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ORIGINAL

RESEARCH PROGRESS OF CHILD ATHLETE'S SPEECH SOUND DISORDERS

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ABSTRACT

Child athletes with speech sound disorders may experience difficulties communicating with coaches, teammates, and others in sports-related contexts. To improve communication abilities and overall athletic performance, research has made progress in exploring the impact of speech therapy and exercise programs on child athletes with speech sound disorders. These programs aim to enhance neural connections between the brain regions responsible for speech production and motor skills needed for sports, as well as boost confidence in social situations. By utilizing advanced diagnostic tools, such as speech sound assessments and imaging techniques, researchers have identified new methods for identifying and treating speech sound disorders in child athletes. This paper reviews the recent research progress on child athlete's speech sound disorders, discussing the implications for speech therapy and exercise programs in sports training, as well as the potential for improved communication and athletic performance.

KEYWORDS: Speech sound disorders; Child athletes; pathogeny; overview

INTRODUCTION

Speech Sound Disorders (Speech Sound Disorders, SD) refers to the general

term of diseases with abnormal speech intelligibility caused by various secondary factors or unknown reasons, accounting for 48.1% of communication disorders in school-age child athletes (Black, Vahratian, & Hoffman, 2015). Its clinical manifestation is unclear articulation, which limits children's daily communication, and is prone to emotional problems such as an inferiority complex(Beitchman et al., 2001), which may hurt school and employment in the long term(Overby, Trainin, Smit, Bernthal, & Nelson, 2012). The etiology of SSD is complex, and various etiologies have unique clinical characteristics and clinical diagnosis and treatment methods. Based on the etiology of SSD, this article reviews the research progress of its clinical characteristics, diagnosis, treatment and prognosis.

Abnormal speech perception system

The reception of signals by a speech perception system is the premise of speech production, and its function realization depends on the ability of auditory perception and auditory discrimination. The auditory sense ability is responsible for receiving signals, and this functional abnormality makes the child athletes lack of speech signal stimulation, which leads to abnormal speech development. Auditory discrimination is responsible for further classification and analysis of signals, which depends on the integration of signals by the central nervous system and is another important link in the realization of auditory function. Research has confirmed that child athletes with abnormal auditory perception have abnormal speech articulation and rhythm(Kalathottukaren, Purdy, & Ballard, 2017). At the same time, SSD children's ability to distinguish initial consonants, vehicles, animal sounds and final consonants is weaker than those of normal-hearing child athletes (Hashemi et al., 2018), and the processing speed of the cortex to distinguish auditory differences is also significantly slower than that of normal child athletes (Gao, Zheng, Hong, Luo, & Jiang, 2013). In addition, research shows that the surface area, thickness and weight of the left occipital cortex in child athletes with severe and extremely severe hearing loss are significantly smaller than those in normal child athletes, and this area is known to be a functional area closely related to advanced cognitive function(Shiohama, McDavid, Levman, & Takahashi, 2019).After hearing loss child athletes processed speech tasks, their attention decreased, reaction time prolonged, and fatigue increased more significantly than normal hearing child athletes (Gustafson, Key, Hornsby, & Bess, 2018). Besides, there were more signal exchange bypasses and invalid information exchange in the brain of elderly patients with hearing loss(Bidelman et al., 2019). This suggests that in addition to abnormal signal reception, the abnormal information transmission and processing functions of the auditory - speech - motor pathway of the brain may be another reason for the abnormal speech perception system leading to SSD.

Individuals with abnormal hearing have a 63% higher risk of speech and language disorders than those with normal hearing(Pereira, Befi-Lopes, & Samelli, 2015). Because of abnormal interruption in pronunciation, slow pronunciation conversion and prolonged phoneme pronunciation, the speech speed of hearing loss patients decreased. At the same time, due to the abnormal hearing threshold, such child athletes may have difficulties in acquiring phonemes with similar phonetic characteristics, such as phonemes with the same pronunciation position and different air delivery methods such as /g /, /k /(Hung, Lee, & Tsai, 2017). In addition, child athletes with hearing loss have difficulty in tone acquisition, resulting in the lack of second, third and fourth tones when pronouncing(Zhang, Jin, Shen, & Wu, 2006). Normal child athletes are often easier to master vowels, but the articulation of vowels in child athletes with hearing loss may be abnormal, and it is manifested as exaggerated lip movements and reduced tongue movement range when pronouncing(Xue, Zhang, Bai, & Wang, 2018). The degree of speech impairment in such child athletes is related to the degree of hearing loss. Child athletes with severe sensorineural hearing loss, compared with child athletes with mild to moderate hearing loss and normal hearing, have significant differences in speech skills, reading comprehension and information processing(Olivier et al., 2019). At the same time, speech intelligibility is related to the type of hearing loss. The vowel intelligibility of conductive hearing loss and mixed hearing loss is significantly reduced, and the vowel intelligibility of sensorineural hearing loss is not significantly abnormal.

The previous view that unilateral hearing is the minimum requirement to ensure language development is wrong, and the harm of unilateral hearing loss has gradually been recognized(Rohlfs et al., 2017). In the early stage of life, the impact of unilateral hearing loss may not be easily detected, but with the increase of child athletes motor ability, the reception distance of sound stimulation increases with the improvement of child athletes motor ability, and this damage is relatively easy to recognize(Lieu, Tye-Murray, Karzon, & Piccirillo, 2010). Such child athletes scores in the receptive and expressive language tests are lower than those of normal hearing child athletes, and can affect their academic and life quality(Griffin, Poissant, & Freyman, 2019).

Judging the function of the speech perception system is an important link in the diagnosis of child athletes with SSD(Rohlfs et al., 2017). When inquiring the medical history, attention should be paid to the family history of hearing loss, previous hearing test results, and risk factors of hearing loss, including the use of ototoxic drugs, viral infection, low birth weight, premature delivery, etc. (Liming et al., 2016). It is worth noting that due to the compensatory effect of the vision, we cannot rely on the response to sound in our daily life to evaluate our listening level(Puschmann et al., 2019). The coverage of newborn hearing screening has been relatively wide, but its false negative

rate of screening for hearing loss can reach 20%(Saunders et al., 2022), while child athletes can cause delayed hearing loss due to otitis media, noise impact, etc(Cai & McPherson, 2017). In the process of growth, so it is necessary to complete the diagnostic hearing test for SSD children. The International Consensus on the Assessment of child athletes Hearing Loss suggested that the diagnostic hearing test should adopt the combination test method. Child athletes over 6 months of age can jointly use Acoustic immittance, OAEs（otoacoustic emission）, ABR（auditory brainstem response）,Behavioral assessment. The behavioral assessment of young children can choose visual reinforcement audiometry or conditioned play audiometry, and children with good compliance can choose pure tone audiometry(Farinetti, Raji, Wu, Wanna, & Vincent, 2018). For a long time, the average hearing threshold of less than 25dBHL has been regarded as normal hearing, but the American Hearing Society's Guidelines for Children's Hearing Screening proposed that children's hearing screening baseline can be set at 20dBHL, and any single frequency hearing threshold of more than 20dBHL at 1000, 2000, and 4000HZ can be regarded as screening abnormalities. This strict standard may help to detect child athletes with mild hearing loss. It is noteworthy that hearing threshold detection cannot reflect the auditory discrimination ability, and its detection can be based on test methods such as cortical auditory evoked potentials(Legris et al., 2018). Imaging examination is helpful to find the cause of hearing loss and evaluate the feasibility of intervention. Child athletes with bilateral hearing loss are recommended to perform high-resolution temporal bone CT thin-layer scanning routinely. MRI can better display the status of cochlear nerve or cochlear diseases, and can be used as a supplementary examination for child athletes with severe hearing loss without abnormal CT examination(Funamura, 2017).

Child athletes with definite diagnosis should be equipped with hearing aids as soon as possible. For child athletes with poor intervention effect after using hearing aids for more than 3 months or pure tone hearing threshold exceeding 70dBHL, cochlear implantation can be considered. For child athletes without indications for cochlear implantation, auditory brainstem implantation is a new technology choice, but this technology was approved for school-age child athletes in 2013, and the best beneficiaries and the effect of language intervention need to be further studied(Liu, Anne, & Horn, 2019). After hearing support, the hearing function of child athletes may be partially improved, but they will still have abnormal speech intelligibility, so speech training is still necessary and crucial. In general, the speech prognosis of child athletes with hearing loss is related to the degree of hearing loss, the timing of hearing support, cognitive level, mother's educational level and other factors.

Abnormal speech expression system

The normal structure and function of the speech expression system is an

important link to ensure speech output, so oral and pharyngeal diseases such as cleft lip and palate, laryngeal trauma, laryngeal papilloma, etc. can affect speech. The incidence of orofacial cleft in Asia is about 1.57 /1000, and the proportion of such malformations with speech disorders can be as high as 80%, of which cleft palate is the most common, followed by cleft lip and palate and cleft lip.

Abnormal structure of articulation organs in cleft lip and palate patients is a common cause of SSD. In the process of normal pronunciation, correct and rapid opening and closing of velopharyngeal orifice ensure the correct production of voice. When pronouncing vowels and non-nasal consonants such as /p /, /t /, /z /and vowels, the soft palate is lifted up to the posterior pharyngeal wall, while the lateral pharyngeal wall and the posterior pharyngeal wall both contract inward, thus closing the velopharyngeal orifice and guiding the ascending airflow into the mouth. When pronouncing nasal consonants [m], [n] and vowels related to nasal consonants [- ng], the soft palate drops and the velopharyngeal orifice opens so that the airflow can enter the nasal cavity to generate resonance.

Because of the deformity, the nasopharynx cavity is connected and the velopharyngeal closure is incomplete, most child athletes produce additional resonance in the nasal cavity when producing non-nasal sounds, and the airflow leaks from the nasal cavity when producing nasal sounds, resulting in the voice characteristics of excessive nasal sounds or nasal leakage. Some children can reduce nasal sounds due to maxillary retraction, nasal obstruction, etc. At the same time, child athletes with cleft lip and palate may have difficulties in producing apical such as /z /, /d /, which require the joint participation of the tongue and teeth in the articulation due to the combination of abnormal occlusion and irregular dentition. In addition, because child athletes with cleft lip and palate have tongue retraction, apical can be mistaken for velar. The more severe the deformity of cleft lip and palate is, the more obvious the tongue lifting, retraction and nasal air leakage are, and the more significant the voice abnormality is. In addition to abnormal speech intelligibility, child athletes with cleft lip and palate may have poor development of receptive language and expressive language, which reduces the diversity of consonants and tends to pronounce monosyllabic syllables. In addition, children with cleft lip and palate may suffer from hearing loss due to eustachian tube dysfunction or tympanic membrane perforation, which aggravates the adverse effects on speech. With the development of imaging technology, the abnormal brain nerve function of child athletes with cleft lip and palate has been gradually recognized. There are structural differences between child athletes with cleft lip and palate and normal child athletes in several brain regions related to cognitive function, such as central cingulate gyrus and bilateral frontal lobes, suggesting that the abnormal neural function may be another reason for the abnormal voice of child athletes with cleft lip

and palate.

When receiving SSD child athletes, the oral structure should be checked routinely. At the same time, when inquiring about the medical history, attention should be paid to whether there are pathogenic risk factors, such as maternal obesity, smoking, folic acid deficiency, and the use of antiepileptic drugs. For child athletes with no obvious abnormality in face, but with nasal drip during feeding, abnormal resonance during pronunciation, nasal leakage, etc., it is recommended that the specialist evaluate whether there is a submucosal cleft palate.

After the repair of cleft lip and palate, 5%~40% of child athletes still have speech disorders due to velopharyngeal insufficiency, maxillary and mandibular deformities. The improvement of child athlete's speech after the operation is the focus of doctors and caregivers. For the speech evaluation of such children, in addition to the traditional speech pathologists' subjective test to distinguish the speech characteristics, the development of signal processing technology in recent years has made the speech automatic evaluation become a reality. For example, the automatic recognition algorithm of high nasal level of cleft palate speech can determine the existence of high nasal level and grade it by computer. The manner and timing of the operation, the severity of the deformity, etc. can affect the speech prognosis. After the operation, the combination of palatopharyngeal function training, lip and tongue strength function training, respiratory training, etc. can improve speech.

Nervous system abnormality

This kind of speech disorder is often called motor dysarthria, which is caused by neuropathy or abnormal muscle movement, and can be caused by brain trauma, tumor, muscle weakness, cerebral palsy, stroke and other reasons. Cerebral palsy is a common cause of SSD in childhood. About 90% of children with cerebral palsy have speech problems. The severity of the disease is related to the location of brain injury. The degree of speech abnormalities in children with basal nucleus and cerebellar injury is relatively serious, and the damage of focal brain injury is relatively light. Moreover, brain trauma is a common accidental injury in childhood. About 10%~60% of the patients after trauma can be combined with voice abnormalities.

Correct pronunciation requires the coordinated movement of tongue, lip, jaw and other organs by the nervous system. Through the analysis of the muscle movement characteristics of patients with motor dysarthria by using electromagnetic articulography, it was found that the movement distance of the lip and tongue was shortened, the movement speed was reduced and unstable, indicating that the strength of the lip and tongue muscles was

weakened, and the strength control stability was poor. At the same time, the up and down and forward and backward movements of the tongue are uncoordinated, suggesting that there is a deviation in the perception of the position of the tongue and lip when pronouncing. Due to the limitation of tongue movement, patients can have a compensatory increase in the range of mandibular movement, which is common in patients with mild and moderate speech disorders, but in patients with severe speech disorders, the range of mandibular movement is reduced, indicating that their compensatory ability is limited. In addition, if the disease involves respiratory muscle groups, the respiratory movement may be uncoordinated during speech, which is manifested by shortness of breath during communication and abnormal interruption of breath.

For the evaluation of such patients, it is necessary to pay attention to whether there are high risk factors of hypoxia during pregnancy and delivery, evaluate the neuropsychological development, complete physical examination of the nervous system to confirm whether there are postures, muscle tone abnormalities, etc., and evaluate the activity of its vocal organs under speech conditions. Because the acoustic characteristics of child athletes with motor dysarthria change with the type of pathogeny, the treatment should be targeted at its acoustic characteristics while treating the primary disease. For example, child athletes with spastic dysarthria can focus on relaxation training, and child athletes with delayed dysarthria should focus on tongue and lip muscle strength training. In addition to training the corresponding injured muscle strength and coordination in the non-verbal situation, the training in the speech process is also particularly important. It can generate compensatory nerve cells in the damaged nerve pathway, thus improving the muscle function and speech intelligibility.

Unknown reasons

This kind of speech disorder is usually called functional speech disorder, which refers to the abnormal speech intelligibility of child athletes whose language development has reached the age of 4 years without secondary causes. Studies have shown that gene FOXP2, EKNI1, DYX2 and some chromosome regions such as 3p12-13 may be molecular genetic markers related to their occurrence. In addition, the cognitive level of children with functional speech impairment is also a research hotspot. Although the IQ test score is within the normal range, there is an imbalance of intelligence structure with low operating quotient, which may be related to the backward ability of inhibition control, working memory, and spatial perception. At the same time, the abnormal oral function caused by environmental factors such as family history of language and speech abnormalities and a preference for soft food is also a risk factor for its occurrence.

Consonant errors in child athletes with functional speech disorders are more common than vowels. Among them, substitution is the most common form of consonant error, followed by distortions and omissions, and addition is rare. Its phonetic errors have the characteristics of simplifying. For example, in English pronunciation, it has the phonetic characteristics of omitting the last consonant, omitting the unstressed syllable, and replacing the fricative sound with simple explosive sound. In the Mandarin language family, the error rate of the apical which acquired after the age of 3.5 is the highest, and the error rate of the bilabial (/m /, /b /, /p /) which acquired at the age of 2.5 is the lowest, and the error rate of the non-aspirated voice that simplifies the pronunciation mode is higher than that of the aspirated voice. In Mandarin, vowels and nasal consonants /- n /, /- ng /form a vowel. The most common error types in vowels are omissions substitutions, on and distortions. The most common errors are nasal vowels such as /an /, /eng /, etc. When pronouncing with different vowels, the error types of consonants can change.

Child athletes voice gradually matures with age, vowels and tones are relatively easy to acquire, while most consonants are acquired before the age of 3.5, and consonants /k /, /g /, /c /are acquired at the age of 4.5-5. However, children with SSD often suffer from language retardation, so the assessment of language development process can understand whether their speech errors are consistent with the age of language development, and help to develop intervention programs for their development process. In addition, SSD child athletes can be combined with neurodevelopmental disorders such as attention deficit and hyperactivity disorder, while child athletes with mental disorders and autism spectrum disorders can also be combined with language development abnormalities, so neuropsychological evaluation based on the characteristics of the medical history cannot be ignored.

Without intervention, the speech errors of child athletes with functional speech disorders have no tendency to improve with age, while long-term mispronunciation may form abnormal neuromuscular movement patterns, so speech intervention is necessary. However, the diagnosis of such speech disorders is relatively difficult, and the complete diagnosis process should be completed by a multidisciplinary collaborative team composed of stomatology, otorhinolaryngology, psychiatry, rehabilitation, developmental behavioral pediatrics, etc. At present, most child athletes with SSD are treated in the department of stomatology and Child Healthcare department separately due to their age of onset or voice characteristics, and there are still irregularities in diagnosis and treatment due to insufficient understanding of the disease.

Conclusion

Abnormal speech perception system, expression system and nervous system are the common causes of SSD, and the causes of some child athletes with

SSD are still unclear. child athletes with abnormal speech perception system have the characteristics of slow speech speed, single intonation, exaggerated pronunciation and movement, and reduced range of tongue movement. child athletes with abnormal speech expression system may have abnormal resonance and nasal leakage due to velopharyngeal insufficiency, as well as abnormal dentition and tongue retraction. child athletes with SSD caused by abnormal nervous system have abnormal muscle movement patterns of lips, tongue and other organs, and may be accompanied by respiratory movement disharmony. Consonant errors are common in child athletes with functional speech disorders, and phonetic errors have the characteristics of simplifying pronunciation. When receiving SSD child athletes, the medical history inquiry should pay attention to the risk factors of hearing loss, abnormal oral structure, and abnormal development of nervous system. The physical examination of oral cavity and nervous system should be paid attention to. Diagnostic hearing test is necessary, and neuropsychological evaluation should be made in combination with the medical history. For child athletes with SSD caused by various causes, the primary disease should be actively treated. However, after hearing support and cleft lip and palate repair, there is still voice abnormality. At the same time, the voice errors of child athletes with functional speech disorders have no tendency to improve by themselves. Therefore, child athletes with SSD caused by all causes should be given speech training. The potential causes of child athletes with functional speech disorders need to be further explored, and the establishment of a multidisciplinary diagnosis and treatment model can promote the improvement of the prognosis of SSD.

Declaration of Competing Interest

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