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· 综 述 ·

数字锻炼游戏在儿童青少年健康促进中的应用进展

刘文烁[1],金宗强[1],王璇[1],王巍[2]

1.天津体育学院运动训练学院,天津 301617;2.山东第二医科大学基础医学院

【摘要】 近年来,基于动作捕捉及体感交互技术的数字锻炼游戏逐渐兴起,并成为一种新的运动潮流。由于数字锻炼游戏巧妙融合了体力活动与电子游戏的双重属性,从而使其在提升儿童青少年健康水平方面展现出巨大的优势。研究旨在通过系统分析数字锻炼游戏对儿童青少年身体成分、运动能力、肌肉力量与骨密度、心血管健康、执行功能以及情绪方面的干预效果,以期为改善中国儿童和青少年健康状况探索新的途径与方法。

【关键词】 电子游戏;运动活动;健康促进;儿童;青少年

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Application progress of digital exercise games in health promotion among children and adolescents

LIU Wenshuo*, JIN Zongqiang, WANG Xuan, WANG Wei

* *School of Sports Training, Tianjin University of Sport, Tianjin* 301617, *China*

【**Abstract**】 In recent years, digital exercise games based on motion capture and body-sensing interaction technologies have gradually emerged and become a new trend in sports. Due to the ingenious integration of physical activity and electronic games, digital exercise games have demonstrated significant advantages in improving the health of children and adolescents. The paper aims to systematically analyze the intervention effects of digital exercise games on children and adolescents' body composition, motor ability, muscle strength and bone density, cardiovascular health, executive function as well asemotions, aiming to explore new approaches and methods to improve the health status of children and adolescents in China.

【**Keywords**】 Video games; Motor activity; Health promotion; Child; Adolescent

近年来,基于动作捕捉及体感交互技术的数字锻炼游戏逐渐兴起,并成为一种新的运动潮流。这种融合了体力活动与游戏元素的新型运动形式,不仅在改善儿童青少年健康状况方面具有积极效果[1],同时在提高锻炼依从性、增加运动时间、培养锻炼习惯方面展现出较大潜力[2-3]。目前,国内数字锻炼游戏领域已涌现出诸多产品,代表性的硬件设备能够通过多种交互技术提升儿童青少年的运动沉浸感与参与动机;同时,以国产应用“天天跳绳”为代表的软件平台整合了丰富的数字锻炼游戏,且已尝试应用于体育教育实践[4]。本文旨在通过梳理数字锻炼游戏促进儿童青少年健康状况的干预效果,为提高我国儿童青少年健康状况提供新的方法与途径。

1 数字锻炼游戏应用于儿童青少年健康促进的效果

1.1 *数字锻炼游戏对身体成分的干预效果* 数字锻炼游戏改善超重或肥胖儿童青少年身体成分的有效性已得到多维研究证据支持。家庭场景下,Staiano等[2]对超重儿童实施 24 周居家数字锻炼游戏干预后,体质量指数(body mass index,BMI) Z 值较对照组显著降低。社区环境下,Christison 等[5]研究显示,10 周基于社区的干预方案同样能降低受试儿童 BMI,表明不同环境下的数字锻炼游戏干预均能有效改善身体成分,为家校协同采用数字锻炼游戏改善身体成分提供了参考。同时 Adamo 等[6]研究发现,数字骑行游戏与常规音乐骑行均可使受试者体脂百分比显著降低,且两者效果相似,强化了该锻炼方式在减脂方面的积极效果。此外,有研究结果显示超重肥胖青少年间歇性断食期间进行 4 周数字锻炼游戏干预后,体重、BMI、体脂显著下降,且下降幅度优于仅控制饮食的对照组[7],证实了合理运动及饮食控制在改善身体成分方面的有效性,可通过数字锻炼游戏与饮食控制相结合帮助儿童青少年减重。

1.2 *数字锻炼游戏对运动能力的干预效果* 有氧能力是除体温、脉搏、呼吸、血压之外的另一重要生命体征[8]。当前部分研究表明,数字锻炼游戏能够改善儿

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【作者简介】 刘文烁(1996-),男,山东潍坊人,在读博士,主要研究方向为体力活动与健康促进。

【通信作者】 金宗强,E-mail:zongqiangjin@126.com

童青少年有氧能力[6,9-11]。7~12 岁超重儿童经过 12 周电子舞蹈游戏干预后,摄氧量峰值、分级运动测试成绩均有所提高,且与对照组相比有显著差异[11]。超重或肥胖青少年干预 10 周后,有氧测试中峰值心率、峰值工作负荷以及疲劳时间均有显著改善,其效果与自行车耐力训练相似[6],提示数字锻炼游戏可作为一种耐力骑行的代替方案改善有氧能力。但也有研究得到了不同结果,有研究报道超重或肥胖儿童经过 6 周(每周 3 次,每次 30 min)的数字锻炼游戏后,峰值摄氧量未发生显著性变化;深入分析发现,该研究每次训练的运动负荷较低且干预时长较短,可能因未达到推荐的负荷标准导致干预无效[12]。因此,采用数字锻炼游戏改善有氧能力时需适当提高训练量与强度,以确保整体运动负荷达到改善有氧能力所需阈值。

平衡能力是身体在运动或受到外力作用时维持姿势稳定的能力[13]。近年来,基于虚拟现实技术的数字锻炼游戏通过多模态感官整合与即时反馈机制,为改善平衡能力提供了新的解决方案。Harkness-Armstrong 等[14]研究显示,发育型协调障碍儿童在基于 Switch 的数字锻炼游戏训练后,运动能力成套测试得分在干预第 6 周显著提高;而在健康群体中进一步证实,8 周 Kinect 平衡游戏可使静态与动态平衡能力同步改善[15]。此外,有研究发现受试儿童仅经过 5 周(每周 2 次,每次 20 min)训练,平衡标准评分即有显著改善,且效果在训练干预 4 个月后仍然存在,表明短期训练可对受试者平衡能力带来长期稳定的干预效果[16]。由此可见,数字锻炼游戏是改善平衡能力的有效方式,可能与虚拟环境通过前庭—视觉耦合增强空间定位精度以及数字锻炼游戏实时重心轨迹反馈优化姿势调整策略有关。

同时,数字锻炼游戏在改善基本运动技能方面展现出独特优势[17]。Kwon 等[18]研究显示,发育障碍儿童 12 周数字锻炼游戏训练后,单脚连跳、立定跳、过肩投球、运球等基本运动技能得到显著改善。一项纳入 20 篇文献的 Meta 分析进一步证实,数字锻炼游戏在改善非典型发育儿童移动技能与非移动技能方面均有显著效果[19],且数字锻炼游戏在提升站立和行走等运动技能方面优于传统物理治疗[20]。事实上,儿童青少年基本运动技能与身体活动之间存在正相关[21],通过数字锻炼游戏提高儿童青少年基本运动技能,可能会帮助他们参与到更广泛的体育活动中进而改善整体健康状况。

1.3 数字锻炼游戏对肌肉力量与骨密度的干预效果 数字锻炼游戏对肌肉功能改善具有积极效应。Kwon 等[18]发现,受试儿童经过 12 周数字锻炼游戏干预后,立定跳远距离显著提高。但仅靠跳跃距离无法精确反映受试者力量变化,Bonney 等[22]通过 MicroFET2 数字测力仪测量受试者力量变化情况,结果显示数字锻炼游戏与任务导向的功能训练干预结果相似,均可使受试者膝关节伸展肌力、踝关节背屈肌力、跖屈肌力显著改善。此外,数字锻炼游戏在提高上肢力量方面同样有效[23],研究显示超重或肥胖儿童在干预 5 个月后上肢握力显著提升[24]。原因可能是数字锻炼游戏要求参与者通过挥拍、出拳等重复性肌肉收缩活动,诱导肌纤维横截面积增加及神经肌肉适应,进而改善了肌肉力量。

同时有研究发现,持续 12 周(每周 3 次,每次 60 min)舞蹈视频游戏后,超重或肥胖青少年女性躯干和脊柱骨密度显著改善[25],此举对于超重肥胖儿童青少年具有重要意义。通常而言,体脂与骨密度存在显著负相关[26],提示超重或肥胖儿童青少年可能因骨密度较低而增加骨质疏松与骨折风险,而数字锻炼游戏通过较高负荷促进骨骼发育,提高骨密度,进而降低骨质疏松与骨折发生率。

1.4 数字锻炼游戏对心血管健康的干预效果 Staiano 等[2]研究发现,24 周数字锻炼游戏干预后,超重或肥胖儿童舒张压与收缩压显著降低。有研究显示,每周 5 d 且持续 12 周的电子舞蹈游戏可使受试者平均动脉压下降(5.62 ± 7.03) mmHg (1 mmHg = 0.133 kPa)[11]。但也有部分研究得到了不同的结果,受试者一段时间训练后血压未出现显著改善[12,24],可能与运动强度不足有关。既往研究认为,运动强度是改善血压的关键因素,较高的运动强度会增加血流,进而促使血管活性物质释放降低血压[27]。可见,达到一定运动强度的数字锻炼游戏是降低血压的一种有效方式,有研究推荐采用 70%最大心率以上强度来诱导血压产生积极适应[28]。

现有研究证实,数字锻炼游戏能有效改善超重儿童内皮功能,受试者经过 12 周的训练后,其血流介导的舒张功能改善,且与对照组相比差异显著[11]。即使在高脂饮食后,一次视频运动游戏仍可使女性超重青少年血流介导的血管舒张功能(flow-mediated dilation, FMD)显著改善 16%[29]。通常而言,高脂饮食后 2~6 h血管功能会出现恶化[30],提示高脂饮食后可通过数字锻炼游戏来减轻对血管功能的损害。综上,长期数字锻炼游戏和急性数字锻炼游戏训练均可改善儿童青少年内皮细胞功能,内在机制可能为训练干预过程中增加血流对内皮细胞的剪切力,进而通过增加内皮型一氧化氮合酶的活性[31]以及骨骼肌收缩刺激抗炎细胞因子的释放,改善内皮功能[32]。

此外,Almeida-Ramos 等[33]探讨了数字锻炼游戏对超重或肥胖青少年血管微循环的影响,每周 3 次、持续 8 周的数字锻炼游戏训练后,超重或肥胖青少年最大血流、充血面积和闭塞后反应性充血有所改善,且

与对照组相比差异显著。数字锻炼游戏改善受试者血管微循可能在一定程度上降低动脉粥样硬化等严重心血管疾病的发生风险。

1.5 数字锻炼游戏对执行功能的干预效果 执行功能是在完成复杂的认知任务时对其他认知过程进行控制、调节的高级认知过程[34],患有神经发育障碍类疾病的儿童青少年额叶皮层发育较晚,执行功能普遍较弱[35]。研究已证实数字锻炼游戏是改善此类儿童青少年执行功能的有效方式,患有孤独症谱系障碍或注意缺陷多动障碍的儿童青少年在经过一段时间数字锻炼游戏干预后,执行功能均出现显著改善[36-37]。

数字锻炼游戏同样可以提升健康学前教育儿童执行功能。研究者将 4~5 岁受试者随机分为数字锻炼游戏组与常规体育活动组,干预前、干预 2 周和干预 4 周分别评估抑制控制、认知灵活性、工作记忆等执行功能,结果显示游戏组经过 4 周训练干预后,受试者抑制控制显著提升,而认知灵活性、工作记忆在 2 周后显著改善,且与常规体育活动组差异显著[38]。数字锻炼游戏干预过程中,运动强度与认知参与对儿童执行功能改善起到重要作用[39],其中一次性训练执行功能急性提升是运动强度引起的;而长期训练受试者执行功能改善是运动强度与认知参与共同作用的结果,且认知参与的作用大于运动强度[40]。提示在改善儿童青少年执行功能时不仅需要考虑运动强度,同时也要考虑数字锻炼游戏的认知参与因素。

1.6 数字锻炼游戏对情绪的干预效果 研究已证实数字锻炼游戏可以降低儿童青少年负面情绪。Lee 等[41]研究中,134 名小学三、四年级学生在 30 min 的数字锻炼游戏后,抑郁、焦虑负面情绪评分显著改善,原因可能与较强互动性的数字锻炼游戏训练方案促进了神经递质释放有关[42]。此外,该研究还发现干预后活力评分降低,可能是干预过程中运动负荷较高导致的,既往研究已表明过高的运动负荷会导致受试者活力评分降低[43]。

2 数字锻炼游戏应用于儿童青少年健康促进的策略

首先,结合儿童青少年年龄和身体发育状况,选择既能锻炼特定运动技能,又符合其理解与接受能力的数字锻炼游戏,如低龄儿童可选择跳绳、舞蹈类游戏练习协调性与节奏感,年龄较大青少年可选择复杂锻炼游戏提升综合能力。其次,不同运动负荷可产生差异化训练刺激,提高训练效果应根据个性化训练目标科学设计不同的运动负荷。例如要提高有氧能力需选择中高运动负荷,改善儿童青少年情绪则选择较低运动负荷。此外,鼓励儿童青少年选择多人游戏模式,与家人、朋友或同学组队运动营造锻炼氛围,增强数字锻炼游戏互动性与趣味性;同时,定期组织数字锻炼游戏比赛提高竞争性,让孩子在竞争中享受运动乐趣,提高锻炼坚持性、培养长期锻炼习惯。最后,家长或教师在儿童青少年数字锻炼游戏过程中进行全面监督,确保运动强度及运动量达到预期标准;同时对技术动作进行科学指导,及时发现错误动作并予以纠正,提高数字锻炼游戏干预效果并避免运动损伤发生。

3 小结与展望

数字锻炼游戏对改善儿童青少年身体成分、运动能力、肌肉力量与骨密度、心血管健康、执行功能以及情绪等健康状况效果显著。为提高数字锻炼游戏干预效果,可依据个体特征选择合理游戏内容,根据训练目标科学设计运动负荷,营造积极氛围强化锻炼坚持性,通过监督引导提高训练干预效果。

尽管当前已针对数字锻炼游戏进行了大量研究,但此领域仍存在以下局限:(1)随着干预时间延长,部分受试者因新鲜感消退出现参与度下降或中途退出情况,反映出长期参与机制方面尚存挑战;(2)多数数字锻炼游戏依赖专用体感设备、成本较高,在一定程度上限制其普及与应用;(3)目前针对国产数字锻炼游戏有效性相关证据仍需进一步充实。未来可从以下方面进一步深化研究:(1)探索通过游戏内容多样化和沉浸感提升维持长期参与的有效策略;(2)开发对硬件依赖较低、成本更优的数字锻炼方案,并验证其在大规模推广中的适用性与有效性;(3)加强国产数字锻炼游戏的研发与实证研究,为其在健康促进领域的科学应用提供依据。

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参考文献

[1] MORRIS P O, HOPE E, FOULSHAM T, et al. Exploring the use of a dance-based exergame to enhance autistic children's social communication skills in the home and school environments: a feasibility study [J]. Int J Dev Disabil, 2025, 71(1): 141-158.

[2] STAIANO A E, BEYL R A, GUAN W, et al. Home-based exergaming among children with overweight and obesity: a randomized clinical trial[J]. Pediatr Obes, 2018, 13(11): 724-733.

[3] FOGEL V A, MILTENBERGER R G, GRAVES R, et al. The effects of exergaming on physical activity among inactive children in a physical education classroom[J]. J Appl Behav Anal, 2010, 43(4): 591-600.

[4] 孙彬. "互联网+"背景下济南市小学体育家庭作业的设计与应用研究:以"天天跳绳"APP 为例[D]. 济南:山东体育学院, 2023.
SUN B. The experimental research of the design and application of physical education homework in primary schools in Jinan under the background of "Internet +": a case study of "Tian Tian Skipping Rope" APP[D]. Jinan: Shandong Sport University, 2023. (in Chinese)

[5] CHRISTISON A, KHAN H A. Exergaming for health: a community-

based pediatric weight management program using active video gaming [J]. Clin Pediatr, 2012, 51(4):382-388.

[6] ADAMO K B, RUTHERFORD J A, GOLDFIELD G S. Effects of interactive video game cycling on overweight and obese adolescent health[J]. Appl Physiol Nutr Metab, 2010, 35(6):805-815.

[7] ABEDELMALEK S, ALOUI K, DENGUEZLI B M, et al. Exergaming during Ramadan intermittent fasting improve body composition as well as physiological and psychological responses to physical exercise in adolescents with obesity[J]. Front Nutr, 2022, 9:851054.

[8] ROSS R, BLAIR S N, ARENA R, et al. Importance of assessing cardiorespiratory fitness in clinical practice:a case for fitness as a clinical vital sign:a scientific statement from the American Heart Association [J]. Circulation, 2016, 134(24):e653-e699.

[9] COMERAS-CHUECA C, VILLALBA-HEREDIA L, PEREZ-LASIERRA J L, et al. Effect of an active video game intervention combined with multicomponent exercise for cardiorespiratory fitness in children with overweight and obesity:randomized controlled trial[J]. JMIR Serious Games, 2022, 10(2):e33782.

[10] MASOUD A E, SHAHEEN A A M, ALGABBANI M F, et al. Effectiveness of exergaming in reducing cancer-related fatigue among children with acute lymphoblastic leukemia:a randomized controlled trial [J]. Ann Med, 2023, 55(1):2224048.

[11] MURPHY E C, CARSON L, NEAL W, et al. Effects of an exercise intervention using Dance Dance Revolution on endothelial function and other risk factors in overweight children[J]. Int J Pediatr Obes, 2009, 4(4):205-214.

[12] VAN BILJON A, LONGHURST G, SHAW I, et al. Role of exergame play on cardiorespiratory fitness and body composition in overweight and obese children[J]. Asian J Sports Med, 2021, 12(1):e106782.

[13] CHILLAKURU C R, JAMBU N, DEEPAK A. A comparison of the proprioception of osteoarthritic knees and post total knee arthroplasty [J]. Int J Res Orthop, 2017, 3(4):781-786.

[14] HARKNESS-ARMSTRONG C, HODSON-TOLE E, WOOD G, et al. Short report on a 6-week at-home exergaming intervention to improve balance in children with developmental coordination disorder [J]. Res Dev Disabil, 2025, 156:104900.

[15] ZHANG C, HAN T, TAN X, et al. Effect of exergame intervention on balance ability of adolescents: a randomized controlled trial [J]. Games Health J, 2023, 12(3):249-258.

[16] DRAGHI T T G, SMITS-ENGELSMAN B, GODOI-JACOMASSI D, et al. Short- and long-term changes in balance after active video game training in children with and without developmental coordination disorder:a randomized controlled trial[J]. Motor Control, 2024, 28(2):174-192.

[17] BRYANTON C, BOSSé J, BRIEN M, et al. Feasibility, motivation, and selective motor control: virtual reality compared to conventional home exercise in children with cerebral palsy[J]. Cyberpsychol Behav, 2006, 9(2):123-128.

[18] KWON H, MAENG H, CHUNG J. Development of an ICT-based exergame program for children with developmental disabilities[J]. J Clin Med, 2022, 11(19):5890.

[19] LI S, SONG Y, CAI Z, et al. Are active video games useful in the development of gross motor skills among non-typically developing children? A Meta-analysis[J]. BMC Sports Sci Med Rehabil, 2022, 14 (1):140.

[20] TOBAIQI M A, ALI ALBADAWI E, ALI FADLALMOLA H, et al. Application of virtual reality-assisted exergaming on the rehabilitation of children with cerebral palsy:a systematic review and Meta-analysis [J]. J Clin Med, 2023, 12(22):7091.

[21] LUBANS D R, MORGAN P J, CLIFF D P, et al. Fundamental movement skills in children and adolescents: review of associated health benefits[J]. Sports Med, 2010, 40(12):1019-1035.

[22] BONNEY E, FERGUSON G, BURGESS T, et al. Benefits of activity-based interventions among female adolescents who are overweight and obese[J]. Pediatr Phys Ther, 2019, 31(4):338-345.

[23] YE S, LEE J E, STODDEN D F, et al. Impact of exergaming on children's motor skill competence and health-related fitness:a quasi-experimental study[J]. J Clin Med, 2018, 7(9):261.

[24] COMERAS-CHUECA C, VILLALBA-HEREDIA L, PEREZ-LASIERRA J L, et al. Active video games improve muscular fitness and motor skills in children with overweight or obesity[J]. Int J Environ Res Public Health, 2022, 19(5):2642.

[25] STAIANO A E, MARKER A M, BEYL R A, et al. A randomized controlled trial of dance exergaming for exercise training in overweight and obese adolescent girls[J]. Pediatr Obes, 2017, 12(2):120-128.

[26] 高欢, 冯连世, 张漓, 等. 超重及肥胖青少年骨密度、骨矿含量与脂肪和去脂软组织质量关系的研究[J]. 中国运动医学杂志, 2015, 34(5):437-442.
GAO H, FENG L S, ZHANG L, et al. Relation of bone mineral density and bone mineral content to fat mass and lean soft tissue mass in overweight and obese adolescents[J]. Chin J Phys Med, 2015, 34 (5):437-442.(in Chinese)

[27] KIRCHER E, KETELHUT S, KETELHUT K, et al. A game-based approach to lower blood pressure? Comparing acute hemodynamic responses to endurance exercise and exergaming:a randomized crossover trial[J]. Int J Environ Res Public Health, 2022, 19(3):1349.

[28] HERNANDEZ-MARTINEZ J, PEREZ-CARCAMO J, MELKI H, et al. Effects of exergaming on morphological variables, biochemical parameters, and blood pressure in children and adolescents with overweight/obesity:a systematic review with Meta-analysis of randomized controlled trials[J]. Children, 2024, 12(1):29.

[29] PARK S H, YOON E S, LEE Y H, et al. Effects of acute active video games on endothelial function following a high-fat meal in overweight adolescents[J]. J Phys Act Health, 2015, 12(6):869-874.

[30] PADILLA J, HARRIS R A, FLY A D, et al. The effect of acute exercise on endothelial function following a high-fat meal[J]. Eur J Appl Physiol, 2006, 98(3):256-262.

[31] JUNGERSTEN L, AMBRING A, WALL B, et al. Both physical fitness and acute exercise regulate nitric oxide formation in healthy humans[J]. J Appl Physiol, 1997, 82(3):760-764.

[32] STEENSBERG A, VAN HALL G, OSADA T, et al. Production of interleukin-6 in contracting human skeletal muscles can account for the exercise-induced increase in plasma interleukin-6[J]. J Physiol, 2000, 529(Pt 1):237-242.

[33] ALMEIDA-RAMOS T D, MEDEIROS C C M, FIGUEIROA J N, et al. Effects of exergaming on the microcirculation of adolescents with overweight or obesity:a clinical trial efficacy[J]. Appl Physiol Nutr Metab, 2023, 48(5):379-385.

(下转第 1672 页)

velopment of the FitSight fitness tracker to increase time outdoors to prevent myopia[J]. Transl Vis Sci Technol, 2017, 6(3): 20.

[31] YE B, LIU K, CAO S, et al. Discrimination of indoor versus outdoor environmental state with machine learning algorithms in myopia observational studies[J]. J Transl Med, 2019, 17(1): 314.

[32] SIMPSON C E M, CURTIS R G, VIRGARA R, et al. Financial incentives for physical activity and sports participation in young people[J]. Exerc Sport Sci Rev, 2024, 52(3): 108-114.

[33] LEE Y, KEEL S, YOON S. Evaluating the effectiveness and scalability of the World Health Organization Myopia Ed digital intervention: mixed methods study[J]. JMIR Public Health Surveill, 2024, 10: e66052.

[34] LESTER R T, RITVO P, MILLS E J, et al. Effects of a mobile phone short message service on antiretroviral treatment adherence in Kenya (WelTel Kenya1): a randomised trial[J]. Lancet, 2010, 376(9755): 1838-1845.

[35] LEE J P, LEE Y S. Structural equation model of elementary school students' quality of life related to smart devices usage based on PRECEDE model[J]. Int J Environ Res Public Health, 2021, 18(8): 4301.

[36] MCCRANN S, FLITCROFT I, LALOR K, et al. Parental attitudes to myopia: a key agent of change for myopia control? [J]. Ophthalmic Physiol Opt, 2018, 38(3): 298-308.

[37] ZENG J, QIU N, LEITZELAR B N, et al. Parental support is associated with moderate to vigorous physical activity among Chinese adolescents through the availability of physical activity resources in the home environment and autonomous motivation[J]. Children, 2022, 9(9): 1309.

[38] DE CAMARGO E M, DA COSTA C G, PIOLA T S, et al. Is greater social support from parents and friends related to higher physical activity levels among adolescents? [J]. Children, 2023, 10(4): 701.

[39] RODRIGUES F, MONTEIRO D, LOPES V P. The mediation role of perceived benefits and barriers in the relationship between support provided by significant others and physical activity of adolescents[J]. Percept Mot Skills, 2023, 130(2): 902-922.

[40] KHAN A, UDDIN R. Parental and peer supports are associated with an active lifestyle of adolescents: evidence from a population-based survey[J]. Public Health, 2020, 188: 1-3.

[41] SHI J J, WANG Y J, LYU P P, et al. Effects of school myopia management measures on myopia onset and progression among Chinese primary school students[J]. BMC Public Health, 2023, 23(1): 1819.

[42] 王丽蒙, 王向东, 史慧静. 中小学生近视相关健康信念与户外活动的相关性研究[J]. 上海预防医学, 2019, 31(5): 344-348.
WANG L M, WANG X D, SHI H J. Correlation between myopia related health beliefs and outdoor activities among primary and middle school students[J]. Shanghai J Prev Med, 2019, 31(5): 344-348. (in Chinese)

[43] 李良, 徐建方, 路瑛丽, 等. 户外活动和体育锻炼防控儿童青少年近视的研究进展[J]. 中国体育科技, 2019, 55(4): 3-13.
LI L, XU J F, LU Y L, et al. Research progress on myopia prevention and control by promoting outdoor activity and physical exercise in children and adolescents[J]. China Sport Sci Technol, 2019, 55(4): 3-13. (in Chinese)

[44] 王天笑, 王菁菁, 杜林琳, 等. 父母受教育程度与儿童户外活动时长的关联[J]. 中国学校卫生, 2024, 45(12): 1704-1707.
WANG T X, WANG J J, DU L L, et al. Association between parental education level and time spent outdoors among children[J]. Chin J Sch Health, 2024, 45(12): 1704-1707. (in Chinese)

[45] YANG J L X, LI D L, CHEN J, et al. Effect modification of time spent outdoors on the association between early childhood overweight and myopia: a one-year follow-up study[J]. J Public Health, 2024, 46(1): 107-115.

[46] MACKINTOSH K A, CHAPPEL S E, SALMON J, et al. Parental perspectives of a wearable activity tracker for children younger than 13 years: acceptability and usability study[J]. JMIR Mhealth Uhealth, 2019, 7(11): e13858.

[47] 张康, 屈莎, 赵星, 等. 户外活动与儿童近视进展文献可视化研究[J]. 中国学校卫生, 2019, 40(5): 733-737, 741.
ZHANG K, QU S, ZHAO X, et al. Visualization study of outdoor activities affecting the development of children's myopia[J]. Chin J Sch Health, 2019, 40(5): 733-737, 741. (in Chinese)

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(上接第 1667 页)

[34] FUNAHASHI S. Neuronal mechanisms of executive control by the prefrontal cortex[J]. Neurosci Res, 2001, 39(2): 147-165.

[35] DIAMOND A. Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex[J]. Child Dev, 2000, 71(1): 44-56.

[36] NEKAR D M, LEE D Y, HONG J H, et al. Effects of augmented reality game-based cognitive-motor training on restricted and repetitive behaviors and executive function in patients with autism spectrum disorder[J]. Healthcare, 2022, 10(10): 1981.

[37] BENZING V, SCHMIDT M. The effect of exergaming on executive functions in children with ADHD: a randomized clinical trial[J]. Scand J Med Sci Sports, 2019, 29(8): 1243-1253.

[38] LIU Z M, CHEN C Q, FAN X L, et al. Usability and effects of a combined physical and cognitive intervention based on active video games for preschool children[J]. Int J Environ Res Public Health, 2022, 19(12): 7420.

[39] BEST J R. Exergaming immediately enhances children's executive function[J]. Dev Psychol, 2012, 48(5): 1501-1510.

[40] 盖笑松, 许洁, 闫艳, 等. 体感游戏促进儿童的执行功能: 运动强度和认知参与的作用[J]. 心理学报, 2021, 53(5): 505-514.
GAI X S, XU J, YAN Y, et al. Exergame can improve children's executive function: the role of physical intensity and cognitive engagement[J]. Acta Psychol Sin, 2021, 53(5): 505-514. (in Chinese)

[41] LEE J E, XIANG P, GAO Z. Acute effect of active video games on older children's mood change[J]. Comput Hum Behav, 2017, 70: 97-103.

[42] 孙延林, 王志庆, 姚家新, 等. 体育锻炼与心理健康: 认知、焦虑、抑郁和自我概念的研究进展[J]. 生理科学进展, 2014, 45(5): 337-342.
SUN Y L, WANG Z Q, YAO J X, et al. Physical exercise and mental health: cognition, anxiety, depression and self-concept[J]. Prog Physiol Sci, 2014, 45(5): 337-342. (in Chinese)

[43] DUNCAN M J, CLARKE N D, BIRCH S L, et al. The effect of green exercise on blood pressure, heart rate and mood state in primary school children[J]. Int J Environ Res Public Health, 2014, 11(4): 3678-3688.

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