

专家介绍



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运动在肥胖儿童体重管理中的作用及机制

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摘要: 儿童及青少年肥胖已成为全球性的重大公共卫生挑战, 呈现发病率持续上升且低龄化的趋势。儿童肥胖显著增加 2 型糖尿病、高血压、非酒精性脂肪肝、哮喘及阻塞性睡眠呼吸暂停等并发症的风险, 并增加远期心血管疾病风险。目前, 以营养、运动和行为矫正为核心的生活方式干预是国内外指南推荐的一线体重管理策略, 其中运动干预是关键环节。然而, 肥胖儿童普遍存在体力活动水平低、久坐时间长、运动参与不足等困境, 严重限制了干预效果。本综述系统阐述了运动在儿童肥胖体重管理中的核心作用与内在生理机制。运动通过增加总能量消耗、增强骨骼肌脂肪氧化、改善胰岛素敏感性、促进脂肪分解及调节食欲相关激素等途径, 直接对抗能量正平衡与脂肪堆积。此外, 规律运动能有效改善肥胖相关的慢性低度炎症状态, 通过降低 C 反应蛋白(CRP)、白细胞介素-6(IL-6)、肿瘤坏死因子- α (TNF- α)等促炎因子水平, 并促进 IL-10 等抗炎因子以及鸢尾素、IL-15 等有益肌细胞因子的释放, 从代谢与免疫层面协同发挥健康促进作用。综上所述, 运动是儿童肥胖防治中不可或缺的非药物干预手段, 具有双重健康效益。

关键词: 儿童肥胖; 运动; 体重管理; 能量代谢; 炎症; 肌细胞因子

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Role and mechanisms of exercise in weight management of obese children

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Abstract: Childhood and adolescent obesity has become a major global public health challenge, with a continuously rising prevalence and a trend toward younger age of onset. The escalating rates of childhood obesity significantly increase the risk of various complications, including type 2 diabetes, hypertension, non-alcoholic fatty liver disease (NAFLD), asthma, and obstructive sleep apnea, substantially elevating the long-term risk of cardiovascular diseases. Currently, lifestyle interventions centered on nutrition, physical activity, and behavioral modification are the first-line weight management strategies recommended by both domestic and international guidelines, with exercise intervention being a critical component. However, obese children commonly face challenges such as low levels of physical activity, prolonged sedentary time, and insufficient exercise participation, which severely limit intervention effectiveness. This review systematically elucidates the core role and underlying physiological mechanisms of exercise in weight management for obese children. First, exercise directly counteracts positive energy balance and fat accumulation through multiple pathways: increasing total energy expenditure, enhancing skeletal muscle fat oxidation capacity, improving insulin sensitivity, promoting lipolysis, and regulating appetite-related hormones. Second, regular exercise effectively ameliorates obesity-related chronic low-grade inflammation by reducing levels of pro-inflammatory factors such as C-reactive protein (CRP),

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interleukin-6 (IL-6), and tumor necrosis factor- α (TNF- α), while promoting the release of anti-inflammatory factors like IL-10 and beneficial myokines including irisin and IL-15, thereby exerting synergistic health-promoting effects at both metabolic and immune levels. In conclusion, exercise represents an indispensable non-pharmacological intervention with dual benefits for the prevention and management of childhood obesity.

Keywords: childhood obesity; exercise; weight management; energy metabolism; inflammation; myokines

全球儿童及青少年肥胖发病率持续上升,且呈现明显的低龄化趋势,已成为全球公共卫生领域面临的严峻挑战^[1]。世界卫生组织(WHO)数据显示,截至 2022 年,全球 5~19 岁儿童及青少年中已有超过 3.9 亿人超重,其中肥胖人数约 1.6 亿^[1]。2024 年《世界肥胖报告》数据显示,5 岁以上儿童中,超重/肥胖率将从 2020 年的 38% 迅速增加到 2035 年的 51%,人数由 2020 年的 26 亿人攀升到 2035 年的超过 40 亿人^[2]。在低龄儿童群体中,超重与肥胖问题同样日益突出。截至 2022 年,全球约有 3 700 万名 5 岁以下儿童处于超重状态^[3]。中国作为世界上儿童人数最多的国家,其超重与肥胖流行态势同样严峻。据 2015 年《中国居民营养与慢性病状况报告》显示,我国 6~17 岁儿童青少年超重肥胖率分别为 9.6% 和 6.4%^[4],而 2020 年《中国居民营养与慢性病状况报告》显示 6 至 17 岁、6 岁以下儿童青少年超重肥胖率分别达到 19% 和 10.4%^[5]。肥胖发病年龄显著提前,不仅直接影响儿童生长发育,还可能使高血压、2 型糖尿病、非酒精性脂肪肝等传统意义上的“成人病”在儿童期即出现,导致相关并发症发生时间整体前移,对儿童健康构成长期威胁。

1 儿童肥胖的多系统并发症

儿童期肥胖是成人肥胖的明确危险因素,仅有少数儿童能够成功减重并达到理想体重^[6]。持续的体重增加易导致腹部肥胖,从而诱发各种并发症并缩短预期寿命。1) 代谢性疾病:肥胖是糖尿病前期和 2 型糖尿病(type 2 diabetes, T2D)的独立危险因素,且在 10 岁以下儿童中发病率呈上升趋势^[7]。肥胖儿童患 T2D 的风险是体重正常儿童的 4 倍^[7]。2) 呼吸系统疾病:肥胖是导致阻塞性睡眠呼吸暂停的首要风险因素,超过 60% 的肥胖儿童和青少年患有阻塞性睡眠呼吸暂停,或睡眠时呼吸中断。肥胖和阻塞性睡眠呼吸暂停还可引起其他合并症,包括白天过度嗜睡、神经认知功能、体力活动减少、心血管负担和高血压^[8]。哮喘也与肥胖密切相关,超重及肥胖儿童哮喘发病时间更早,症状更为明显(如呼吸更急促、气道高反应性降低和哮喘控制丧失)^[9]。3) 心血管系统疾病: BMI 升高是儿童高血压的最大危险因素^[10]。肥胖儿童高血压的患病率约为 25%,

远高于普通人群的 3%。一项 meta 分析显示,与正常体重儿童相比,超重、肥胖儿童的收缩压分别升高 4.54 mm Hg 和 7.49 mmHg。Hardy 等^[11]研究显示,患有肥胖相关高血压的儿童心血管发病率和死亡率的风险增加。4) 肝脏疾病:非酒精性脂肪肝(non-alcoholic fatty liver disease, NAFLD)是引起儿童肝脏疾病的主要原因之一,流行病学研究表明 NAFLD 与肥胖、不健康饮食和久坐行为之间存在关联^[12]。肥胖的年轻人中 NAFLD 的患病率尤其高,22.5%~52.8% 的肥胖儿童患有 NAFLD,远超普通儿童的 2.6%^[13]。由于非酒精性脂肪性肝炎及肝硬化等合并症,导致人群预期寿命显著缩短。预计到 2025 年,非酒精性脂肪性肝炎将成为儿童肝移植的主要适应症之一^[14]。

2 儿童体重管理以生活方式干预为主要手段,运动是干预的核心

鉴于肥胖及其并发症的严重危害,早期干预至关重要^[15-16]。目前,国际共识推荐将体重减少 5%~15% 及以上作为肥胖儿童体重管理的目标^[17]。国内外相关指南均明确将生活方式干预作为超重或肥胖儿童的首选策略,药物及手术仅作为补充^[18-19]。该体系涵盖营养指导、运动锻炼与行为矫正:饮食指导是基础,运动处方是关键环节,而行为矫正则是确保干预效果可持续的重要支撑^[20]。在运动干预方面,建议 6~17 岁健康儿童每日至少进行 20min 中高强度体育活动,并力争达到 60min;运动形式以有氧运动为主,每周至少包含 3 天高强度有氧运动及抗阻训练。同时应限制非学习目的的屏幕时间至每日 1~2h 以内,减少久坐行为^[21-22]。

3 肥胖儿童运动干预的实施困境

尽管规律运动益处明确,但肥胖儿童的依从性普遍偏低^[23]。研究表明,仅约 10% 的肥胖儿童能达到“每日至少 60min”体育活动的标准^[24],8% 符合每日屏幕使用时间少于 2h 的建议,而能同时满足这两项建议的患儿仅占 1%^[25]。Yu 等^[26]研究进一步指出,在清醒时段内,肥胖儿童青少年体力活动的时间比正常体重同龄人少 30%,而久坐时间则多出 51%。肥胖儿童常因体重负荷大、运动技能发展不

足及久坐倾向,难以启动并维持规律运动^[27]。这种状况易使其在运动过程中产生负面体验与情绪,进一步增加活动中断的可能性,从而陷入“体力活动减少-久坐行为增加”的恶性循环^[28]。

4 运动在儿童体重管理中的作用

4.1 增加能量消耗,有效预防脂肪堆积 人体能量平衡状态取决于能量摄入与消耗之间的动态关系。当能量摄入持续大于消耗时,过剩能量会以甘油三酯形式储存在脂肪组织中,进而导致脂肪堆积^[29]。而规律运动可通过增加能量消耗,从多途径有效预防脂肪堆积:首先,运动能增强骨骼肌线粒体功能及脂肪酸转运蛋白的表达,从而提高脂肪氧化利用率^[30]。研究证实,持续中等强度运动可激活 AMPK-PGC-1 α 信号通路,进而促进脂肪酸 β 氧化关键酶的表达^[31]。其次,运动有助于降低胰岛素抵抗,抑制脂肪合成^[32];同时可升高肾上腺素、生长激素等脂解激素水平,通过激活激素敏感性脂肪酶来促进脂肪分解^[33]。再次,高强度间歇锻炼能够刺激白色脂肪组织褐变,增加产热型米色脂肪细胞的数量,从而提升脂肪组织自身的能量消耗^[34]。最后,适量运动还可调节瘦素、胃饥饿素等食欲调控激素的分泌,有助于避免运动后因食欲增加而导致的过度能量摄入^[35]。

4.2 发挥抗炎作用,改善代谢 运动作为一种非药物干预手段,已被证实能够延缓肥胖相关并发症的发生、改善成人与儿童的心血管健康水平,并对炎症反应具有调节作用^[36]。肥胖个体常伴随慢性低度炎症状态,其循环中炎症因子水平通常较健康成人升高 2~4 倍^[37]。Haapala 等^[38]研究表明,在儿童群体中,较高水平的中等强度身体活动和高强度身体活动,以及缩短久坐时间(ST),与循环炎症生物标志物水平降低显著相关。2016 年一项纳入 83 项随机对照试验的系统综述与荟萃分析进一步指出,持续超过 2 周的运动干预可降低 C 反应蛋白(C-reactive protein,CRP)水平,且这种降低在运动伴随脂肪量和体重指数下降时更为显著^[39]。此外,越来越多的研究报道指出,其他炎症标志物如白细胞介素-6(interleukin-6,IL-6)和肿瘤坏死因子- α (tumor necrosis factor- α ,TNF- α)也与身体活动呈负相关^[40]。运动不仅能够降低促炎因子水平,还可促进抗炎因子如 IL-10 的释放。IL-10 是一种强效抗炎因子,能够进一步抑制包括 IL-1 α 、IL-1 β 、TNF- α 以及趋化因子 IL-8 和巨噬细胞炎症蛋白-1 α (macrophage inflammatory protein-1 α ,MIP-1 α)等多种促

炎因子的合成^[41]。此外,运动还能诱导肌肉释放鸢尾素、IL-15 等一系列肌细胞因子。例如,鸢尾素是一种新近发现的肌动蛋白,运动后其在循环中的水平显著升高,并能促使白色脂肪细胞向“米色”脂肪细胞转化。这类细胞具有类似棕色脂肪细胞的表型,即通过增强产热和能量消耗来调节代谢,而非像白色脂肪细胞那样主要承担脂质储存功能。因此,鸢尾素可能在能量稳态和代谢调节中扮演重要角色。IL-15 同样由收缩的骨骼肌产生,并对肥胖程度表现出改善作用。动物实验表明,IL-15 能够减少腹部脂肪积累^[42];在人体研究中,循环 IL-15 水平亦与躯干脂肪含量呈负相关^[43]。

综上,儿童及青少年肥胖已成为全球性的重大公共卫生挑战,其流行态势日益严峻且呈低龄化发展。肥胖不仅显著增加儿童期罹患高血压、2 型糖尿病、非酒精性脂肪肝、哮喘及睡眠呼吸暂停等多种并发症的风险,更是成年期心血管疾病及代谢异常的重要预警信号。当前,以营养指导、运动锻炼与行为矫正为核心的生活方式干预,是国内外指南一致推荐的首选体重管理策略。然而,肥胖儿童普遍存在体力活动水平低、久坐时间长、运动参与不足的现实困境,使其难以从运动中充分获益。运动在体重管理中扮演着多重关键角色:一方面,它通过增加能量消耗、增强脂肪氧化、改善胰岛素敏感性及调节食欲激素等途径,直接对抗脂肪堆积;另一方面,规律运动能有效改善肥胖伴随的慢性低度炎症状态,通过调控 CRP、IL-6、TNF- α 等炎症因子,并促进 IL-10 等抗炎因子以及鸢尾素、IL-15 等有益肌因子的释放,从代谢与免疫层面协同发挥健康促进作用。

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