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Evaluation of N1-P2 cortical auditory evoked potential results in adult stutterers

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Abstract

Background Stuttering is a fluency disorder characterized by changes in speech flow caused by neuroaudiological factors linked to central auditory processing. We aimed to assess the affection of cortical auditory evoked potentials (CAEP) in stutterers with secondary intention to compare the results with non-stutterers.

Methods This was a case–control study, involved 80 participants distributed into 2 groups: 40 adults stutterers formed the study group and 40 adult non stutterers as the control group, aged between 18 and 45 years. N1-P2 recordings were done using tone bursts stimuli. The absolute amplitudes of the N1 and P2 cortical auditory evoked potential wave forms, as well as the peak-to-peak amplitudes and latencies of the N1 and P2 waves, were measured.

Results Latencies N1 and P2 CAEP waves were statistically significant prolonged in stutterers than the control group. Regarding N1-P2 amplitudes, there was no significant difference between the two groups. There was a statistically significant negative correlation between N1-P2 amplitude and degree of stuttering.

Conclusion Cortical auditory evoked potentials could be an important tool in diagnoses and in assessment of improvement in adult stutterer individuals throughout treatment phases.

Keywords Adults, Auditory, Evoked potentials, N1-P2, Stuttering

Background

A subgroup of speech fluency disorders called persistent developmental stuttering is characterized clinically by abnormally frequent or long-lasting interruptions in speech, such as repetitions, prolongations, and/or blocks [1]. Two types of stuttering can be found overt or covert stuttering. Overt type shows repetitions, prolongation, and blocks with or without intra-phonemic disruptions, while covert type shows word substitutions and interjections [2].

The most important reason of stuttering has yet to be determined, and it is unclear if it is anatomical or environmental in origin. For this fascinating thing, researchers are looking into language and speech, as well as psychological, neurological, genetic, and biomechanical factors. It affects up to 5% of children and has a 1% frequency in adult population [3, 4].

Stuttering severity is classified into four levels based on symptoms: the first level occurs when stuttering is infrequent and consists only of recurrence to which the individual is oblivious, the second level occurs when stuttering is persistent, additional methods of disruption develop, and the person is aware of his problem, the third level occurs when stuttering occurs in worried instances and word replacement can be utilized to prevent feared word, and the fourth level occurs when stuttering occurs

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when the person suffers from word fear and situation avoidance [5].

Long latency auditory evoked potentials (LLAEPs) can be utilized to test auditory ability as an objective assessment of cognitive function. LLAEPs represent physical properties of the evoking stimuli which could be exogenous potentials or endogenous potential [6].

Cortical auditory evoked potentials (CAEPs) are formed of positive and negative peaks designated P1-N1-P2-N2 that occur between 50 and 300 ms following the stimulus onset. The P1-N2 complex has been proposed as a sensory representation of auditory stimuli [7]. CAEP peaks are produced by auditory thalamo-cortical tracts that involve the primary and association auditory cortices [8].

Speech and language function are dominated by the left hemisphere, as demonstrated by greater amplitudes and shorter latencies in Dichotic Listening (DL). However, these investigations have either looked at latency or amplitude, not both. As a result, the whole cortical dynamics underpinning processing are unknown. Both of these measurements may be used to determine the degree of cortical activation as well as the efficiency of neural transmission [9].

Research on stuttering disorder and the LLAEP found variations in P300 amplitudes, with stutterers having a lower amplitude [10].A different study revealed no variations between stutterers and non-stutterers in P300 latencies or amplitudes [11].

Aim of the work

To study the effect of stuttering on cortical auditory evoked potentials findings with secondary intention to compare the results with non-stutterers.

Methods

The present study was a case–control study conducted in the Phoniatric Unit, and in the Audio-Vestibular Unit, Kasr Al-Ainy Faculty of Medicine, Cairo University. The study was conducted during the period from first of October 2019 to June 2022. The Study population was divided into the cases group which included 40 adult stutterers and 40 healthy non-stutterer adult individuals from relatives of the cases. The adult stutterers with different degrees of severity were recruited at the time they were seeking advice at the phoniatric unit. They gave history of receiving speech therapy only at their childhood period. They were of both genders, whose ages were above 18 years. They were literate who can read and write. The control group adults were selected to be age and gender matched to the cases. The ethical committee of Beni-Suef University's Faculty of Medicine approved the study. All participants provided written informed consent.

All subjects had bilateral within normal peripheral hearing. Individuals with any retro-cochlear lesion, neurological disorders, cognitive disorders, and conductive hearing loss were excluded. Stuttering had been diagnosed and the severity of stuttering was determined according to the protocol of assessment used in Phoniatric Unit, Cairo University [12] and by using Stuttering Severity Instrument (SSI-3) [13]. Stuttering severity instrument Arabic form is standardized on Arabic speaking stutterers. It measures the frequency of stuttering, the mean duration of the three longest blocks, and the observable physical concomitants.

The test was applied by getting two speech samples. The first one was by asking the cases to talk spontaneously about a common topic such as their jobs or daily routine for about three minutes and with at least 150 words. Stuttering moments were counted then the second task was reading certain passage administered in the test and the stuttering moments were counted.

The entire samples are used to estimate the duration of the three longest blocks and to observe the physical concomitants. The first and last 25 words should be skipped for the frequency count. Then, the count of stuttering moments was calculated. The percentage was computed separately for the spontaneous speech and the reading task. Then the total frequency scores in addition to the scores of the duration, physical concomitants and the severity of stuttering were obtained using tables of normative data.

The audiological assessment was performed at the unit of audio-vestibular medicine in Kasr Al-Ainy Hospital. Pure tone audiometry, speech recognition threshold [14], speech discrimination [15], and immittancemetry were used to perform basic audiological assessment. The two channels Neuro-Audio (Neurosoft Ltd., Russia) recorded cortical auditory evoked potentials (CAEPs) utilizing tone burst stimuli.

Stimuli and recording parameters

Tone burst with linear rise/fall times of 10 ms at frequencies of 1 kHz and above (20 ms at lower frequencies) and a plateau time of 60 ms. Stimulations were delivered at a comfortable supra-threshold level of 20 dB dBSL (20 dB above the subject PTA's threshold) at a rate of 1.1 pulses per second. The stimulus was delivered via air conduction using an insert earphone EAR-3A10. The rejection level for artefacts was 200 V. Each participant received a total of 500 accepted sweepstakes. Visual inspection of the recordings was used to assess N1P2 morphology and waveforms.

Table 1 Comparison between study group and control group as regards demographic data

	Study group ($n=40$)		Control group ($n=40$)		Test of sig	*P* value
	No	%	No	%		
Gender:						
Male	28	70.0%	22	55.0%	$\chi2=1.92$	0.166
Female	12	30.0%	18	45.0%		
Age (years):						
(Min.–max.)	(18–45)		(18–55)		$t=-1.06$	0.292
Mean ± SD	27.70 ± 7.53		29.88 ± 10.56			

χ2 chi-square test; *t* Student's *t* test, *p p* value for comparing between the studied groups

Statistical analysis

Version 25 of SPSS (Statistical Package for Social Science) was used. The Student *t* test was used for comparing two groups with normally distributed quantitative variables. The Mann–Whitney *U* test was used to compare two groups with non-normally distributed quantitative data. To study the comparability and association of two qualitative variables, the chi-square test ($\chi2$) was performed. To compare quantitative variables that did not have a normal distribution, the Wilcoxon test was applied. A statistically significant *P* value of <0.05 was used.

Results

There were two groups of 80 adult patients: The study group included 40 stuttering patients aged 18 to 45 years with a mean of 27.70 years and an SD of 7.53 years, and the control group included 40 healthy non-stutterer individuals from the cases' relatives aged 18 to 55 years with a mean of 29.88 years and an SD of 10.56 years. The study group had 28 (70%) males and 12 (30%) females, whereas the control group had 22 (55%) males and 18 (45%) females. There were no statistically significant differences between the two groups as regards age and gender ($p>0.05$) (Table 1).

Table 2 shows the distribution of the degree of stuttering in the study group and the mean stuttering severity index in the different degrees of stuttering.

Table 2 The mean stuttering severity index in the different degrees of stuttering severity in the study group

Stuttering severity	Study group SSI			
	Mean	SD	Min	Max
Very mild ($n=10$)	7	6.481	2	16
Mild ($n=19$)	22.58	1.121	21	24
Moderate ($n=11$)	26.18	2.316	25	32
Total ($n=40$)	19.68	8.3	2	32

Table 3 shows that N1 and P2 latencies were statistically significant delayed in the study group than the control group, while no significant difference was found between groups as regards N1-P2 amplitude.

Table 4 and Fig. 1 show that there was no statistically significant correlation between N1 and P2 latencies and the stuttering severity index score, but as regards N1-P2 amplitude, there was statistically significant negative correlation between N1-P2 amplitude with the stuttering severity index score.

Table 5 shows that there was no statistically significant correlation between CAEP N1 and P2 Latencies and N1-P2 amplitude and age and the duration of stuttering.

Table 6 shows that there was no statistically significant difference between males and females as regards the tested CAEP parameters.

Discussion

Stuttering is a fluency disorder that causes changes in the flow of speech. Recent concepts combine hereditary, neurological, motor, language-related, and environmental factors to explain the underlying etiology of persistent developmental stuttering (PDS) [16].

Auditory processing may be compromised, interfering with speech fluency. As a result, electrophysiological research of late latency evoked potentials in relation to stuttering is critical because an objective evaluation can help in a better detection of the factors that hinder speech fluency and aid in therapeutic rehabilitation methods [17].

In the present study, we have a target to analyze and compare the CAEP results of adult stutterers and fluent adults by testing auditory function using late latency evoked potentials to detect if stuttering result from auditory feedback delay or not.

Our results of CAEP in patients show statistically significant delay in N1 and P2 latencies than the control group, while there was not any statistically significant difference between the two groups regarding N1-P2

Table 3 Comparison between study group and control group as regards cortical auditory evoked potential (CAEP) parameters

CAEP	Study group ($n=40$)			Control group ($n=40$)			*P* value
	Mean	±	SD	Mean	±	SD	
	Min	–	Max	Min	–	Max	
Latency (msec)							
N1	121.50	±	9.31	116.03	±	6.17	0.007*
	107.20	–	140.20	101.90	–	129.30	
P2	146.29	±	13.81	137.95	±	6.45	0.008*
	124.40	–	175.90	124.40		156.40	
Peak to peak amplitude (μV)							
N1-P2	2.55	±	0.79	2.56	±	0.53	0.460
	2.00	–	5.00	2.00	–	4.00	

P p value for comparing between the studied groups by Mann–Whitney *U* test

* *p* value < 0.05 is significant

Table 4 Correlation between CAEP N1 and P2 latencies and N1-P2 Amplitude with the stuttering severity index score

	Stuttering severity	
	r	*P*
CAEP		
N1	0.186	0.252
P2	0.220	0.173
N1-P2	−0.631	0.037*

CAEP cortical auditory evoked potential, *r* Spearman's correlation coefficient

* *p* value < 0.05 is significant

amplitude (Table 3). In accordance with our findings, Prestes et al. [18] found there was a statistically significant delay in N1 and P2 latencies in the stutterers group than the control group and they hypothesized that stutterers need extra time to elicit these components so this affects the sound auditory processing.

Although Reis and Frizzo [6] who investigated LAEP measurements from 20 stutterers adults and 12 normal adults using a 103 dB tone burst, found that P1, N1, and P2 amplitudes had statistically significant lowered amplitudes for stutterers group when compared to control group.

Meanwhile, the results of Ünsal et al. [19] who compared a group of stutterers with a group of normal individuals, did not show any statistical significant difference in P1 or N1latencies and amplitudes and stated that stutterers have no problem of realization of sounds.

On the other hand, Ismail et al. [20], found that there were prolonged mean latencies and decreased mean amplitudes of P1, N1, P2, and N2 in the 30 stutterers children when compared to the 30 normal children control group.

Conture and Walden [21] stated that decreased amplitude of cortical auditory evoked potentials may be explained by smaller number of synchronously active neurons elicited by the stimulus and reduced activation of the auditory cortex with impaired processing.

Jeronimo et al. [22] studied other components of late auditory evoked potentials P300 and MMN in a group of children with stuttering and compared them with control group, found that P300 had longer latencies and smaller amplitudes in the stutterers group, whereas MMN had delayed latencies and higher amplitudes in the stutterers group. They determined that children who stutter needed a longer period to distinguish between the standard and the rare.

In our findings, there were different degrees of stuttering severity according to SSI in the study group (Table 2). Very mild degree ($n=10$), mild degree ($n=19$), moderate degree ($n=11$). When we correlated these degrees with CAEP, we noticed that there was a statistically significant negative correlation between N1-P2 amplitude in patients group and stuttering severity. This reflects that CAEP N1-P2 amplitude is affected by stuttering.

No correlation was found between N1, P2 latencies and stuttering severity index (Table 4). This reflects that latency is not affected by stuttering severity. However, this study included very mild to moderate degrees of stuttering, perhaps if severe degrees were included, this correlation would have yielded significant results.

In agreement with the present study, Ismail et al. [20] and Liotti et al. [23] stated that the higher the severity of stuttering, the smaller CAEP amplitudes in children who stutter. They noticed a lower mean amplitude of P1, N1,

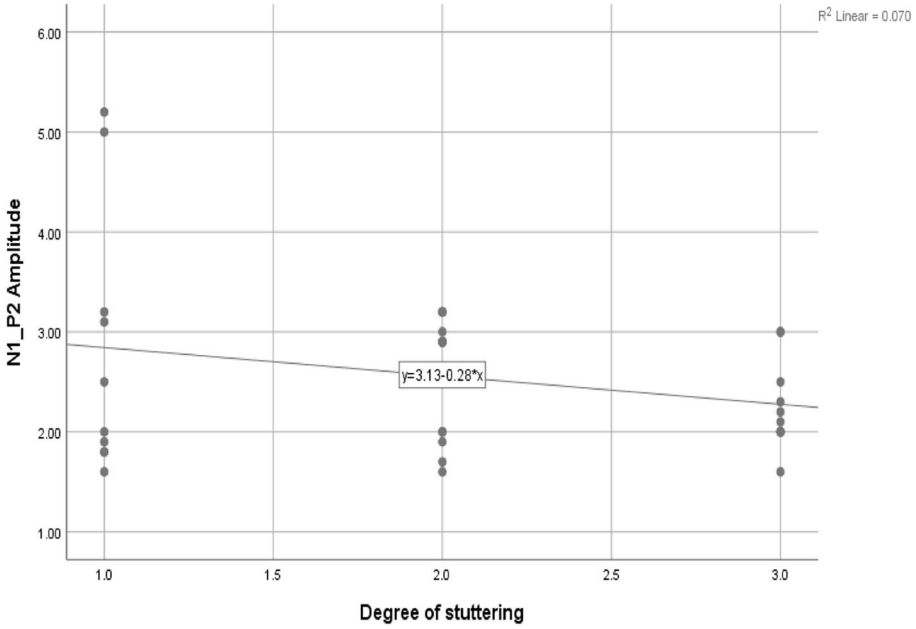

Fig. 1 Correlation between stuttering severity index score and N1-P2 amplitude

Table 5 Correlation between CAEP N1 and P2 latencies and N1-P2 amplitude and the age of the study group, and the duration of stuttering

	Age		Duration of stuttering	
	r	*p*	*r*	*P*
CAEP				
N1	0.027	0.81	0.069	0.672
P1	0.055	0.628	0.219	0.174
N1-P2	−0.001	0.996	0.168	0.299

CAEP cortical auditory evoked potential, *r* Spearman's correlation coefficient

P2, and N2 in stutterers when compared to normal children which explains the correlation.

There was no statistically significant correlation between CAEPs latencies and amplitudes and the age (Table 5). This reflects that the effect of stuttering on the CAEPs latencies or amplitudes is not dependent on the patients' age. While Poulsen et al. [24] and Jang et al. [25], demonstrated that P1-N1 latencies reduced with age in fluent adults with normal hearing and indicated that P1-N1 latencies become shorter with maturation.

Table 6 Comparison between males and females of the study group regarding CAEP N1 and P2 latencies and N1-P2 amplitude

CAEP	Male			Female			*P* value
	Mean	±	SD	Mean	±	SD	
	Min	–	Max	Min	–	Max	
Latency (msec)							
N1	118.43 ± 9.1			119.32 ± 6.91			0.421
	(101.9–140.2)			(107.2–132.1)			
P2	141.91 ± 12.81			142.47 ± 9.12			0.315
	(124.4–175.9)			(124.4–166.6)			
Peak to peak amplitude (μV)							
N1-P2	2.52 ± 0.714			2.62 ± 0.65			0.645
	(2–5)			(2–5)			

There was no statistically significant correlation between CAEP N1, P2 latencies, or N1-P2 Amplitudes with the duration of stuttering of the study group (Table 5). This also reflects that as the stuttering occurs no matter how long it lasted, the cortical auditory potentials are affected. Similar to our findings, Ünasl et al. [19] showed no correlation between CAEP P1, N1 waves latencies or amplitudes and stuttering duration.

In the current study we noticed that there was no gender difference regarding CAEPs N1, P2 latencies, or N1-P2 amplitudes in stutterers.This reflects that the effect of stuttering on the CAEPs latencies or amplitudes is not dependent on the patients' gender. Ferreira et al. [26] studied a group of children stutterers by P300 found that no statistically significant differences were obtained for the latency values or the amplitude values of the P300 regarding the gender variable. Stuttering appears to be more common in males than females, despite the gender difference [27].

Conclusion

CAEPs of adults who stutter showed significant delayed latencies and reduced amplitudes when compared to non-stutterers group, irrespective of age, gender, or duration of stuttering. CAEP amplitude is adversely affected by stuttering severity. CAEPs could be a useful tool in diagnosis and in assessment of improvement in stutterers adults throughout treatment phases.

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Authors' contributions
AK contributed significantly to the idea of the study. AD was the key to the analysis, interpretation and drafting of the manuscript. DA collected independently the study data from the participated selected individuals. AF had a significant effect on data collection and analysis. RK had significant contributions to the data analysis, writing and editing of the paper. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets during an/or analyzed during the present study available from the corresponding author.

Declarations

Ethics approval and consent to participate
All Participants received their consent after the study approved by Beni Suef University's Research Ethics Committee (Approval No :FMBSUREC/01102019).

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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References

1. Guitar B (2006) Stuttering, an integrated approach to its nature and treatment, 5(6), 3rd edn. Lippincott Williams and Wilkins, Baltimore, pp 159–178
2. (2013) Fogle: essentials of communication science and disorders, 4(3). Cengage learning Inc, Florence, pp. 334–455
3. Stapells DR (2002) Cortical Event-related potentials to auditory stimulus. In: Katz J (ed) Handbook of Clinical Audiology, 5th edn. Lippincott Williams &Wilkins, Philadelphia, pp 378–400
4. Sharma A, Martin K, Roland P, Bauer P, Sweeney MH, Gilley P (2005) P1 Latency as a bio-marker for central auditory development in children with hearing impairment. J Am Acad Audiol 16(8):568-77
5. Bloodstien O (1988) Is it stuttering? Am Speech Hear Assoc 30(12):13–45
6. Reis AC and Frizzo CF (2015) Cognitive auditory evoked potential. In: Boéchat EM, Menezes PL, Couto CM, Frizzo AC, Scharlach RC, Anastasio AR. Audiology treatise. 2 ed. Guanabara Koogan, Rio de Janeiro, p. 140
7. Weber F, Hampton W, Arnold H (2013) Early childhood stuttering and electrophysiological indices of language processing. J Fluen Disord 38(2):206–219
8. Neef M, Sommer M, Paulus W, Von Gudenberg A, Kujala T, Suominen K (2013) Linguistic multifeature paradigm as a measure of central auditory processing and novelty detection in two-year old children. Cogn Neurosci 4:99–106
9. Friedrich P, Ocklenburg S, Heins N (2017) Callosal microstructure affects the timing of electrophysiological left-right differences. NeuroImage 163:310–318
10. Hampton A, Weber-Fox C (2008) Non-linguistic auditory processing instuttering: evidence from behavior and event-related poten-cials. J Fluency Disord 33:253–273
11. Khedr M, El Nasser WA, Abdel-Haleem EK, Bakr MS, Trakhan MN (2000) Evoked potentials and eletroencephalography in stuttering. Folia Phoniatr Logop 55:178–86
12. Shohdi S (1999) Assessment protocol of stuttering. Thesis for Doctrate Dissertation, ENT Department, Faculty of Medicine, Cairo University
13. Rifaie N (1999) Arabicization and standardization of the Stuttering Severity Index (SSI) on the Arabic environment. Ain Shams Med J 50:75–79
14. Soliman SM, Fathalla A, Shehata M (1985) Development of Arabic staggered spondee words (SSW) test. In proceeding of 8th Ain Shams Med Cong
15. Soliman S (1976) Speech discrimination audiometry using Arabic phonetically balanced words. Ain Shams Med J 27:27–30
16. Jansson-Verkasalo E, Eggers K, Järvenpää A, Suominen K, Van den Bergh B, DeNil L (2014) Atypical central auditory speech-sound discrimination in children who stutter as indexed by the mismatch negativity. J Fluency Disord 41:1–11
17. Oliveira CM, Bohnen AJ (2017) Differential diagnosis of fluency disorders. In: Lamônica AP, Britto DB. Language treatise: contemporary perspectives. Book Toy, Ribeirão Preto, p.17 5–82
18. Prestes R, Andrade AN, Santos RBF, Marangoni AT, Schiefer AM, Gill D (2017) Temporal processing and long latency auditory evoked potential in stutterers. Braz J Otorhinolaryngol 83(2):142–146
19. Ünsal S, Ünsal D, Kaya M, Gunduz M (2016) Analysis of auditory evoked potential late latency potentials in stuttering ENT and BBC Magazine 24(3):65–9
20. Ismail N, Sallam Y, Behery R and Al Boghdady A (2017) Cortical auditory evoked potentials in children who stutter. Int J Pediatric Otorhinolaryngol 97:93–101
21. Conture E, Walden T (2010) A dual diathesis-stressor model of stuttering. Neurology 41(4):136–142
22. Jerônimo1 GM, Scherer APR, Sleifer P (2020) Long-latency auditory evoked potential in children with stuttering. Einstein (São Paulo) 18:eAO5225. https://doi.org/10.31744/einstein_journal/2020AO5225
23. Liotti M, Ingham C, Takai B, Kothmann D, Perez R, Ingham J (2010) Spatiotemporal dynamics of speech sound perception in chronic developmental stuttering. Brain Lang 115(2):141–147

24. Poulsen C, Picton TW, Paus T (2007) Age-related changes in transient and oscillatory brain responses to auditory stimulation in healthy adults 19-45 Years Old. Cereb Cortex 17(6):1454–67
25. Jang JH, Jang HK, Kim SE, Oh SH, Chang SO, Lee JH (2010) Analysis of P1 latency in normal hearing and profound sensorineural hearing loss. Clin Exp Otorhinolaryngol 194–8
26. Ferreira TN, Rodrigues LR, Correia DV, Andrade SM, Alves GA (2021) Rosa MRTemporal processing skills in people who stutter. Revista CEFAC 24:23
27. Rosenfield DB (1982) Stuttering. Curr Probl Pediatr 12(8):1–27

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