ORIGINAL ARTICLE

Effect of an Auditory Temporal Training Program on Speech Fluency of Children with Developmental Stuttering

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Abstract

Objectives

The present study aims to investigate the effect of a temporal processing-based auditory training program on alleviating stuttering severity in children diagnosed with auditory temporal processing disorders.

Materials & Methods

Thirty-one children with stuttering diagnosed with auditory temporal processing disorders participated in this study (intervention group: 17 participants between seven to 12 years old; control group: 14 participants between eight to 12 years old). The auditory temporal processing test and Stuttering Severity Instrument-3 (SSI-3) were examined before/after 12 sessions (nearly 540 minutes) of training and three months following the conclusion of the intervention.

Results

According to the results, auditory temporal processing improved significantly in the intervention group after temporal processing-based auditory training. Besides, the differences between the intervention and control groups were significant ($P<0.05$). The improvement of auditory temporal processing skills remained stable in the post-training evaluation after three months ($P>0.05$). Although the SSI-3 score was somewhat improved in the intervention group, no significant difference was found between the two groups ($P=0.984$).

Conclusion

The findings revealed that auditory temporal processing training acted as a complementary therapy alleviating the stuttering severity

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of children who stutter with auditory temporal processing disorders to some extent.

Keywords: Auditory training; Auditory temporal training; Auditory processing disorder; Developmental stuttering;; Timing

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Introduction

Stuttering is a well-known speech fluency disorder with primary symptoms such as involuntary and abnormal repetitions and prolongations of sounds, syllables, words, phrases, and silent pauses that disrupt the rhythmic flow of speech(1). With a prevalence rate of 2-5%, this disorder emerges mainly at 3-6 years of age nearby 1% of this population will continue to have persistent stuttering until adulthood (2). Stuttering is neurodevelopmentally (3), associated with several factors(4). Numerous studies and theories point to defective neural centers for speech control, auditory processing disorders, genetic and language impairments, and other cognitive, emotional, and social processing as the underlying causes of stuttering (5).

Currently, the basic neurogenic knowledge of stuttering is not directly linked with clinical programs(6). More promising and effective management and treatment of stuttering appear to be more logically rooted in its potential neural mechanisms (6, 7). Several studies and theories highlight the auditory system, its associated processing, and its roles, which might be the structures linked with this disorder (8).

The role of auditory processing in speech production and control must be considered to explain how it is related to stuttering. For this reason, stuttering is a production disorder, seemingly caused by defective speech control. People who stutter (PWS) suffer from aberrant auditory-motor integration. Evidence suggests that timing deficits cause sensory-motor mismatches(9, 10). Howell *et al.* (2000) reported an auditory temporal processing deficit in CWS and mentioned a correlation between backward masking (BM) thresholds and percent words stuttered (%WS) in primary school CWS (8). Proposedly, the primary defect in CWS was associated with their inability to perceive temporal patterns of sound sequences. This skill lays the foundation for rhythm processing, speech production, and comprehension(10).

The therapeutic methods proposed by speech-language pathologists (SLPs) for children who stutter(CWS) are centered around two principles: 1) an indirect method underlining the roles of attitude, environmental manipulation, and correction of verbal and non-verbal behavior of those in the patient's circle, and 2) a direct method emphasizing the treatment of the primary symptoms of stuttering itself (4). Other treatments offer an integrated approach derived from these two principles. Despite the abundance of stuttering rehabilitation and management methods for all ages, no consensus has yet been reached among the experts on the optimal method, with some shown to be ineffective (4).

The stuttering rehabilitation process lasts longer during school age than in earlier years and is less effective through conventional rehabilitation methods. Furthermore, this disorder adversely impacts a child's education, social interactions, and excitement at this age compared with other stages of life. Accordingly, developing and introducing more effective rehabilitation methods should represent a priority in research on stuttering, particularly concerning school-age children(11).

Recent studies in neuroscience indicated that the central auditory nervous system (CANS) exhibits a remarkable degree of plasticity, enabling the enhancement of auditory temporal processing (ATP) skills through rehabilitation and training (12, 13). Auditory training, expressly from a temporal perspective deemed a contributing factor in stuttering, has been neglected in therapeutic approaches to stuttering. Nevertheless, a review of the available literature failed to reveal any relevant research on CWS. According to this research's hypothesis, auditory temporal training may alleviate stuttering severity in CWS diagnosed with ATP disorders. Accordingly, this study aimed to evaluate the effectiveness of an auditory training program based on temporal processing in a group of CWS with auditory temporal processing disorder.

Materials & Methods

2.1. Participants

In this study, thirty-four CWS were selected from private speech therapy centers and the Children's Medical Center hospital in Tehran, Iran, through convenience sampling based on the inclusion criteria. Inclusion criteria: 1. Being aged 7-12 years old; 2. Being diagnosed with stuttering by an experienced SLP working in the specified centers and SSI-3 scores of ≥ 8; 3. Pure-tone air-and bone-conduction audiometry thresholds within 500 to 4000 Hz in the normal range of ≤ 15 dB HL; 4. Typical otoscopic results; 5. Average scores on the Wechsler Intelligence Scale for Children, Fourth Edition (14), administered by a psychologist (≥ 85); 6. Right-handedness (evaluated by the Edinburgh Handedness Inventory) (15); 7. Abnormal scores, *i.e.*, two standard deviations away from normalcy, in at least two ATP tests(16); 8. Speaking Persian as the native language; 9. Lack of a history of medication use, neurological and psychological disorders, traumatic brain injury, ear surgeries and disorders based on self-reports, learning or linguistic disorders according to expert opinions of an SLP, and ADHD as diagnosed by a psychiatrist; 10. Lack of engagement in cognitive activities such as music; 11. Lack of a history of auditory training; 12. Suffer from developmental stuttering before school age as diagnosed by an experienced SLP.

Exclusion criteria included 1. Loss of entry conditions, 2. The unwillingness of the individual or parents to cooperate at any research stage, and 3. Incomplete completion of rehabilitation courses for any reason.

2.2. Procedure

The research procedure was first explained thoroughly to children and their parents. The participants were then enrolled in the study after completing informed consent forms and confirming their correspondence with the inclusion criteria. They were allowed to leave the research at any time. All children were screened for peripheral hearing, and all tests were conducted in a soundproof room with a background noise level of less than 30 dB. ATP test materials were delivered using laptops and Sennheiser HD 202 headphones. Besides, stimulus intensity levels were calibrated using a Brüel & Kjær (B&K) 2250 L sound level meter and B&K Type 4153 artificial ears (Denmark) connected to the scale or adapter of the circumaural headphones. The scores of ATP tests and Riley's SSI-3 were used for pre-and post-training evaluations.

2.2.1. Dysfluency Evaluation

An interview of almost 20-minute length involving reading and spontaneous speech (storytelling) tasks with a minimum of 200 syllables was recorded from each child to evaluate speech dysfluency. Furthermore, any accompanying physical behavior was recorded separately by the two testers. This interview evaluated frequency, stuttering, and secondary and physical behavior. Scoring was then performed according to Riley's (1994) guidelines (17). Evaluatingand scoring were done by an experienced speech and language pathologist and a trained assistant student with a master's degree.

2.2.2. ATP Tests

2.2.2.1. Backward masking test

In this test, the listener should detect a tonal stimulus delivered immediately before a masking noise at various intensity levels from suprathreshold to threshold. Stimuli were presented monaurally in the right ear using the 3-interval alternative forced choice (3IAFC) paradigm(18, 19). Each task involved three stimuli with 800-msec interstimulus intervals, including two 300-msec noise-burst stimuli and a random tone-noise (the target signal) stimulus(18). The examinee was required to select the target stimulus from three choices corresponding to cards 1, 2, and 3. The adaptive two-down, one-up procedure with 2-dB steps was used for threshold determination and estimating the 71% correct point on the psychometric function. Thresholds were estimated by averaging the last four out of ten reversals. Threshold determination was repeated twice when the threshold discrepancies exceeded 2 dB. The mean value of three evaluations was deemed the final threshold (18).

2.2.2.2. Duration pattern test:

This test involved a set of patterns made up of three 1000-Hz tones of 250-msec (short) and 500-msec (long) durations. It was performed monaurally with a stimulus delivery level of 50 dB HL or 70 dB SPL(20).

2.2.2.3. Gap-In-Noise Test

This test consisted of several 6-second segments of broadband (white) noise. Each segment contains 0-3 silent intervals, *i.e.*, gaps. The interstimulus interval between successive segments lasted five seconds, and the gap durations were 2, 3, 4, 5, 6, 8, 10, 12, 15, and 20 msec. This test has two measurement criteria: 1. the approximate threshold is defined as the shortest gap duration in which the examinee gives four out of six correct responses, and 2. the percentage of correct responses out of the total number of gaps. Stimuli were presented monaurally. This test included four lists randomly presented to each ear (21).

2.2.3. Intervention

The participants were divided equally into the intervention and control groups (17 participants in each group) using the randomized block design. Out of the thirty-four CWS assigned randomly to two groups of 17 participants, three in the control group were excluded from the study because of a change in the primary residence and, consequently, the treatment center. Thirty-one children (17 in the intervention group and 14 in the control group) participated in all stages of the study. The intervention and control groups received an identical conventional speech therapy program. In addition to speech therapy, the intervention group also received the auditory temporal training program. The conventional speech therapy program included the Lidcombe program, Gradual increase in length and complexity of utterance (GILCU), Light articulatory contact (LAC), Respiratory modification and easy onset (EO), and slow speech with prolongation (1).

ATP intervention was implemented in three areas: temporal resolution, temporal masking, and pattern recognition, which involved gap detection (GD), backward masking, and duration pattern practices (28, 41).

2.2.3.1. Gap Detection practices

These exercises were implemented in Angel Sound software in which broadband and narrowband noise stimuli with identical (within-channel: 1.1 kHz, 2.2 kHz) and different (between-channel: 1.2 kHz, 2.1 kHz) marker frequencies were delivered with a 300-msec duration and a 500-msec interstimulus interval. Each task involved three stimuli, among which only one target stimulus, randomly distributed among the tasks, contained different silent intervals between the two sounds. Using the adaptive two-down, one-up procedure, the silent intervals changed between 0 and 500 msec at 1, 2, 5, 10, 20, and 50-msec steps from easy to difficult, based on the children's performance(22). Children were instructed to select the target stimulus from the three stimuli by clicking on one of the three masks on the laptop screen. Visual and auditory feedback was provided following the children's responses. The exercises were presented in 30-task blocks. The score of each session was considered the basis for exercises in the following session. Stimuli were delivered to both ears at a comfortable intensity level (70 dB SPL) (22).

2.2.3.2. Backward Masking

practices The exercises were performed using the 3IAFC paradig

m. The stimuli were presented monaurally. The acoustic specifications of the stimuli were identical to those in the test, except for the target stimulus for which a tone was delivered before noise in a 50 msec interval for threshold determination (23). The overall threshold of each session was the average of three measurements and represented the basis for the initial intensity level in the following session. Various visual enhancements and verbal feedback were randomly provided in relevance to children's responses. In cases where an incorrect response was received, the correct one was shown to the children.

2.2.3.3. Duration Pattern practices

Using MATLAB R2014b, pure-tome stimuli with rise-fall times of 10 msec were delivered to both ears at a comfortable intensity level at three low- (500 Hz), mid- (1000 Hz), and high-frequency (4000 Hz) ranges in different duration patterns. The children's performance selected the exercise difficulty levels. Patterns, stimulus duration discrepancies, and interstimulus intervals were the components for changing difficulty levels. The pattern difficulty levels were altered by presenting binary pattern discrimination, followed by binary and ternary pattern recognition tasks. In each pattern, the stimuli were delivered with different duration discrepancies and interstimulus intervals at a specific frequency from easy to challenging levels. Both stimuli were of different durations in the binary pattern. In the ternary pattern, two stimuli had identical durations, whereas the other stimulus had a different duration. At each difficulty level, exercise blocks involved 20 tasks where performance criteria for 70% and 30% correct responses rendered the exercise level more complex and more manageable, respectively. Children were randomly provided with visual and verbal feedback. In cases where an incorrect response was received, the correct one was given to children (24, 25).

Equal numbers of auditory training and speech therapy sessions were available. In general, the intervention group received 12 auditory temporal training (each session was 45-minute, twice a week) and 12 speech therapy (each session was 45-minute) sessions. In contrast, the control group received merely 12 speech therapy sessions (each session was 45-minute). The ATP and stuttering severity tests were evaluated three times for all children: 1. Before treatment, 2. One session after treatment (session 13), and 3. Three months after the completion of treatment. Attempts were made to match auditory training programs in terms of training duration and number of trials so that each child in the intervention group would receive nearly 540 minutes of temporal training and a maximum of 2160 trials by the end of the auditory training. Each week, certain practices were assigned to prevent fatigue and lack of motivation in children. Children in the intervention group were rewarded after several rehabilitation sessions to encourage and maintain their motivation. Notably, an individual outside the research team evaluated the stuttering severity results. Finally, all results were compared between the intervention and control groups.

2.3. Data Analysis

Analytical procedures consisted of group-level analyses using parametric and nonparametric tests. In a preliminary analysis, the researchers made within-group comparisons using Repeated measures and the Friedman test to verify whether a difference was found between the scores of the auditory temporal processing tests and the severity of stuttering as dependent variables pre, post, and three months after the completion of treatment in the intervention and control group (see Table 2 and 3). Likewise,, the Repeated measures test was used to determine group main effect differences and interactions across time for data with normal distribution to determine whether a difference in the rate of change was found between the two groups. Accordingly, this determines whether the intervention has effectively reduced the stuttering severity and improved auditory temporal processing scores. The Mann-Whitney U test was used to evaluate the effect of the intervention on the scores with non-normal distribution. This test compared mean scores between two groups three times (pre, post, and three months after training). The significant value was adjusted based on Bonferroni correction to avoid type I error in multiple comparisons in the Mann-Whitney U test, which was $P<0.017$ (0.05/3). Statistical analyses were conducted in SPSS v. 23 (IBM, Armonk, NY, USA).

Results

Demographic data for each group are shown in (Table 1). Children in both groups had a Stuttering Severity Instrument-3 (SSI-3) range of very mild to moderate (score 8-27).

3.1. Analyzing the Effect of Auditory Temporal Training on ATP Test Scores

In this section, data related to ATP tests before, immediately, and three months after auditory temporal training are compared between the intervention and control groups.

3.1.1. Duration pattern test

Table 2 shows a significant difference between the three interventions Duration pattern tests measurement levels (Table 2). The pairwise comparison test, by considering the Bonferroni adjustment indicated that the post-training (session 13) scores of the intervention group improved remarkably (right and left ear: $P<0.001$). An improvement was also observed in the control group, albeit non-significant (right ear: P=1.0, left ear: P=0.468). The analysis of the resulting stability revealed persistent improvement in the intervention group based on the post-training evaluation after three months (right ear: P=0.005, left ear: P=0.012). No significant difference was observed in the control group's scores after three months (right ear: P=0.396, left ear: P=1.0). The between-subject primary effect test, found a significant difference between the intervention and control groups across the three measurement levels (P<0.001). The interaction of time and group was substantial (P<0.001) (Table 2).

3.1.2. Backward masking test

Table 2 illustrates a significant difference between the three measurement levels in both groups (Table 2). In the pairwise comparison test by considering Bonferroni adjustment, a significant improvement was observed in both groups in terms of backward masking test scores after the completion of treatment (intervention group: P<0.001, control group: P=0. 003), persisting up to three months after the treatment for the intervention group (P=0.067), but the scores improvement continued three months after speech therapy in the control group (P=0.022). A significant difference was seen between the two groups across the three measurement levels (P<0.001). The interaction of time and group was significant (P<0.001) (Table 2).

3.1.3. Gaps- In- Noise percent correct response

The results of the Repeated measures indicated a significant difference in the intervention group in terms of percent correct response across different measurement levels (right and left ear: P<0.001, Eta^{2} right ear=0.65 and Eta^{2} left ear=0.57). However, no significant difference was found significant difference in the control group across different measures levels (right ear: P=0.315 Eta^{2}=0.083, left ear: P=0.907 Eta^{2}=0.008) (Table 2). The pairwise comparison test showed a marked improvement in the post-training (one session after treatment) scores of the intervention group (right ear: P<0.001, left ear: P=0.004). There was no significant difference in the control group's scores before and after 12 speech therapy sessions (right and left ear: P=1.0). The post-training evaluation after three months revealed consistency in the right ear scores of the intervention group (P=0.057), but in this evaluation, the left ear scores improved significantly (P=0.037). The post-training evaluation after three months revealed consistency in the control group's scores (right ear: P=0.599, left ear: P=1.0). No significant difference was found between the two groups across the three measurement levels (right ear: P=0.087, left ear: P=0.065). The interaction of time and group was significant (right ear = 0.002, left ear=0.001) (Table 2).

3.1.4. Gaps- In- Noise threshold

A Friedman test showed a significant difference between thresholds measured before auditory temporal training, one session, and three months after auditory temporal training in the intervention group (Right ear: $_{f}(2)$=18.375, P<0.001, Kendall's= 0.54 and left ear: $_{f}(2)$=19.818, P<0.001, Kendall's= 0.58) and a non-significant difference in the control group (right ear: $_{f}$ (2) =1.00, P=0.607, Kendall's= 0.036 and left ear$_{f}$ (2) =1.75, P=0.417, Kendall's= 0.063) (Table 3). Post hoc tests using a pairwise comparison test showed that the scores of session 13 were significantly better than the pre-training in the intervention group (Right ear: P=0.014, left ear: P=0.011). No significant difference was observed between the scores of session 13 and three months after training (Right and left ear: P=1.0), and the difference between pre and three months after the intervention was significant in the intervention group (Right ear: P=0.002, Left ear: P=0.003). Multiple comparisons were not performed for the control group because the overall tests retained the null hypothesis of no differences. The significant value was adjusted based on Bonferroni correction that was P<0.017 (0.05/3) to avoid type I error in multiple comparisons in the Mann-Whitney U test. The results of the Mann-Whitney U test revealed no significant difference between the two groups regarding right-and left-ear thresholds before (right ear: U=83.5, P=0.11, left ear: U=86.00, P=0.143) and one session after the intervention (right ear: U= 80.00, P=0.093, left-ear: U= 97.00, P=0.334). A significant difference was found between the two groups in right ear scores three months after auditory training (U=62.5, P=0.015); the intervention group's scores were better than the control group. No significant difference was observed between the two groups regarding left ear score three months after training (U= 73.00, P=0.049) (Table 3).

3.2. Analyzing the Effect of Auditory Temporal Training on Stuttering Severity

SSI-3

The results showed a significant difference between the mean SSI-3 scores of the intervention and control groups across the three measurement levels (intervention group: P=<0.001 Eta^2=0.6, control group: P=0.011 Eta^2=0.367) (Table 2). In the paired-wise comparison, a considerable improvement was observed in the scores of the intervention group one session after training sessions (P=0.001), remaining stable up to three months after the conclusion of the intervention (P=1.0). No significant difference was noticed in the control group between pre- and post-sessions (one session after treatment or session 13) (P=0.053) and between session 13 and three months after treatment (P=1.00). The difference between pre and three months after the conclusion of the training in the intervention and control group was significant (intervention group: P<0.001, control group: P=0.032), in both groups, the score of three months after training was better than pre-training (see Figure.1). No significant difference was noticed between the two groups in three consecutive values (P = 0.984). The interaction of time and group was insignificant (P= 0.346) (Table 2).

Table 1. Mean and standard deviation of age range and gender distribution in intervention and control groups

Group	Age (7-12 yrs.)	Gender
	Mean ±SD	Male Female
Intervention (n=17)	9.98 1.78	14 (82.35%) 3(17.67%)
Control (n=14)	9.75 1.42	13 (92.85%) 1(7.14%)

SD: Standard Deviation

Table 2. Repeated measures test results for Duration Pattern, Backward Masking, Percent correct responses of Gaps- In -Noise tests and SSI-3 (n= 31)

Tests	Group		Time		p-Value Time	P-Value Time*Group
		Before Mean(±SD)	Session 13 Mean(±SD)	After 3 months Mean(±SD)		
Duration Pattern (right ear)	Intervention	49.8(±7.99)	79.002(±8.79)	84.69(±8.75)	<0.001*	<0.001*
	Control	56.65(±6.12)	58.06(±9.02)	61.16(±7.58)	0.072	
Duration Pattern (left ear)	Intervention	52.32(±9.26)	76.85(±9.81)	81.75(±8.84)	<0.001*	0.001*
	Control	54.51(±11.29)	57.6 (±8.99)	59.62(±6.91)	0.065	
Backward masking	Intervention	70.003(±10.75)	46.95(±6.49)	42.06(±6.45)	<0.001*	<0.001*
	Control	64.42(±9.11)	60.8(±7.53)	57.73(±7.4)	<0.001*	
GIN percent correct response Right ear	Intervention	58.31(±8.6)	66.84(±6.64)	70.67(±6.12)	<0.001*	0.002*
	Control	60.09(±7.53)	60.21(±7.42)	62.72(±10.08)	0.315	
GIN percent correct response Left ear	Intervention	60.26(±8.03)	67.34(±5.98)	70.58(±5.86)	<0.001*	0.001*
	Control	61.29(±8.55)	61.65(±7.21)	62.12(±8.96)	0.907	
SSI-3	Intervention	18.17(±6.2)	12.64(±6.30	12.29(±5.74)	<0.001*	0.346
	Control	16.92(±6.78)	13.07(±5.85)	13.00(±4.64)	0.011*	

**p*<0.05

Table 3. Friedman and Mann-Whitney U test results for Gap-In-Noise threshold and SS% in reading (n=31)

Tests	Groups	Time			P-Value [a]
		Before Mean(±SD)	Session 13 Mean(±SD)	After 3 months Mean(±SD)	
GIN threshold (right ear)	Intervention	6.94(±1.24)	5.64(±0.78)	5.41(±0.87)	<0.001*
	Control	6.36(±0.93)	6.28(±1.26)	6.21(±1.05)	0.607
P-Value [b]		0.11	0.093	0.015	
GIN threshold (left ear)	Intervention	6.76(±1.09)	5.64(±0.78)	5.47(±0.87)	<0.001*
	Control	6.21(±1.05)	5.92(±1.07)	6.14(±1.17)	0.417
P-Value [b]		0.143	0.334	0.049	

a: based on Friedman test, b: based on Mann- Whitney U test.
* $p<0.05$

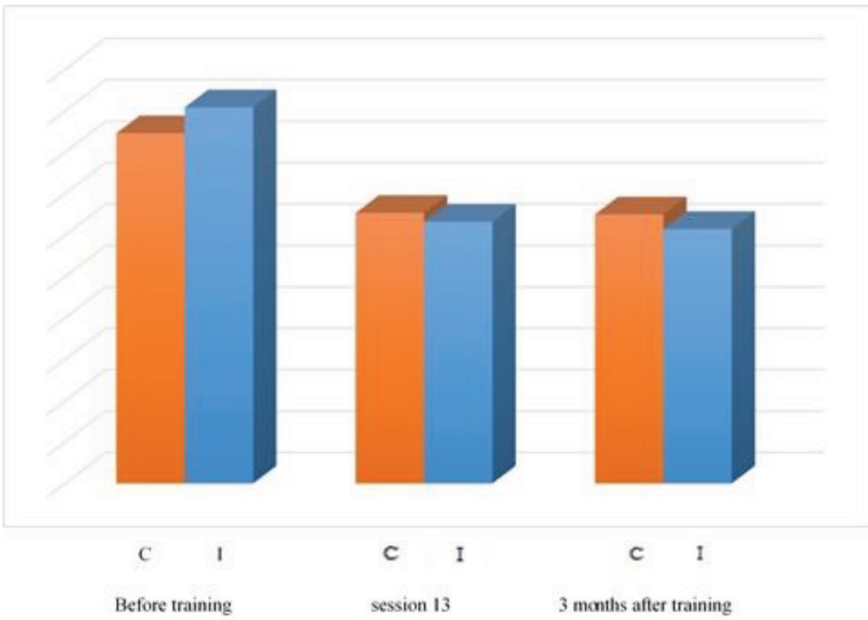

Figure 1*. Changes in SSI-3 mean scores in control and intervention groups, (C: Control group, I: Intervention group).*

Discussion

In this study, a marked improvement was noticed in the intervention group temporal processing test scores, especially in tests similar to training exercises, *i.e.*, Duration pattern and Backward masking tests, after implementing an adaptive auditory temporal training program. These changes remained stable until three months after the completion of auditory training.

A literature review failed to reveal any study on the effect of auditory training on the enhancement of processing disorders in PWS. Notably, numerous studies have addressed the significant effects of training on the enhancement of processing abilities and neuronal response characteristics in higher-level circuits of the brain, as well as the long-term stability of auditory-perceptual learning in various disorders, such as auditory processing disorders (23, 26). Tomlin and Vandali (2019) showed that a pitch training program could successfully and entirely improve temporal pattern processing defects in children suffering from this disorder. They underlined the role of deficit-specific auditory training programs in improving developmental auditory processing delay and the importance of implementing individual auditory training programs peculiar to individual processing disorders(27).

According to Moore (2007), auditory training also modifies listening ability in both the short- and long-term(28). In addition to Moore, other researchers emphasize that short-term training programs are more effective than intense ones. Similarly, long-term training programs are more practical regarding the consistency of sensory processing enhancement and generalizability (long-term programs include multi-month programs with multi-hour sessions) (28, 29).

An interesting finding of the present study was the improvement in the auditory temporal processing scores of a few children in the control group to some degree, despite their lack of a history of auditory intervention and reception of any auditory processing training (only the backward masking test scores reflected significant changes). Similarly, the stuttering severity scores of these children showed an improvement in the evaluation periods, albeit not as significant as those in the intervention group. Moore and Amitay (2007) stated that mere arousal maintenance during exercise was adequate for achieving minimum measurable learning. Such high generalizability can be materialized in any task or exercise. They concluded that auditory learning might depend significantly on non-sensory processing, such as attention, arousal, and motivation, despite the effects of learning being partially specific to the stimulus being trained (28). The improvement of auditory temporal skills in the present study is probably caused by the direct and indirect effects (due to increased arousal) of speech therapy on the performance of the auditory regions of the brain. Alam *et al.* (2014) discussed the effect of speech therapy on auditory evoked responses (AERs), including brainstem AERs, late auditory responses (ALRs), and auditory middle-latency responses (AMLRs) in PWS. They observed specific small changes towards a reduced latency and an increased amplitude of different evoked response components in several participants after three months of speech therapy; nevertheless, these changes were statistically insignificant for the most part. They maintained that a speech therapy program could potentially bring about specific changes in the auditory nervous system (30). Studies that examined the effect of auditory rehabilitation programs through electrophysiological testing reported that improved auditory performance resulting from training was manifested by reduced latencies and increased amplitudes of auditory potentials(31).

During the study, the SSI-3 scores improved in both intervention and control groups (The accompanying behaviors of both groups showed significant improvement compared to other indices of SSI-3 score). The improvement was more in the intervention group, but these changes were not statistically significant compared to the control group. The heterogeneous and multifactorial nature of stuttering may be one of the possible reasons for the insignificant changes. The post-training SSI-3 scores did not show an improvement for all children in the intervention group. This was more evident than in children with stuttering severities of very mild to mild. The SSI-3 scores of children with very mild stuttering were not different in the three evaluation periods. In their study, Beal et al. found that mild stutterers have different nervous mechanisms to compensate for their stuttering than more severe types (32). In the present study, children with milder stuttering did not significantly improve their intensity after the rehabilitation program, perhaps because they have a different mechanism for compensating for their stuttering.

The control group yielded more mixed results, with stuttering relapse observed in one child in different speech therapy periods (the SSI-3 score increased by a maximum of five points). Auditory temporal training has been somewhat effective in reducing stuttering severity. Possibly, auditory temporal training has affected speech production and control areas of the brain in specific ways. Functional magnetic resonance imaging (fMRI) studies demonstrated that a variety of temporal tasks in each sensory modality would activate a set of timing network components, including the basal nuclei and the supplementary motor area (SMA), interacting with other neural networks supporting that sense (the auditory cortex in the case of the auditory sense ((10, 33). Several studies show the positive effect of rhythmic auditory stimulation (RAS) on the speech fluency of PWS (10, 34, 35). Studies have indicated that the auditory and motor systems are connected through widely distributed neural networks, and there is a "close link between auditory areas and basal ganglia"(36). These connections are essential in internal timing and fluent speech control processes(10, 33). These findings are in line with evidence pointing to the effect of auditory temporal processing tasks and exercises (interval distinction) on motor areas (38). Wright and Sabin (2007) discussed the effect of auditory temporal processing tasks on the activities of different areas of the brain other than the auditory system, including the basal ganglia(38). The activities of the premotor cortex and cerebellar-basal ganglia connections, including the putamen, caudate, and pallidum nuclei, as well as the cortico-cerebellar network, are modified by listening to regular auditory rhythms(36). A study on the effect of rhythmic auditory stimulation (simultaneity of motor actions with specific-rhythm sounds) on Parkinson's disease and stuttering revealed that rhythmic auditory stimulation could affect the motor control abilities and internal timing defects of individuals suffering from these disorders and improve the speech fluency (34, 35). As a stimulus whose main elements consist of rhythm and auditory temporal patterns (34), music can reduce stuttering owing to its substantial impact on brain networks responsible for maintaining internal timing, motor actions, motor fluency, cognitive actions, emotional control, and stress management (39).

5. Limitations

In the present study, the findings of the auditory temporal processing and the scores of stuttering severity tests in children with developmental stuttering were compared in three stages before, after, and three months after the intervention. Initially, access to children with stuttering ranged from seven to 12 years according to inclusion criteria was challenging. Indeed, it was very morally and practically difficult to consider the control group of children with stuttering and with auditory temporal processing disorder without receiving a mentioned training program that must be examined and followed at specific and long times.

In Conclusion

According to the research results, auditory temporal processing training can partly mitigate stuttering severity in CWS suffering from auditory temporal processing disorders. Accordingly, auditory temporal training accompanied by a regular speech therapy program appears useful for stuttering children.

It is recommended to investigate the effect of auditory temporal training on reducing stuttering in a larger sample size of children with this disorder. Also, auditory training programs be implemented for children and adults with a stutter from various temporal processing aspects with a greater diversity of verbal stimuli, and their effects on the various dimensions of stuttering severity are analyzed in future research.

Given the complex nature of stuttering and its significant contingency on emotional and environmental factors, stuttering severity scores are likely to change after three months of training. Accordingly, follow-up evaluations should be performed at longer intervals of 1-2 years to analyze and verify the stability of the effects of auditory processing training on stuttering severity.

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Author’s Contribution

The first author was involved in the recruitment of patients.The author was responsible for the main idea, data collection and writing of the article. Other authors were guides and consultants in data writing and analysis

Conflict of interest

None of declare

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