

ORIGINAL ARTICLE

Hearing status in vitamin B12-deficient children

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Aim: The aim of this study is to investigate the effects of vitamin B12 deficiency on hearing in school-aged children by pure-tone audiometry.

Methods: Forty-three vitamin B12-deficient children and 37 age-matched control subjects were enrolled in the study. Tympanometric evaluations and pure-tone audiometry including high frequencies were performed on the subjects. The results were compared between the two groups.

Results: Both right and left ear pure-tone hearing thresholds (PTHTs) at 0.25–4 kHz, and four-frequency pure-tone average values were significantly better in the control group compared with the patient group ($P < 0.05$). However, PTHTs at 8–16 kHz were not different between the two groups ($P > 0.05$). Vitamin B12 level also did not show any significant correlation with the PTHTs at 0.25–16 kHz ($P > 0.05$).

Conclusion: This study indicates that vitamin B12 deficiency may contribute to hearing impairment at low frequencies as a possible aetiological factor in children.

Key words: children; hearing; vitamin B12 deficiency.

What is already known on this topic

- 1 There are studies showing a negative impact of vitamin B12 deficiency on hearing in adults especially in the elderly population.
- 2 There is only one study in the literature about the effects of vitamin B12 deficiency on the evoked brain potentials in infants.

What this paper adds

- 1 Vitamin B12 deficiency may cause low frequency hearing impairment in school-age children.

Vitamin B12 (cobalamin) is a water-soluble vitamin that plays an important role in haematopoiesis and neurological function.¹ Vitamin B12 deficiency is a significant health problem in children, especially in developing countries. In some studies, prevalence of vitamin B12 deficiency in children has been reported up to 40% in developing countries.^{2,3} Vitamin B12 deficiency can cause haematologic and neurologic alterations. Neurologic findings may develop without haematologic abnormalities.¹ The most common haematologic manifestation of vitamin B12 deficiency is megaloblastic anaemia.¹ Vitamin B12 is also an important vitamin for the nervous system. Cobalamin deficiency can cause myelopathy, neuropathy, irritability, weakness, hypotonia,

sensory deficits, loss of deep tendon reflexes, movement disorders, paralysis, seizures, apathy, developmental delay and mental alterations in infants and children.⁴

Dietary factors can affect auditory system.^{5,6} There are several studies showing the negative impact of vitamin B12 deficiency on hearing function in adults.^{7–11} However, some studies have failed to find any evidence supporting such association.^{12–14} Vitamin B12 deficiency may cause cochlear pathology by influencing myelination, cellular metabolism and neuronal and vascular function.^{9,15} Because hearing problems have a negative impact on speech, language and academic skills in children, timely detection and proper intervention of hearing impairment are very important.

We propose that demyelination, dysmyelination or axonopathy due to vitamin B12 deficiency may affect cochlear nerve and can cause hearing impairment. To the best of our knowledge, there are no studies assessing the effects of B12 deficiency on hearing function in children, except a case control study about the effects of vitamin B12 deficiency on the evoked brain potentials in infants.¹⁶ Therefore, we aimed to evaluate the effects of vitamin B12 deficiency on hearing status in older children.

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Methods

A case controlled single-centre prospective study was performed with a total of 80 participants. The patient group (group 1) was composed of 43 vitamin B12-deficient children. Subjects referred

to the haematology department with complaints of weakness, fatigue, pallor, alopecia, amnesia or chest pain were included. The cause of the vitamin B12 deficiency was mostly nutritional, but three of the patients had chronic gastritis. All subjects were newly diagnosed patients, and had not previously received vitamin B12 treatment. The control group (group 2) included 37 normal healthy age-matched children with normal vitamin B12 levels. The control group was selected among the children of hospital staff. All subjects were asked about a history of hearing loss, ototoxic drug exposure, head trauma, ear surgery, neurodegenerative disorders, *in utero* infections, birth asphyxia, low birthweight, prolonged mechanical ventilation, severe hyperbilirubinaemia, meningitis, recurrent or persistent otitis media, speech/language delay and craniofacial abnormalities prior to performing the hearing tests. The inclusion criteria included vitamin B12 levels <200 pg/mL; normal iron, ferritin, folic acid and biochemical values; intact ear drums; and normal middle ear function as indicated by tympanometry. The exclusion criteria included frequent middle ear infections (>4 times a year), ototoxic medications, genetic hearing loss, head trauma, ear surgery and presence of structural or mechanical occlusive problems leading to hearing loss, tympanic membrane perforation, unilateral hearing loss, conductive hearing loss, folic acid or iron deficiencies and air-bone gap greater than 10 decibel (dB) hearing level at any frequency. Thus,

Table 1 Clinical and laboratory characteristics of the groups

Characteristics	Group 1 (patient group)	Group 2 (control group)
<i>n</i>	43	37
Age, years	13.19 ± 2.34	13.33 ± 2.36
Females, <i>n</i> (%)	31 (72.1)	25 (67.6)
Males, <i>n</i> (%)	12 (27.9)	12 (32.4)
Serum vitamin B12, pg/mL	141.39 ± 32.49†	328.02 ± 8.50†
Serum folate, ng/mL	8.77 ± 2.87	8.55 ± 2.31
Haemoglobin, g/dL	13.54 ± 0.98	13.54 ± 0.98
Ferritin, ng/mL	36.46 ± 23.59	30.61 ± 12.84
MCV, fL	84.81 ± 5.61	84.48 ± 4.63

†Statistical significance is determined at $P < 0.05$.

Values are means ± SD or *n* (%).

MCV, mean corpuscular volume.

Table 2 Comparison of pure-tone hearing thresholds of the groups

Frequencies (kHz)		Pure-tone thresholds		<i>P</i>
		Group 1 (<i>n</i> = 43)	Group 2 (<i>n</i> = 37)	
FFPTA	R	10.74 ± 2.92 (10)	8.72 ± 3.15 (10)	0.013†
	L	10.53 ± 3.09 (10)	7.72 ± 3.70 (8)	0.002†
0.25	R	16.62 ± 6.96 (15)	13.37 ± 3.91 (15)	0.032†
	L	16.16 ± 7.30 (15)	12.97 ± 4.15 (15)	0.046†
0.5	R	13.13 ± 4.63 (10)	10.67 ± 3.15 (10)	0.014†
	L	12.44 ± 5.04 (10)	10.00 ± 3.53 (10)	0.038†
1	R	10.46 ± 3.41 (10)	8.24 ± 3.76 (10)	0.008†
	L	10.46 ± 3.41 (10)	8.24 ± 3.37 (10)	0.008†
2	R	9.76 ± 2.87 (10)	7.97 ± 3.98 (10)	0.04†
	L	9.53 ± 3.23 (10)	7.56 ± 3.03 (10)	0.013†
4	R	10.58 ± 4.90 (10)	7.83 ± 3.64 (10)	0.006†
	L	11.04 ± 4.94 (10)	7.83 ± 4.17 (10)	0.005†
8	R	11.39 ± 4.40 (10)	9.59 ± 3.60 (10)	0.72
	L	12.32 ± 5.80 (10)	10.94 ± 5.37 (10)	0.168
10	R	8.69 ± 7.65 (10)	10.00 ± 3.72 (10)	0.051
	L	8.69 ± 7.57 (10)	9.59 ± 3.20 (10)	0.076
12	R	8.95 ± 6.77 (10)	9.32 ± 4.73 (10)	0.457
	L	9.06 ± 8.18 (10)	9.45 ± 4.21 (10)	0.271
14	R	6.66 ± 5.25 (5)	8.19 ± 3.80 (10)	0.198
	L	8.57 ± 7.83 (5)	8.33 ± 3.96 (10)	0.522
16	R	9.53 ± 8.71 (10)	10.41 ± 4.68 (10)	0.099
	L	10.46 ± 10.34 (10)	9.86 ± 5.40 (10)	0.437

†Statistical significance is determined at $P < 0.05$.

Values are means ± SD; median values are given in parentheses.

FFPTA, four-frequency pure-tone average (0.5, 1, 2 and 4 kHz); L, left ear; R, right ear.

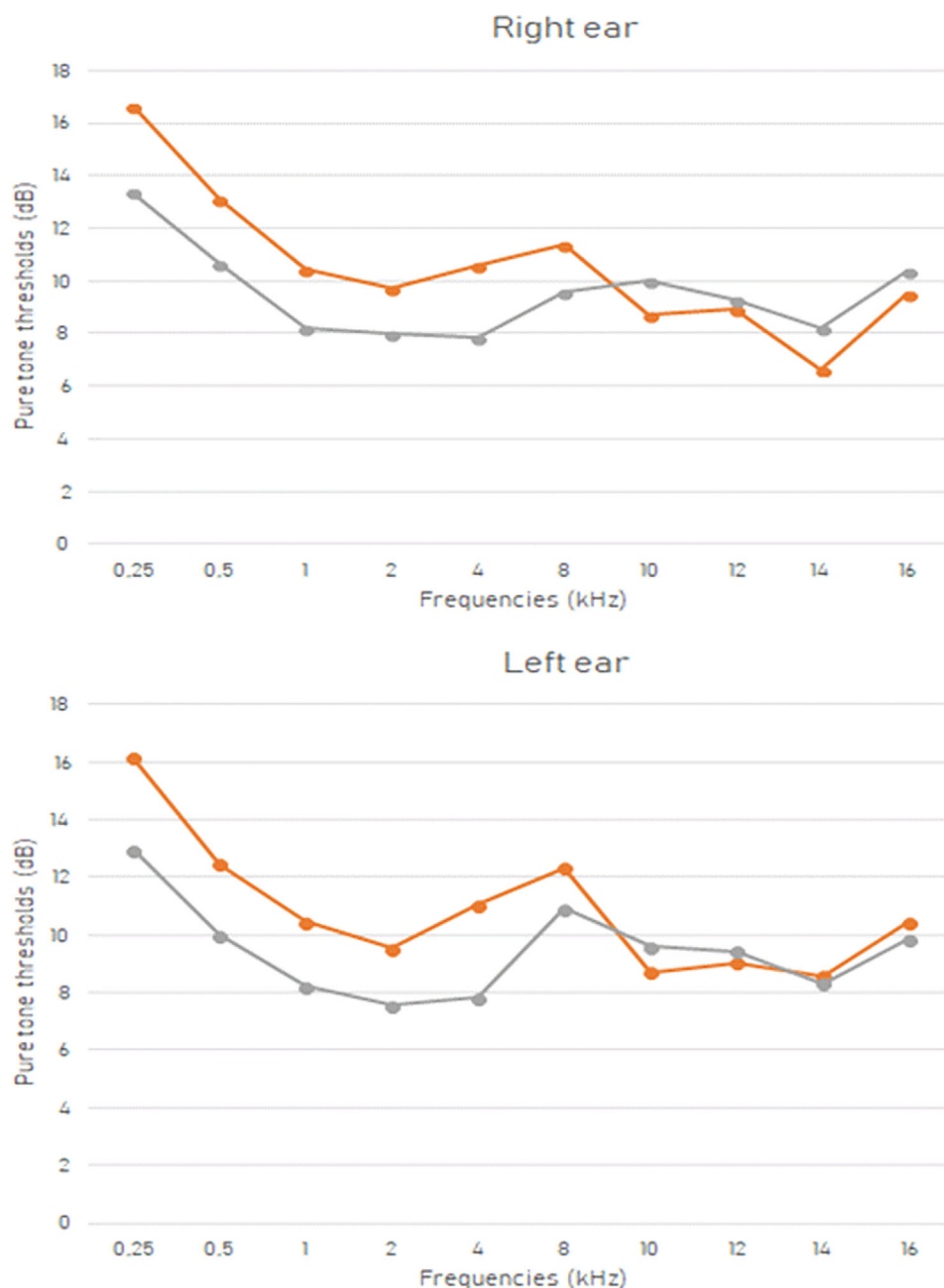


Fig. 1 Mean auditory pure-tone hearing thresholds of both ears of the groups at 0.25–16 kHz. Differences between the two groups at 0.25–4 kHz are significant ($P < 0.05$) (—●—, group 1; —●—, group 2).

the patients included in the study were assured to be patients with pure vitamin B12 deficiency. The study was approved by Human Research Ethics Committee of Elazığ (number: 97521439-36). Written informed consent was obtained from the parents of all of the children participating in the study.

Blood was collected after an overnight fast, and blood testing was performed on the same day of the blood collection at our institution. The complete blood counts; serum electrolytes; serum vitamin B12, folate, iron, iron binding capacity and ferritin levels; and renal and liver function tests of all children were studied to

exclude other factors that might affect hearing. The serum vitamin B12 levels were assessed with a Beckman Access analyzer (Beckman Coulter, Brea, CA, USA). Vitamin B12 deficiency was defined as plasma vitamin B12 < 200 pg/mL (< 148 pmol/L).

Before audiometric examination, otoscopic examinations of the outer ear and ear canal were conducted by an ear, nose and throat specialist to detect ear wax and other disorders of the ear canal or ear drum that might prevent a reliable evaluation. Tympanometric evaluations, acoustic reflex measurements and pure-tone audiometry, including high frequencies were

Table 3 Comparison of pre- and post-treatment pure-tone hearing thresholds of group 1 patients

Frequencies (kHz)		Pure-tone thresholds		P
		Pre-treatment (n = 8)	Post-treatment (n = 8)	
FFPTA	R	10.74 ± 2.92 (10)	10.87 ± 1.95 (11)	0.202
	L	10.53 ± 3.09 (10)	10.62 ± 2.38 (10)	0.308
0.25	R	16.62 ± 6.96 (15)	11.87 ± 2.58 (10)	0.236
	L	16.16 ± 7.30 (15)	12.50 ± 2.67 (10)	0.236
0.5	R	13.13 ± 4.63 (10)	11.25 ± 3.53 (10)	0.414
	L	12.44 ± 5.04 (10)	11.25 ± 3.53 (10)	0.461
1	R	10.46 ± 3.41 (10)	9.37 ± 3.20 (10)	0.102
	L	10.46 ± 3.41 (10)	9.37 ± 3.20 (10)	0.102
2	R	9.76 ± 2.87 (10)	10.00 ± 3.77 (10)	0.564
	L	9.53 ± 3.23 (10)	9.37 ± 3.20 (10)	0.655
4	R	10.58 ± 4.90 (10)	11.25 ± 3.53 (10)	0.655
	L	11.04 ± 4.94 (10)	11.87 ± 2.58 (10)	0.705
8	R	11.39 ± 4.40 (10)	11.87 ± 3.72 (10)	0.450
	L	12.32 ± 5.80 (10)	12.50 ± 3.77 (10)	0.480
10	R	8.69 ± 7.65 (10)	10.62 ± 5.62 (10)	0.596
	L	8.69 ± 7.57 (10)	8.75 ± 5.17 (10)	0.157
12	R	8.95 ± 6.77 (10)	7.50 ± 3.77 (10)	0.056
	L	9.06 ± 8.18 (10)	8.12 ± 2.58 (10)	0.068
14	R	6.66 ± 5.25 (5)	11.25 ± 5.82 (10)	0.564
	L	8.57 ± 7.83 (5)	11.25 ± 9.16 (10)	0.102
16	R	9.53 ± 8.71 (10)	13.12 ± 7.52 (10)	0.024†
	L	10.46 ± 10.34 (10)	15.00 ± 7.07 (10)	0.288

†Statistical significance is determined at $P < 0.05$.

Values are means ± SD; median values are given in parentheses.

FFPTA, four-frequency pure-tone average (0.5, 1, 2 and 4 kHz); L, left ear; R, right ear.

performed in both groups by a trained examiner in a sound-isolated room (Industrial Acoustics Company-IAC, Hampshire, UK). Pure-tone audiometry were performed with a diagnostic audiometer (Interacoustics AC40, Assens, Denmark). All subjects underwent air-conduction and bone-conduction pure-tone threshold estimations at frequencies of 0.25–16 kHz in a quiet environment and pure-tone hearing thresholds (PHTs) were noted in dB as hearing level. The hearing loss was classified as: slight hearing loss (16–25 dB), mild hearing loss (26–40 dB), moderate hearing loss (41–55 dB), moderately severe hearing loss (56–70 dB), severe hearing loss (71–90 dB) and profound hearing loss (90+ dB).¹⁷ Middle-ear pressure and acoustic stapedial reflex measurements were performed using an impedance audiometer (Interacoustics AZ26). The audiologic measurements of eight patients in group 1 were repeated after vitamin B12 supplementation (100 mcg daily for 1 week, 100 µg weekly for 3 weeks and 500 mcg monthly thereafter), and pre- and post-vitamin B12 supplementation PHTs were compared statistically.

All data were analysed with SPSS (Statistical Package for the Social Sciences) software for Windows (version 22.0; IBM, Armonk, NY, USA). Quantitative data were summarised using descriptive statistics including mean, standard deviations and medians (minimum–maximum). Categorical data were summarised using number (*n*) and percentages. Normality of data distribution was verified by Shapiro–Wilk test. As the data were distributed non-parametrically, the significance of difference

between the groups was compared by Mann–Whitney *U*-test. Pre- and post-treatment values of eight patients in group 1 were compared by Wilcoxon signed-rank test. Evaluation of categorical data was performed by Pearson's χ^2 and Fisher's exact test. Correlation analyses were performed with Spearman's correlation test. When assuming an effect size (change in pure-tone hearing values in dB) of 0.82, type I error (alpha) of 0.05 and type II error (beta) of 0.10 (power = 0.90), a sample size of 32 children per group was calculated based on *a priori* power analysis. *P* values <0.05 were considered statistically significant.

Results

Eighty patients who met the inclusion criteria of the study were evaluated in the 18-month period. The vitamin B12-deficient patient group (group 1) was composed of 43 children (31 females and 12 males) with a mean age of 13.19 ± 2.34 (range 7.5–18) years. The control group (group 2) included 37 children (25 females and 12 males) with a mean age of 13.33 ± 2.36 (range 9–17) years. There were no significant differences between the two groups in terms of age or gender ($P > 0.05$). The mean vitamin B12 level of group 1 was 141.39 ± 32.49 pg/mL. The mean vitamin B12 level of group 2 was 328.02 ± 8.5 pg/mL. The vitamin B12 level was statistically significantly lower in group 1 compared with the controls ($P < 0.05$). Haemoglobin, mean corpuscular volume and serum folate and ferritin levels were similar

Table 4 Correlation of vitamin B12 levels and pure-tone hearing thresholds in group 1 patients

Frequencies (Hz)		Vitamin B12	
		<i>r</i>	<i>P</i>
FFPTA	R	0.022	0.890
	L	0.037	0.812
0.25	R	0.029	0.854
	L	0.112	0.475
0.5	R	0.021	0.896
	L	0.172	0.270
1	R	0.054	0.730
	L	-0.059	0.706
2	R	0.083	0.598
	L	0.039	0.803
4	R	0.009	0.954
	L	0.001	0.993
8	R	-0.088	0.576
	L	-0.032	0.838
10	R	-0.890	0.592
	L	-0.062	0.699
12	R	-0.123	0.433
	L	0.014	0.931
14	R	-0.114	0.471
	L	-0.205	0.192
16	R	-0.231	0.136
	L	-0.084	0.594

Statistical significance is determined at $P < 0.05$.

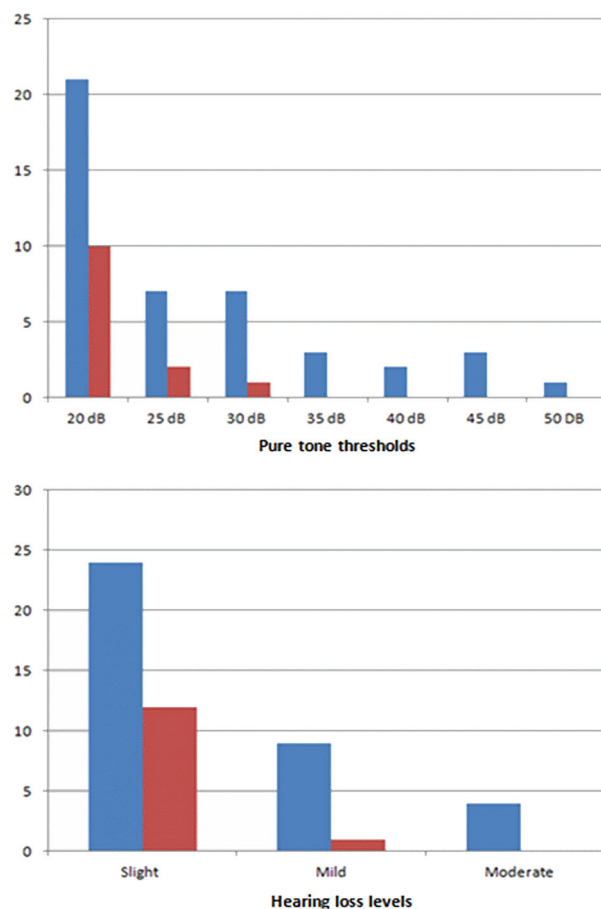
FFPTA, four-frequency pure-tone average (0.5, 1, 2 and 4 kHz); L, left ear; R, right ear.

between the groups. The clinical and laboratory characteristics of the participants are shown in Table 1.

There were no differences between boys and girls at any PTHTs ($P > 0.05$). Both right and left ear PTHTs at 0.25–4 kHz, and four-frequency pure-tone average of 0.5, 1, 2 and 4 kHz (FFPTA) values were significantly better in control group compared with the patient group ($P < 0.05$). However, PTHTs at 8–16 kHz were not different between the groups ($P > 0.05$) (Table 2). Figure 1 shows the mean PTHTs at 0.25–16 kHz in both groups. Vitamin B12 supplementation did not cause any changes in hearing tests in eight patients in group 1 (Table 3). Vitamin B12 level in group 1 did not also show any significant correlation with the PTHTs at 0.25–16 kHz ($P > 0.05$) (Table 4).

There were six patients whose vitamin B12 level was below 100 pg/mL (severe vitamin B12 deficiency) in group 1. When the hearing status of children with vitamin B12 levels below and above 100 pg/mL was compared, no significant difference was found neither in FFPTA values nor in PTHTs at 0.25–16 kHz ($P > 0.05$).

Slight hearing loss (16–25 dB) at any frequencies was detected in 24 patients in group 1, and 12 patients in group 2 ($P < 0.05$). Mild hearing loss (26–40 dB) at any frequencies was detected in nine patients in group 1, and one patient in group 2 ($P < 0.05$). Moderate hearing loss (41–55 dB) at any frequencies was detected in four patients in group 1, and none in group 2 ($P > 0.05$). Moderately severe, severe and profound hearing loss were not detected in any

**Fig. 2** Hearing impairment status in each group according to the different pure-tone thresholds and hearing loss levels (■, group 1; ■, group 2)

group. Figure 2 shows hearing impairment status in each group according to the different pure-tone thresholds and hearing loss levels.

Discussion

The early detection and correction of hearing disorders in children is very important because hearing disorders can have impact on language development, socialisation, school performance and academic performance.¹⁸ Hearing abnormalities related to vitamin B12 deficiency in young adults and older people have been reported by several studies.^{7,10,11,19} The present study shows that the FFPTA values and PTHTs at 0.25–4 kHz were worse and slight and mild hearing losses were more likely in the vitamin B12-deficient group compared with the control group in school-aged children.

In agreement with our study, Houston *et al.*⁷ showed a possible association between vitamin B12 status and hearing loss in 55 healthy women. The authors found that women with hearing impairment had a 38% lower serum vitamin B12 level than women with normal hearing. Karaer and Akalin⁸ showed that both vitamin B12 and vitamin D deficiencies impair the cochlear functions. In their study, they found that transiently evoked otoacoustic emissions at 1, 2, 3 and 4 kHz and distortion product

otoacoustic emissions at 1, 2 and 6 kHz were lower in women with vitamin B12 deficiency. In a study by Shemesh *et al.*⁹ on army personnel, it was found that B12 deficiency was present in 47% of subjects suffering from both noise-induced hearing loss and tinnitus. The authors also reported some improvement in patients following B12 replacement, suggesting a relationship between B12 deficiency and auditory dysfunction. In another study, it was shown that increased rates of absent vestibular evoked myogenic potentials and decreased amplitudes with normal latencies in patients with vitamin B12 deficiency attributed to peripheral vestibular hypofunction.²⁰

It was reported that B12 deficiency was associated with increased inflammation, and hearing loss is perhaps the result of inflammation.²¹ As another mechanism, increased methylmalonic acid as a result of vitamin B12 deficiency can cause neurotoxicity and vasculotoxicity in the inner ear.²² Similarly, homocysteine, which is elevated during vitamin B12 deficiency, can cause hearing abnormalities to be as a vasculotoxin and a neurotoxin.²³

In contrast to the studies that found positive association between hearing disorders and low vitamin B12 status, there are some others which do not confirm such relationship. For example, Lasisi *et al.*¹² failed to find any relationship between vitamin B12 levels and age-related hearing loss. Similarly, in another study involving patients over the age of 50 years, serum vitamin B12 levels were not found to be associated with hearing loss.¹³ In the present study, we found that there were no differences between patient and control groups at higher frequencies (8–16 kHz).

Demir *et al.* have shown a positive correlation between the degree of vitamin B12 deficiency and abnormal hearing thresholds.¹⁶ They proposed that the severity of clinical symptoms is directly related to the severity of vitamin B12 deficiency. In our study, the majority of the subjects in group 1 did not have severe vitamin B12 deficiency, defined as <100 pg/mL. There were six patients whose vitamin B12 level was below 100 pg/mL, and the mean vitamin B12 level in group 1 was 141.39 pg/mL. Therefore, the depth of vitamin B12 deficiency might not have been enough to cause any auditory disturbances at all frequencies. As a support to this hypothesis, Kalita *et al.*²⁴ found acute axonal degeneration in early stage, and chronic axonopathy with demyelination in the late stage of vitamin B12 deficiency in their nerve conduction and biopsy study.

Demir *et al.*¹⁶ reported statistically significant improvements in brain-stem auditory evoked potentials in vitamin B12-deficient infants after 3 months of vitamin B12 supplementation. However, Park *et al.*¹¹ reported no improvements in hearing status in vitamin B12-deficient individuals having short-term vitamin B12 supplementation. In our study, vitamin B12 supplementation did not also cause any changes in hearing tests in vitamin B12-deficient children after a mean of 3.8 months.

Apart from vitamin B12 deficiency, other nutritional deficiencies such as iron, folic acid and vitamin D can also affect auditory system.^{5,7,8,13} In our study, iron parameters and folic acid levels were studied and only children with normal values were included in the study to exclude effects of these nutritional deficiencies and general malnutrition as much as possible.

The strength of this study is that we evaluated the effects of vitamin B12 deficiency on hearing for the first time in school-aged children where the developmental consequences of unidentified hearing loss are more important and demonstrated significant differences at several hearing thresholds compared to the

control group. There were some limitations of this study: First, there is a female preponderance in the study. Chakraborty *et al.* showed that serum vitamin B12 levels were found to be lower in rural school-aged adolescent females having lower socioeconomic status.²⁵ The majority of our patients also consisted of adolescent girls from low-income families. Although female subjects were preponderant in our study, there was no difference between male and female subjects in terms of hearing status at any hearing thresholds. Second, we did not have the universal neonatal hearing screening test results of children participating in the study because universal newborn hearing screening was not available in our region at the time when they were born. However, children who did not have a history of hearing loss and whose language development was compatible with their peers were included in the study despite not having routine hearing screening test. Third, there were only six patients with severe vitamin B12 deficiency (B12 level < 100 pg/mL). When we compared the hearing thresholds of children with severe and non-severe vitamin B12 deficiency, we found no difference in hearing levels. Further studies with more subjects are needed on this issue.

Conclusion

The present study, to the best of our knowledge, is the first to investigate the relationship between vitamin B12 deficiency and hearing thresholds in school-aged children, and demonstrate a possible negative impact of vitamin B12 deficiency in children. We proposed that children with vitamin B12 deficiency should be evaluated for possible hearing impairment. Additional large prospective studies could provide more detailed information regarding this topic.

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References

- 1 Rasmussen SA, Fernhoff PM, Scanlon KS. Vitamin B12 deficiency in children and adolescents. *J. Pediatr.* 2001; **138**: 10–7.
- 2 McLean ED, Allen LH, Neumann CG *et al.* Low plasma vitamin B-12 in Kenyan school children is highly prevalent and improved by supplemental animal source foods. *J. Nutr.* 2007; **137**: 676–82.
- 3 Demir N, Koc A, Ustul L, Peker E, Abuhandan M. Clinical and neurological findings of severe vitamin B12 deficiency in infancy and importance of early diagnosis and treatment. *J. Paediatr. Child Health* 2013; **49**: 820–4.
- 4 Dror DK, Allen LH. Effect of vitamin B12 deficiency on neurodevelopment in infants: Current knowledge and possible mechanisms. *Nutr. Rev.* 2008; **66**: 250–5.
- 5 Schieffer KM, Chuang CH, Connor J, Pawelczyk JA, Sekhar DL. Association of iron deficiency anemia with hearing loss in US adults. *JAMA Otolaryngol. Head Neck Surg.* 2017; **143**: 350–4.

- 6 Peneau S, Jeandel C, Dejardin P *et al.* Intake of specific nutrients and foods and hearing level measured 13 years later. *Br. J. Nutr.* 2013; **109**: 2079–88.
- 7 Houston DK, Johnson MA, Nozza RJ *et al.* Age-related hearing loss, vitamin B-12, and folate in elderly women. *Am. J. Clin. Nutr.* 1999; **69**: 564–71.
- 8 Karaer I, Akalin Y. Low vitamin B12 level and vitamin D level adversely affect on cochlear health in women. *Int. J. Vitam. Nutr. Res.* 2019; **18**: 1–6.
- 9 Shemesh Z, Attias J, Ornan M, Shapira N, Shahar A. Vitamin B12 deficiency in patients with chronic-tinnitus and noise-induced hearing loss. *Am. J. Otolaryngol.* 1993; **14**: 94–9.
- 10 Krumholz A, Weiss HD, Goldstein PJ, Harris KC. Evoked responses in vitamin B12 deficiency. *Ann. Neurol.* 1981; **9**: 407–9.
- 11 Park S, Johnson MA, Shea-Miller K, de Chicchis AR, Allen RH, Stabler SP. Age-related hearing loss, methylmalonic acid, and vitamin B12 status in older adults. *J. Nutr. Elder.* 2006; **25**: 105–20.
- 12 Lasisi AO, Fehintola FA, Yusuf OB. Vitamin B12, and folate in elderly. *Otolaryngol. Head Neck Surg.* 2010; **143**: 826–30.
- 13 Gopinath B, Flood VM, Rochtchina E, McMahon CM, Mitchell P. Serum homocysteine and folate concentrations are associated with prevalent age-related hearing loss. *J. Nutr.* 2010; **140**: 1469–74.
- 14 Berner B, Odum L, Parving A. Age-related hearing impairment and B vitamin status. *Acta Otolaryngol.* 2000; **120**: 633–7.
- 15 Ubbink JB, Vermaak WJH, van der Merwe A, Becker PJ. Vitamin B-12, vitamin B-6, and folate nutritional status in men with hyperhomocysteinemia. *Am. J. Clin. Nutr.* 1993; **57**: 47–53.
- 16 Demir N, Koç A, Abuhandan M, Calik M, Işcan A. Visual and brainstem auditory evoked potentials in infants with severe vitamin B12 deficiency. *Turk. J. Med. Sci.* 2015; **45**: 1274–9.
- 17 Harrell RW. Puretone Evaluation. In: Katz J, Burkard RF, Medwetsky L (eds.). *Handbook of Clinical Audiology*, 5th edn. Philadelphia: Lippincott Williams & Wilkins; 2002; 82.
- 18 Daud MK, Noor RM, Rahman NA, Sidek DS, Mohamad A. The effect of mild hearing loss on academic performance in primary school children. *Int. J. Pediatr. Otorhinolaryngol.* 2010; **74**: 67–70.
- 19 Karlı R, Gül A, Uğur B. Effect of vitamin B12 deficiency on otoacoustic emissions. *Acta Otorhinolaryngol. Ital.* 2013; **33**: 243–7.
- 20 Özdemir D, Mehel DM, Küçüköner Ö *et al.* Vestibular evoked myogenic potentials in patients with low vitamin B12 levels. *Ear Nose Throat J.* 2019; **98**: 1–5.
- 21 Peracchi M, Bamonti CF, Pomati M, De Franceschi M, Scalabrino G. Human cobalamin deficiency: Alterations in serum tumour necrosis factor-and epidermal growth factor. *Eur. J. Haematol.* 2001; **67**: 123–7.
- 22 Kölker S, Ahlemeyer B, Kriegelstein J, Hoffmann GF. Methylmalonic acid induces excitotoxic neuronal damage in vitro. *J. Inher. Metab. Dis.* 2000; **23**: 355–8.
- 23 Bleich S, Degner D, Sperling W, Bönsch D, Thürauf N, Kornhuber J. Homocysteine as a neurotoxin in chronic alcoholism. *Prog. Neuropsychopharmacol. Biol. Psychiatry* 2004; **28**: 453–64.
- 24 Kalita J, Chandra S, Bhoi SK *et al.* Clinical, nerve conduction and nerve biopsy study in vitamin B12 deficiency neurological syndrome with a short term follow up. *Nutr. Neurosci.* 2014; **17**: 156–63.
- 25 Chakraborty S, Mani K, Chopra M *et al.* Prevalence of vitamin B₁₂ deficiency in healthy Indian school-going adolescents from rural and urban localities and its relationship with various anthropometric indices: A cross-sectional study. *J. Hum. Nutr. Diet.* 2018; **31**: 513–22.



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