 2020;45(2):144-54.