

• 综述 •

发展性阅读障碍儿童听处理特征研究新进展

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摘要: 发展性阅读障碍是一种常见的学习障碍类型,通常表现为阅读速度过慢,单词识别与拼写困难,且这种神经性发育障碍不能用感觉或神经系统损伤、缺乏教育机会和学习动机或智力低下来解释。研究显示,这类患儿常存在听处理缺陷,但可能会被良好的外周听力掩盖,往往得不到足够重视。本文从神经解剖结构、行为学、电生理、内在神经机制、基因表型等多方面总结、探讨发展性阅读障碍儿童的听处理特征,为这类儿童的早期识别和康复干预提供科学依据。

关键词: 发展性阅读障碍; 特定学习障碍; 听处理; 儿童

中图分类号: R179 文献标识码: A 文章编号: 1008-6579(2025)03-0298-05 doi:10.11852/zgetbjzz2024-0205

Progress of auditory processing in children with developmental dyslexia

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Abstract: Developmental dyslexia is a common type of learning disability characterized by slow reading speed, difficulties in word recognition and spelling. This neurodevelopmental disorder cannot be explained by sensory or neurological impairment, lack of educational opportunities and learning motivation, or lower intelligence. Studies have shown that children with this condition often have auditory processing defects, which may be masked by good peripheral hearing and therefore often overlooked. This article summarizes and discusses the auditory processing characteristics of children with developmental dyslexia from multiple aspects, including neuroanatomical structures, behavioral studies, electrophysiology, intrinsic neural mechanisms, and genetic phenotypes, so as to provide scientific basis for early identification and rehabilitation intervention.

Keywords: developmental dyslexia; specific learning disabilities; auditory processing; children

阅读障碍,本文主要指发展性阅读障碍(developmental dyslexia, DD),是儿童在智力正常、有足够的学习教育机会、完整的感官能力的情况下,依旧在准确流畅地识别单词和拼写方面存在困难。全球小学生 DD 总患病率为 7.10%,且男童患病率明显高于女童^[1]。在我国约有 2 000 万儿童患有 DD^[2],应当给予足够的重视。

阅读障碍的形成机制尚未完全清楚,遗传、神经发育、环境等多方面的因素都可能参与了阅读障碍的形成。在既往的研究中,阅读障碍曾一度被认为是一种遗传性的视觉问题,但随着认知的不断深入,现在研究者们更倾向于认为这是一种语音技能的缺陷。从广义上讲,语音技能可以定义为关注和处理

语言分段结构的能力,完善的听觉处理是发展合格语音技能的众多先决条件之一,听者需要准确识别处理语音中多种复杂的听觉信号,包括音高和振幅的动态变化等^[3]。除此之外,视觉或注意力也共同参与阅读障碍的形成机制。虽然语音技能缺陷并不能完全单一地解释阅读障碍,但这类儿童的语音技能受损这一观点在众多研究中都得到了证明。有大量研究发现阅读障碍儿童在听处理方面表现出明显缺陷。相关研究主要分为两种研究路线,分别强调不同的认知通路。首先,自下而上的学说认为,较差的基本听处理能力是语音缺陷的基础,低水平神经组织对听觉信号的异常编码可导致大脑皮质异常激活,引起拼读等更高层次的问题。另一种自上而下

基金项目: 江苏省妇幼保健协会(FYX202340);南京市卫生科技发展项目(YKK23152);南京医科大学科技发展基金一般项目(NMUB20220102)

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的学说认为,中枢听觉对词汇及亚词汇等高层次的语言处理过程存在异常,由此导致低级听觉中枢的神经同步性较差,继而引发更普遍的一般听觉问题。这两种不同层次的缺陷可同时存在,共同影响儿童的阅读学习能力。

由于大部分阅读障碍儿童拥有正常的基础听力,他们的听处理缺陷往往未能引起足够的重视。本文旨在通过行为学、电生理、神经机制等不同方面,总结阅读障碍儿童的听处理相关特征,为这类儿童的早期识别、干预寻找更多的依据及改善可能。

1 阅读障碍儿童听处理特征的横断面研究

1.1 阅读障碍儿童中枢神经功能改变 在正常人群中,颞平面(planum temporale, PT) 往往表现出向左的不对称性,即左侧颞平面更大。这一区域长期以来被认为在言语理解中起重要作用。Bloom 等^[4]发现阅读障碍儿童存在颞平面的形态异常,即与正常人群相比他们的右侧颞平面更大,由此导致不对称性明显降低。而 Beelen 等^[5]在研究中则发现,与阅读障碍相关的群体的早期差异主要存在于阅读网络的腹侧区域,即梭状回。该研究调查了 54 名儿童在阅读前阶段的灰质表面积和皮质厚度,发现表现出阅读障碍的阅读前儿童双侧梭状回表面积减少。此外,在双侧颞下回和中回区域观察到与阅读障碍家庭风险相关的表面积减少。在神经功能方面,目前已有大量研究表明大脑的两个半球在许多领域都具有不对称性^[6-7],其中听觉系统也存在明显的偏侧化,例如,左右听觉皮层的神经反应分别与频谱和时间调制的处理有关^[8]。而阅读障碍儿童的偏侧化受损往往影响其语音技能。在 Kuhl 等^[9]的研究中,相较于对照组儿童,阅读障碍儿童的听觉皮层褶皱增加,且大脑左半球网络(包括听觉皮层,颞平面,运动前皮层,弓形束)功能和结构连通性改变。Cao 等^[10]发现,在听觉押韵判断任务中,与年龄或阅读匹配的对照组相比,阅读障碍儿童左背侧额下回的大脑激活减少,且同一区域的大脑激活与阅读技能之间存在正相关。

1.2 阅读障碍儿童的听处理功能改变 目前关于听处理能力的评估主要分为 3 个方面:非正式评估与量表,行为学测试以及更加客观的电生理测试,本文重点介绍后两者。

1.2.1 行为学结果 在针对语音缺陷的研究中,有一个较为普遍的争议在于,阅读障碍儿童听处理缺陷是一般听觉感知水平的缺陷,还是具有言语特异性的高阶感知缺陷。

Rosen 等^[11]观察到阅读障碍人群在言语条件下表现出的缺陷较非言语类似物条件更加明显。Breier 等^[12]观察到,阅读障碍儿童对刺激间期(interstimulus interval, ISI)无特定的敏感性,且在言语任务中相较于对照组表现更差。类似的实验结果似乎支持言语特异性假说。除此以外,大量研究报道了许多声学特征的听觉异常处理,例如:频率、音高、上升时间等^[13]。Ozernov-Palchik 等^[14]研究发现,阅读障碍儿童和成人的音调频率辨别阈值升高,语音识别准确性降低,对言语的感知适应能力下降。这些结果表明,阅读障碍人群在语言和非语言领域存在广泛的听觉认知缺陷,但特定于言语的适应缺陷同样存在。20 世纪末,Tallal^[15]发现部分儿童在婴儿期存在异常的听觉时间处理,进而导致阅读障碍儿童对快速听觉成分的辨别和分类困难。之后大量研究发现,阅读障碍人群对言语和非言语听觉刺激的反应相较于正常人群普遍更差,但如果将刺激呈现速度减慢,则任务表现会得到一定提升。除此以外,另一项假说大细胞通路缺陷理论认为,阅读障碍人群神经系统中大细胞通路受损,除了影响注意力的顺序分配以外,还会造成听觉和视觉排序等多方面的困难,在听觉方面主要表现为时间加工缺陷^[16]。近年来,时间采样理论^[17]也受到越来越多的关注。在接受声学语音信号时,中枢听觉系统在不同频率通道和不同时间尺度上对自然声音的幅度调制进行编码,而时间采样理论整合了振幅包络起始时处理振幅变化率(上升时间)的困难,以及低频 θ 和 δ 振荡机制对输入的时间采样受损的观点。与这一研究理论相符,节奏通常表现为个体对简单节拍和节奏序列的感知及生成,在语言韵律和语音中起着组织作用,阅读障碍儿童在语音技能上往往表现出相应的节奏困难^[18]。Goswami 等^[19]的研究显示,阅读障碍儿童在节拍检测任务(beat-perception task)中表现明显差于正常发育儿童,认为阅读障碍儿童准确处理振幅包络起始能力受损。Bégel 等^[20]在节拍准确测试(beat alignment test, BAT)中同样发现,阅读障碍儿童在预测时间方面表现不佳,且这种缺陷独立于一般运动和认知功能。然而,也有研究发现,节拍任务的时间预测与阅读测量之间并无明显相关性,这也可能受到节拍任务本身的难度影响^[21]。另外,Zhang 等^[22]发现,阅读障碍儿童在某些复杂条件下,例如干扰性言语条件,也表现出一定缺陷:单词识别能力受损。

1.2.2 客观电生理依据 神经系统感受内外刺激过程中会产生各种各样的生物电活动,如给予听觉

刺激时大脑可以产生与刺激声相关的生物电变化,而这类变化能被不同的电生理测试捕捉到。相较于行为学测试,电生理测试更加客观准确,且不受受试者的主观认知背景及配合度影响。

在语音识别的相关任务中,大多数阅读障碍儿童在电生理检测中表现为反应减弱^[23]。Azaiez 等^[24]通过包含母语和外语语音项目的被动听觉古怪范式进行测试,阅读障碍儿童表现出失匹配反应(mismatch response,MMR)不稳定、振幅较低,和晚期判别负性(late discriminative negativity,LDN)反应不显著。Maciejewska 等^[25]研究中发现,阅读障碍儿童事件相关电位(event-related potentials,ERPs)检出率较正常儿童明显偏低,且 P300 潜伏期明显延长。Cainelli 等^[26]发现,即使在安静状态下,与正常儿童相比 DD 儿童在脑电图测量上也表现出差异,特别是 δ 和 θ 频率的增强,和 α 频率的减弱。

2 听处理在阅读障碍儿童中的预测价值

在研究阅读障碍儿童听处理缺陷特征的同时,期望听处理能力可以作为预测鉴别阅读障碍儿童的指标,为临床诊断干预提供帮助。根据先前的一些研究成果,时间和频谱处理能力与语音意识、阅读和拼写发展之间存在联系。在一项新生儿 ERP 研究中,典型阅读儿童的大脑反应在不同的刺激频率之间存在明显差异,而在具有阅读障碍家族风险的儿童组未观察到^[27]。这种异常结果与儿童在二年级时的音素时长感知、阅读速度和拼写准确性显著相关。Mittag 等^[28]一项针对 6 个月和 12 个月婴儿的早期研究中使用脑磁图(magnetoencephalography,MEG)发现,与健康婴儿相比,有 DD 风险的高危婴儿的左半球听觉皮层的激活更大且时间更长,即这类婴儿早期处理简单声音的效率更低,且在后续的生长发育中转向非典型激活。进一步研究发现,这种非典型听觉反应始终预测他们 18~30 月龄期间的句法处理和 18~21 月龄期间的单词生成。在对年龄更大的儿童研究中,Goswami 等^[29]同时使用了语音意识任务和一般听觉感知任务,研究发现 8 岁儿童的一般听觉感知任务中的听处理能力可以作为有别于语音意识的 3 年后阅读能力的独立预测因子。

3 提升学习阅读能力的有效干预措施

目前已有研究发现,当听觉系统仍在发育时,音乐训练对中枢听觉处理和感知有很强的积极影响^[30]。Paula 等^[31]对具有阅读障碍风险的婴儿分别

进行了器乐干预或声乐干预,并设置无干预对照组,结果在 6 个月和 28 个月的随访中发现,接受声乐干预的阅读障碍风险儿童的语音辨别能力得到了增强。Frey 等^[32]研究发现,相较于其他类型的训练,阅读障碍儿童在音乐训练后的语音起始时间(voice onset time,VOT)的前注意处理趋于正常化,且在失匹配负波(mismatch negative,MMN)中对持续时间的偏差刺激 N250 振幅增加。考虑到阅读障碍与言语感知之间的紧密联系,许多研究选择针对言语的训练措施来加强 DD 儿童的阅读能力。Van Herck 等^[33]发现,具有阅读障碍风险的学龄前儿童,在进行包络增强的聆听故事训练后,在幼儿园期间的上升时间辨别就有所改善,且这种提升在小学一年级时保持稳定。Lovio 等^[34]在一项针对语音意识的短时间训练中,儿童仅接受参与了 3h 的音素-字母匹配游戏,结果显示他们在阅读相关技能方面取得的进步超过了按照类似训练格式进行数学练习的对照组,且这种进步可以在 MMN 中得到检验。Cancer 等^[35]选择使用节奏性阅读训练(rhythmic reading training,RRT),将音乐和语言融合在一起,材料中声学刺激以节拍器的方式呈现:弱拍和强拍交替,训练中儿童需大声朗读屏幕上呈现的与声音节奏同步的语言刺激。结果显示 RRT 能显著提高阅读障碍儿童的假词阅读速度。目前现有研究中,阅读障碍最有效的干预方法是音乐训练以及听觉和音乐干预与阅读活动相结合的训练^[36]。

除了行为训练以外还有多种科学技术用于干预阅读障碍人群的阅读能力。非侵入性脑刺激(non-invasive brain stimulation,NIBS)技术通常被用来探索大脑区域与特定任务的相关性,如今也被越来越多地用于改善认知及运动功能。Rufener 等^[37]发现经颅交流电刺激(alternating current stimulation,tACS)对阅读障碍儿童的音素分类任务明显改善,且在脑电图中能记录到振幅(P50-N1)增加。除此以外还可以通过优化环境和提高信号等多方面辅助阅读障碍儿童的学习质量。Hornickel 等^[38]研究发现辅助听力设备:教室调频系统(classroom FM systems)可以通过提高声音清晰度和注意力来减少阅读障碍儿童听觉处理皮层的变异性,增强语音意识和阅读能力。在一项最近的研究中,部分就读于特殊学校的语言障碍儿童在佩戴教室调频系统后语音意识技能得到了显著提升^[39]。

综上所述,DD 儿童可能在多方面的听觉信息处理存在不同认知层面的缺陷,且随着研究的不断深入,这种听处理缺陷的特征表现与形成机制正逐

步明晰,但由于不同研究的结果之间存在一定差异,未来仍需进一步深入探讨。另外,目前多种从不同方向出发的干预方法经过临床实践验证能够有助于 DD 儿童的改善提升,未来期望能够获得更加有效、更易泛化推广的系统化干预手段,最大限度地帮助这类儿童提高阅读学习适应能力。

参考文献

- [1] Yang LP, Li CB, Li XM, et al. Prevalence of developmental dyslexia in primary school children: A protocol for systematic review and meta-analysis[J]. *World J Pediatr*, 2022, 18(12): 804-809.
- [2] Cai L, Chen Y, Hu X, et al. An epidemiological study of Chinese children with developmental dyslexia[J]. *J Dev Behav Pediatr*, 2020, 41(3): 203-211.
- [3] Witton C, Swoboda K, Shapiro LR, et al. Auditory frequency discrimination in developmental dyslexia: A Meta-analysis[J]. *Dyslexia*, 2020, 26(1): 36-51.
- [4] Bloom JS, Garcia-Barrera MA, Miller CJ, et al. Planum temporale morphology in children with developmental dyslexia[J]. *Neuropsychologia*, 2013, 51(9): 1684-1692.
- [5] Beelen C, Vanderauwera J, Wouters J, et al. Atypical gray matter in children with dyslexia before the onset of reading instruction[J]. *Cortex*, 2019, 121: 399-413.
- [6] Mundorf A, Peterburs J, Ocklenburg S. Asymmetry in the central nervous system: A clinical neuroscience perspective[J]. *Front Syst Neurosci*, 2021, 15: 733898.
- [7] Ocklenburg S, Mundorf A, Gerrits R, et al. Clinical implications of brain asymmetries[J]. *Nat Rev Neurol*, 2024, 20(7): 383-394.
- [8] Zatorre RJ. Hemispheric asymmetries for music and speech: Spectrotemporal modulations and top-down influences[J]. *Front Neurosci*, 2022, 16: 1075511.
- [9] Kuhl U, Neef NE, Kraft I, et al. The emergence of dyslexia in the developing brain[J]. *Neuroimage*, 2020, 211: 116633.
- [10] Cao F, Yan X, Wang Z, et al. Neural signatures of phonological deficits in Chinese developmental dyslexia[J]. *Neuroimage*, 2017, 146: 301-311.
- [11] Rosen S, Manganari E. Is there a relationship between speech and nonspeech auditory processing in children with dyslexia? [J]. *J Speech Lang Hear Res*, 2001, 44(4): 720-736.
- [12] Breier JJ, Gray LC, Fletcher JM, et al. Perception of speech and nonspeech stimuli by children with and without reading disability and attention deficit hyperactivity disorder[J]. *J Exp Child Psychol*, 2002, 82(3): 226-250.
- [13] Gu C, Bi HY. Auditory processing deficit in individuals with dyslexia: A Meta-analysis of mismatch negativity[J]. *Neurosci Biobehav Rev*, 2020, 116: 396-405.
- [14] Ozernov-Palchik O, Beach SD, Brown M, et al. Speech-specific perceptual adaptation deficits in children and adults with dyslexia[J]. *J Exp Psychol Gen*, 2022, 151(7): 1556-1572.
- [15] Tallal P. Auditory temporal perception, phonics, and reading disabilities in children[J]. *Brain Lang*, 1980, 9(2): 182-198.
- [16] 许仲青, 邢强. 发展性阅读障碍的认知干预: 基于大细胞通路缺陷理论[J]. *教育生物学杂志*, 2023, 11(4): 329-335. Xu ZQ, Xing Q. Cognitive intervention on developmental dyslexia: Based on theory of magnocellular pathway deficit [J]. *Journal of Bio-education*, 2023, 11(4): 329-335. (in Chinese)
- [17] Goswami U. A temporal sampling framework for developmental dyslexia[J]. *Trends Cogn Sci*, 2011, 15(1): 3-10.
- [18] 李运端, 马小凤, 胡钰. 发展性阅读障碍儿童潜在的早期识别标志——节奏异常及其特点[J]. *心理科学进展*, 2023, 31(12): 2306-2318. Li YD, Ma XF, Hu Y. Potential early identification markers for children with developmental dyslexia: Atypical rhythm and its characteristics[J]. *Advances in Psychological Science*, 2023, 31(12): 2306-2318. (in Chinese)
- [19] Goswami U, Thomson J, Richardson U, et al. Amplitude envelope onsets and developmental dyslexia: A new hypothesis[J]. *Proc Natl Acad Sci U S A*, 2002, 99(16): 10911-10916.
- [20] Bégel V, Dalla Bella S, Devignes Q, et al. Rhythm as an independent determinant of developmental dyslexia[J]. *Dev Psychol*, 2022, 58(2): 339-358.
- [21] Taha J, Carioti D, Stucchi N, et al. Identifying the risk of dyslexia in bilingual children: The potential of language-dependent and language-independent tasks[J]. *Front Psychol*, 2022, 13: 935935.
- [22] Zhang L, Li Y, Zhou H, et al. Sentence context differentially modulates contributions of fundamental frequency contours to word recognition in Chinese-speaking children with and without dyslexia [J]. *Front Psychol*, 2020, 11: 598658.
- [23] Lohvansuu K, Hämäläinen JA, Tanskanen A, et al. Enhancement of brain event-related potentials to speech sounds is associated with compensated reading skills in dyslexic children with familial risk for dyslexia[J]. *Int J Psychophysiol*, 2014, 94(3): 298-310.
- [24] Azaiez N, Loberg O, Lohvansuu K, et al. Discriminatory brain processes of native and foreign language in children with and without reading difficulties[J]. *Brain Sci*, 2022, 13(1): 76.
- [25] Maciejewska B, Wiskirska-Woźnica B, Świdziński P, et al. Assessing auditory processing disorders in children with developmental dyslexia using auditory cognitive event-related potentials[J]. *Folia Phoniatr Logop*, 2013, 65(3): 129-135.
- [26] Cainelli E, Vedovelli L, Carretti B, et al. EEG correlates of developmental dyslexia: A systematic review[J]. *Ann Dyslexia*, 2023, 73(2): 184-213.
- [27] Leppänen PH, Hämäläinen JA, Salminen HK, et al. Newborn brain event-related potentials revealing atypical processing of sound frequency and the subsequent association with later literacy skills in children with familial dyslexia [J]. *Cortex*, 2010, 46(10): 1362-1376.

- [28] Mittag M, Larson E, Clarke M, et al. Auditory deficits in infants at risk for dyslexia during a linguistic sensitive period predict future language[J]. *Neuroimage Clin*, 2021, 30: 102578.
- [29] Goswami U, Huss M, Mead N, et al. Auditory sensory processing and phonological development in high IQ and exceptional readers, typically developing readers, and children with dyslexia: A longitudinal study[J]. *Child Dev*, 2021, 92(3): 1083-1098.
- [30] Schneider P, Groß C, Bernhofs V, et al. Short-term plasticity of neuro-auditory processing induced by musical active listening training[J]. *Ann N Y Acad Sci*, 2022, 1517(1): 176-190.
- [31] Paula V, Vesa P, Anastasia G, et al. Beneficial effects of a music listening intervention on neural speech processing in 0-28-month-old children at risk for dyslexia[J]. *Dev Sci*, 2023, 26(5): e13426.
- [32] Frey A, François C, Chobert J, et al. Music training positively influences the preattentive perception of voice onset time in children with dyslexia: A longitudinal study[J]. *Brain Sci*, 2019, 9(4):91.
- [33] Van Herck S, Vanden Bempt F, Economou M, et al. Ahead of maturation: Enhanced speech envelope training boosts rise time discrimination in pre-readers at cognitive risk for dyslexia[J]. *Dev Sci*, 2022, 25(3): e13186.
- [34] Lovio R, Halttunen A, Lyytinen H, et al. Reading skill and neural processing accuracy improvement after a 3-hour intervention in preschoolers with difficulties in reading-related skills[J]. *Brain Res*, 2012, 1448: 42-55.
- [35] Cancer A, Bonacina S, Antonietti A, et al. The effectiveness of interventions for developmental dyslexia: Rhythmic reading training compared with hemisphere-specific stimulation and action video games[J]. *Front Psychol*, 2020, 11: 1158.
- [36] Cancer A, Antonietti A. Music-based and auditory-based interventions for reading difficulties: A literature review[J]. *Heliyon*, 2022, 8(4): e09293.
- [37] Rufener KS, Krauel K, Meyer M, et al. Transcranial electrical stimulation improves phoneme processing in developmental dyslexia[J]. *Brain Stimul*, 2019, 12(4): 930-937.
- [38] Hornickel J, Zecker SG, Bradlow AR, et al. Assistive listening devices drive neuroplasticity in children with dyslexia[J]. *Proc Natl Acad Sci U S A*, 2012, 109(41): 16731-16736.
- [39] Reynolds G, Werfel K. Impact of FM system use on acquisition of phonological awareness skills for children at risk of dyslexia: A preliminary classroom study[J]. *Am J Speech Lang Pathol*, 2022, 31(5): 2078-2091.

收稿日期:2024-02-28 修回日期:2024-09-08 本文编辑:李少闻

(上接第 287 页)

- [J]. *E Clinical Medicine*, 2022, 48:101452.
- [14] 关宏岩,赵星,屈莎,等. 学龄前儿童(3~6岁)运动指南[J]. *中国儿童保健杂志* 2020, 28(6):714-720.
Guan HY, Zhao X, Qu S, et al. Physical activity guideline for preschoolers aged 3~6 years[J]. *Chin J Child Health Care*, 2020, 28(6): 714-720. (in Chinese)
- [15] Al-Nuaim A, Safi A. Factors influencing saudi youth physical activity participation: A qualitative study based on the social ecological model[J]. *Int J Environ Res Public Health*, 2023, 20(10):5785.
- [16] Morgan PJ, Young MD, Barnes AT, et al. Engaging fathers to increase physical activity in girls: The "dads and daughters exercising and empowered" (DADEE) randomized controlled trial[J]. *Ann Behav Med*, 2019, 53(1): 39-52.
- [17] Lee CY, Ledoux TA, Johnston CA, et al. Association of parental body mass index (BMI) with child's health behaviors and child's BMI depend on child's age[J]. *BMC obes*, 2019, 6(11): 1-10.
- [18] Prince SA, Roberts KC, Melvin A, et al. Gender and education differences in sedentary behaviour in Canada: An analysis of national cross-sectional surveys[J]. *BMC Public Health*, 2020, 20: 1-17.
- [19] Matsushita M, Takagi D, Kamada M. Socioeconomic status and patterns of physical activity and sedentary behavior: A cross-sectional analysis of the J-SHINE[J]. *J Phys Act Health*, 2024, 1(aop): 1-8.
- [20] Welis W, Yendrizal D, Mario DT. Physical fitness of students in Indonesian during the COVID-19 period: Physical activity, body mass index, and socioeconomic status[J]. *Physical Activity Review*, 2023, 11(1): 77-87.
- [21] Kang S, Kim D-H, Lee J. The role of a community-based leisure program for older adults' leisure-time physical activity: A focus on the social-ecological model[J]. *Sustainability*, 2023, 15(20):14851.
- [22] Ke Y, Shi L, Peng L, et al. Associations between socioeconomic status and physical activity: A cross-sectional analysis of Chinese children and adolescents[J]. *Front Psychol*, 2022, 13: 904506.
- [23] Eyimaya AO, Irmak AY. Relationship between parenting practices and children's screen time during the COVID-19 Pandemic in Turkey[J]. *J Pediatr Nurs*, 2021, 56: 24-29.
- [24] Matarma T, Koski P, Löyttyniemi E, et al. The factors associated with toddlers' screen time change in the STEPS Study: A two-year follow-up[J]. *Prev Med*, 2016, 84: 27-33.
- [25] Lloyd AB, Lubans DR, Plotnikoff RC, et al. Maternal and paternal parenting practices and their influence on children's adiposity, screen-time, diet and physical activity[J]. *Appetite*, 2014, 79: 149-157.
- [26] Zahra J, Sebire SJ, Jago R. "He's probably more Mr. sport than me"—a qualitative exploration of mothers' perceptions of fathers' role in their children's physical activity[J]. *BMC Pediatr*, 2015, 15:101.
- [27] Ashton LM, Rayward AT, Pollock ER, et al. Twelve-month outcomes of a community-based, father-daughter physical activity program delivered by trained facilitators[J]. *Int J Behav Nutr Phys Act*, 2024, 21(1): 101.

收稿日期:2025-01-08 修回日期:2025-02-13 本文编辑:李少闻