

· 综述与专论 ·

基于运动的心脏康复视角下急性心肌梗死管理：
全球现状、多模式干预与个性化策略扫描二维码
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【摘要】 急性心肌梗死(AMI)作为全球心血管疾病致死致残的首要病因之一,其术后长期管理策略的优化已成为医学界关注的焦点问题。基于运动的心脏康复(EBCR)作为循证医学推荐的核心干预方案,通过整合多元化运动模式与个性化管理策略,在提升心肺功能、缓解心理应激以及改善生活质量等方面展现出显著疗效。随着精准医疗、智能技术及心理社会干预的深度融合,EBCR在资源受限地区的推广实施迎来新的发展契机。然而,EBCR的全球普及仍面临多重障碍,尤其在医疗资源匮乏区域,受限于服务可及性、经济负担及患者依从性等因素,其应用范围受到显著制约。本研究全面梳理了EBCR的全球实施概况、地域性差异特征以及多维度干预与个性化策略,并就智能化技术应用、政策保障体系构建及跨学科协同创新等发展路径进行深入探讨,旨在为AMI康复管理提供更具针对性的理论支撑与实践指导。

【关键词】 急性心肌梗死; 基于运动的心脏康复; 多模式干预; 个体化管理; 精准医学; 智能技术; 心理社会干预; 依从性; 全球推广

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Exercise-based Cardiac Rehabilitation in Acute Myocardial Infarction Management: Global Perspectives, Multimodal Interventions, and Personalized StrategiesCEN Kaiyuan^{1, 2}, FATIMAH Ahmedy^{2, 3*}, CHEN Hong⁴, SHAO Mingchen⁵, MEXMOLLEN Marcus², MOHD Fadzli Shukor²

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【Abstract】 Acute myocardial infarction (AMI) remains one of the leading causes of mortality and disability worldwide, making the optimization of long-term post-procedural management a key focus in cardiovascular medicine. Exercise-based cardiac rehabilitation (EBCR), as a core intervention recommended by evidence-based medicine, has demonstrated significant benefits in enhancing cardiopulmonary function, alleviating psychological stress, and improving overall quality of life by integrating diverse exercise modalities with personalized management strategies. The rapid advancement of precision medicine, smart technologies, and psychosocial interventions has provided new opportunities for the expansion of EBCR, particularly in

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resource-limited settings. However, the global implementation of EBCR still faces substantial challenges, including limited healthcare accessibility, economic constraints, and poor patient adherence, especially in regions with insufficient medical resources. This study systematically reviews the global landscape of EBCR implementation, regional disparities, and the efficacy of multidimensional interventions and personalized approaches. Furthermore, it explores future directions in the integration of intelligent technologies, policy frameworks, and interdisciplinary collaborations, aiming to provide targeted theoretical insights and practical guidance for optimizing AMI rehabilitation management.

【Key words】 Acute myocardial infarction; Exercise-based cardiac rehabilitation; Multimodal intervention; Personalized management; Precision medicine; Smart technology; Psychosocial intervention; Adherence; Global implementation

急性心肌梗死 (acute myocardial infarction, AMI) 是全球主要的心血管疾病之一, 患者死亡率和致残率较高。尽管经皮冠状动脉介入术 (percutaneous coronary intervention, PCI) 等治疗策略显著提高了 AMI 患者的短期存活率, 但患者的远期管理仍面临挑战。PCI 治疗后患者常面临心室重构及心血管事件复发, 显著影响了长期预后, 导致生活质量降低^[1-2]。指南推荐的心脏康复 (cardiac rehabilitation, CR) 治疗应运而生。基于运动的心脏康复 (exercise-based cardiac rehabilitation, EBCR) 能有效降低心血管事件发生率、改善心肺功能、延长生存期, 是 CR 的核心干预手段^[3-4]。焦虑、抑郁等精神心理障碍时常困扰着 AMI 患者, 并成为 CR 过程的“拦路虎”, 使不良心血管事件发生的风险增加^[5]。已有荟萃分析指出, EBCR 可降低 AMI 患者的全因死亡率和住院率, 改善心理健康, 提高患者健康相关的生活质量 (health-related quality of life, HRQoL)^[6]。CR 领域研究持续深化推动有氧运动、抗阻训练等多模式运动方案的发展, 低强度训练、持续中等强度训练 (moderate-intensity continuous training, MICT) 与高强度间歇训练 (high-intensity interval training, HIIT) 构成多元化选择体系, 显著提升了患者个体化适配空间^[7-9]。康复路径设计需精准匹配患者年龄特征、心理评估数据及体适能基线, 这种个体差异适配机制直接影响 EBCR 远期预后效果^[10]。可穿戴生物传感器、远程康复平台等技术创新正在重构康复医学模式, 实时生理参数追踪结合方案动态优化机制, 有效改善治疗依从性并降低 CR 风险事件发生率^[11-14]。全球范围内 EBCR 实施呈现显著地域差异, 中低收入国家 (lower-middle-income countries, LMICs) 受限于医疗基础设施薄弱与专业人才短缺, 而高收入国家 (high-income countries, HICs) 则面临医疗成本压力与患者主观参与度不足的双重困境^[9]。在 CR 的推进过程中, 如何有效融合多元化干预模式与定制化策略二者间的协同运作机制, 从而契合患者群体存在的差异化需求已成为此领域迫切需要突破解决的核心科学难题^[4, 14-15]。临床实践中亟待解决多维度干预手段的系统性融合问题, 个体化康复路径的动

态优化方案正逐步发展为 CR 研究转型的重要突破口。

1 EBCR 全球参与现状与差异

1.1 全球参与率的差异与原因

EBCR 在冠心病 (coronary heart disease, CHD) 综合治疗体系中保持重要临床价值, 显著改善 AMI 患者预后。多项研究表明该方案不仅能有效降低全因死亡率与再入院风险, 在血压调控、血脂管理和体质量控制等心血管风险干预方面也展现出明确优势, 其二级预防作用已形成广泛共识^[6, 16]。因此, EBCR 在心血管疾病二级预防中的作用得到了广泛认可。然而, 尽管 EBCR 的临床益处显著, 其全球参与率依然较低。有数据显示欧洲疫情前参与率不足 15%; 美国过去 15 年 EBCR 参与率仅为 5%^[17-18], 疫情加剧医疗资源紧张, 进一步压缩了康复服务可及性。尽管 HICs 康复体系相对健全, 服务利用率仍有限; 而在 LMICs, 受医疗资源缺口、基础设施薄弱及患者认知等因素限制, 超过 50% 的康复需求未被满足^[19]。

CR 参与率的悬殊成因错综复杂, 地域间医疗资源配置失衡、基层服务可及性不足构成主要瓶颈。偏远地区人群对康复的需求殷切, 但有限的交通条件及基础设施导致其参与意愿相对较低, 康复参与率低于城镇居民。一项纳入了 1 809 例患者的研究结果表明, 偏远地区人群康复参与率仅为 11.9%, 其康复障碍评分也高于城镇居民 ($P<0.01$), 凸显了偏远地区患者面临的巨大康复困境^[20]。一项涵盖 8 个国家 1 213 例患者的跨国多中心研究指出: 地理隔离严重制约了康复服务的可及性, 身处医疗资源匮乏区域的患者难以适时参与康复服务^[21]。即使在 HICs, 完善的医疗体系也难掩地理因素对康复参与率的影响。加拿大已建立了约 170 个 CR 项目, 但在北部地区几乎空白, 医疗资源的地域分配失衡显著提升了患者接受服务的难度^[22]。经济负担是影响康复参与的壁垒。部分国家的民众可能需要花费年收入的一半以上来完成一个完整的 CR 项目, 而 HICs 的这项支出通常低于 10% 年收入。全球大约有 24.1 亿人亟需 CR 服务; 资源分配失衡, 特别是在 LMICs, 资金

匮乏以及缺乏医疗报销机制,极大制约了EBCR的可及性^[23-24]。患者还需面对交通、住宿等隐形开销,均会加剧经济负担,进而削弱康复意愿。认知偏差也成为康复参与的绊脚石。不少患者对EBCR存在认知误区,误以为康复训练会加重心脏的负担,因此对其敬而远之。患者每接受一次康复诊疗,死亡率或再入院的风险就能降低2%,完成5次CR后风险则锐减10%^[17, 25-26]。文化观念及社会环境亦会影响CR的普及情况,一部分患者担忧康复训练会导致病情反复,进而抗拒EBCR^[18]。

1.2 创新模式与技术手段

近年来,社区型心脏康复(community-based cardiac rehabilitation, CBCR)提升了EBCR的可及性与患者的依从性。65.3%的患者成功参与了CBCR,随访期间仅有5.3%的患者退出^[27]。CBCR改善患者的HRQoL、心理状态及运动耐力;焦虑和抑郁程度降低,6 min步行测试距离平均提高了57.42 m^[22, 24, 27]。在资源匮乏地区,CBCR同样降低了心血管事件复发的风险,因为其有效减少了交通和经济负担,提高了康复项目的参与率^[28]。CBCR模式推动了健康干预的广泛应用,对低收入群体来说格外适合。撒哈拉以南非洲地区的远程医疗让患者就诊等待时间缩短了30%,医疗费用降低了20%,提高了当地居民获取医疗服务的概率^[29]。远程医疗技术的迭代创新正突破传统地理限制。在乌干达,40%的农村患者通过远程医疗获得了专业医疗服务,长途就医需求减少了50%^[30]。可穿戴技术显著提升了患者依从性。医疗机构能实时掌握患者运动量、心率等数据,实现精准的远程管理,使AMI患者的最大摄氧量(maximal oxygen uptake, VO_{2max})能通过远程康复得到显著提高,进而支持后续的康复治疗^[31]。

1.3 政策支持与教育推广

医保政策的调整对EBCR参与度影响深远,患者自付费用直接关乎康复依从性。首次康复评估费用若超25.40美元,参与率锐减30.9%;自付费用每增10美元,患者平均康复参与次数降低0.41次^[25]。经济负担的减轻对患者康复参与至关重要。提升EBCR参与率离不开政策干预,探索医保政策的优化、推广远程康复、减少患者的财务负担都有助于可及性的提升。

多国实践验证了政策干预对提升CR参与度的有效性。美国“Million Hearts”项目通过经济援助与免费康复服务将EBCR的参与率从不足20%提升至70%^[23]。此类政策模式在英联邦国家呈现多样化实践形态:英国采取医疗体系与非营利组织联合行动,澳大利亚建立心脏基金会与政府的双向协作机制,加拿大安大略省则通过公共保险计划覆盖低收入群体需求。依从性提升的重要策略还包括健康教育。系统性健康教育使患者康复依

从性提升30%,在线教育平台突破地域限制推动偏远地区参与率增长25%^[32]。针对新患者的教育讲座可以有效缓解其焦虑情绪、加速融入康复环境^[33]。文化适配理念在LMICs显现独特价值,巴基斯坦“Getting Better Bite by Bite”项目通过本土化心理干预方案设计,将传统宗教元素与现代医学认知相结合,使康复知识接受度提升并显著改善参与持续性^[34]。医疗资源配置不均导致EBCR项目普及受限,标准化干预路径的建立与区域化实施方案的优化亟待突破^[6]。

2 基于EBCR的多模式干预

2.1 有氧运动:EBCR的基础干预

有氧运动能改善心血管健康并降低不良心血管事件的发生率已获广泛证实,是EBCR的核心干预。多项临床试验证实^[6, 35-37],接受CR的急性冠脉综合征及冠状动脉旁路移植术患者的死亡风险分别下降63%和38%,再梗死风险降低47%、心血管相关死亡率降低36%及全因死亡率降低26%。有氧运动显著增强心肌功能适应性,具体表现为患者每搏输出量增加、心脏舒缩功能改善及心室重构减轻^[36]。机制研究揭示,心肌梗死患者接受4周EBCR方案后,心率变异性显著改善;持续6个月干预后,肌肉交感神经活性降低、动脉收缩压下降,自主神经对血压调控能力增强,推动血流动力学指标向生理状态趋近^[38-39]。运动介导的抗炎效应构成另一关键机制。研究显示,运动刺激引发的细胞因子应答具有特异性,不会引起肿瘤坏死因子 α 与白介素(IL)1 β 等经典促炎因子显著升高,而是通过暂时提升IL-6浓度,激活IL-10分泌及IL-1受体拮抗剂释放通路,形成抗炎保护屏障以缓解炎症对心血管系统的病理损伤^[40]。在实际应用方面,指南建议运动强度应控制在峰值摄氧量(VO_{2peak})的40%~80%:身体虚弱或年迈的患者宜采用低强度训练,即 VO_{2peak} 的40%~50%,身体素质优良者则适用MICT或HIIT,使 VO_{2peak} 维持在60%~80%^[41]。部分患者受制于设施不足或依从性欠佳,难以完成线下康复,可穿戴设备的应用成为远程CR的有效解决途径。借助可穿戴设备实时监控心率、运动量,进而优化个体化训练方案,可提升患者有氧运动的依从性与训练效果^[33, 42]。

2.2 抗阻训练与有氧强度分级训练:EBCR的关键补充

抗阻训练在EBCR方案中占据关键地位,该训练模式通过增强AMI患者的肌肉力量有效提升运动耐力并优化骨骼健康指标。研究证据显示,EBCR干预可多方面促进患者功能改善,其中抗阻训练联合多强度有氧训练的策略临床效果更为显著^[41-43]。比较PCI治疗后心力衰竭的AMI患者康复反应,AMI患者在肌力恢复及训练适应方面改善更快,提示病理类型差异可

能影响干预效果。此外,该研究发现,术后患者肌肉扭矩增长与 VO_{2peak} 呈中等相关 ($r=0.51, P<0.01$),提示肌力提升可能参与心肺功能的恢复机制。系统评价结果进一步支持上述发现。YAMAMOTO 等^[44]的荟萃分析显示,抗阻训练可在多个维度带来中等以上效应量的改善。中年组患者下肢与上肢肌力分别提升 0.65 (95%CI=0.35~0.95) 和 0.73 (95%CI=0.48~0.99) 个标准化均数差 (SMD), VO_{2peak} 增加 0.92 (95%CI=0.12~1.72) $mL \cdot kg^{-1} \cdot min^{-1}$;老年组患者在上肢肌力 (SMD=1.18, 95%CI=0.56~1.80) 与日常活动能力 (SMD=0.61, 95%CI=0.21~1.01) 方面的改善亦较为显著。上述结果提示,EBCR 联合抗阻训练可在不同年龄层及病理类型的冠状动脉疾病患者中协同促进肌肉重建与心肺功能恢复。早期研究对阻力训练潜在效应及心血管风险存在争议,最新证据表明医学监督下的中低强度训练 (40%~60% 1 次重复最大力量) 血压变化与同强度有氧运动基本一致。有学者研究证实,心功能稳定的 CHD 患者在中低强度抗阻训练中不仅能提升心血管适应性,还能改善代谢指标与心理健康状态^[45]。AMI 早期康复阶段引入低强度训练和 MICT 方案展现出良好的安全性,接受 2 周干预的心力衰竭患者数据显示,其心源性死亡率与再住院率较常规康复组显著降低^[46]。深入分析该训练模式对不同射血分数心力衰竭患者产生积极影响,发现与对照组相比,射血分数下降的心力衰竭 (HFrEF) 患者的心源性死亡率下降 (31.3% 比 0, $P=0.002$),射血分数轻度下降的心力衰竭 (HFmrEF) 患者再住院率降低 (22.1% 比 3.6%, $P=0.008$)。此外,AMI 患者在心肺运动测试中,当肺泡内呼气末二氧化碳分压 ($PETCO_2$) 厌氧阈值 ≤ 3.5 mmHg (1 mmHg=0.133 kPa) 时,其再住院风险显著增加 ($OR=0.635$, 95%CI=0.463~0.871, $P=0.005$),提示该指标在早期 EBCR 效果评估及预后预测中具有重要应用价值,同时验证了抗阻训练作为康复干预手段的临床安全性及有效性。

有氧运动强度分级在 EBCR 领域持续引发研究关注。HIIT 可通过抑制心室壁的进行性薄化并改善心室舒张功能,实现了心室结构与功能的协同改善^[47]。在为期 16 周的训练过程中,观察到其对心室重构的影响呈容量依赖性,且表现出明显的剂量依赖性。此外,短时程的 HIIT 方案 (单次训练时间 ≤ 20 min,其中高强度阶段 ≤ 10 min) 在临床实践中展现了独特的治疗价值。在确保安全性的前提下,短时程 HIIT 通过优化训练时程,能够有效延缓心室病理性重构的进程,为制订个体化的 CR 处方提供了重要的循证依据。针对老年群体的研究表明^[48],与非运动对照组相比,抗阻训练、HIIT 和联合训练显著改善了患者 BMI ($P \leq 0.0001$)、

体脂百分比 ($P=0.03$)、有氧耐力 ($P=0.03$)、低密度脂蛋白 ($P=0.04$) 和血糖水平 ($P=0.02$),但抗阻训练与 HIIT 如何联合以达最佳效果,还需深入探讨。未来 EBCR 发展的一个主要关注点是患者适配性更优的训练模式,需要把抗阻训练糅合进有氧运动中,在 HIIT 的高效与 MICT 的高依从性之间找到平衡点。

2.3 有氧与身心平衡:EBCR 的协同作用

游泳作为一种低冲击、全身性的运动,在 EBCR 领域,尤其提升运动能力、增强肌肉力量和改善 HRQoL 方面展现出显著的潜在益处。相关研究表明,游泳训练可有效改善心血管功能,促进心脏功能复原,对于 AMI 后稳定性心力衰竭和 CHD 患者,EBCR 是能提供兼具娱乐性和功能性的运动形式^[49-50]。游泳训练对机体多维健康效益的促进作用,使其在 EBCR 体系中具备辅助干预潜力,但实施时需严格遵循医疗监护下的个性化运动处方。另一方面,瑜伽身心结合的特质,使其在 CR 领域展现出广阔的应用空间。相关研究表明,瑜伽干预能够优化生理指标、调节情绪、缓解心理压力,并因此降低未来 10 年心血管疾病风险、改善弗雷明汉风险评分,为 EBCR 提供了完备的健康管理策略^[51]。瑜伽对自主神经系统的调节功能已获证实。针对接受规范药物治疗的 AMI 患者群体,规律瑜伽训练能有效重建交感神经与副交感神经的动态平衡,不仅提升副交感神经活性及心率变异性参数,更通过增强机体应激适应能力显著降低心血管不良事件发生率,同步改善 HRQoL 与心理社会功能^[52]。游泳注重强化心肺耐力,瑜伽则擅长促进神经调节与心理健康,在 EBCR 中,二者各具特色、优势互补。游泳与瑜伽所蕴含的潜在协同效应,极有可能为 CR 患者量身打造更为全面且具个性化特征的治疗策略。将心肺耐力训练同身心调节有机融合,或许能更有效地促进心血管健康与生活质量的提升,共筑 CR 的桥梁。

2.4 联合训练与多维干预:EBCR 的综合策略

联合训练,即有氧运动与抗阻训练的结合,被认为是最大化心血管健康改善的有效策略。相关研究证实,相较于单一的有氧运动模式,联合训练能显著提高心肺适能、增加肌肉力量并优化身体成分^[53]。荟萃分析进一步证实,其可降低体脂百分比 (SMD=-2.30, 95%CI=-3.59~-1.02)、减少躯干脂肪 (SMD=-0.56, 95%CI=-0.96~-0.15),并促进无脂肪质量增加 (SMD=0.90, 95%CI=0.39~1.36)^[54]。上下肢肌肉力量的提升方面,阻力训练优势明显,SMD 分别为 1.07 (95%CI=0.51~1.63) 和 0.77 (95%CI=0.21~1.33)^[55]。短期干预研究揭示,8 周联合训练能降低舒张压、增加瘦体质量,显著改善心肺健康,对高血压及心血管高风险人群效果更佳^[55];长期干预研究表明,8 个月的持

续训练能稳定血压、提高运动能力,而氧化应激水平的调节则需更长的干预周期巩固^[56]。高龄患者亦能从联合训练中获益,患者可表现为肌力增强($SMD=0.60$, $95\%CI=0.43\sim0.77$)、有氧能力提高($SMD=2.71$, $95\%CI=1.96\sim3.45$),以及 HRQoL 改善($SMD=-5.71$, $95\%CI=-9.85\sim-1.56$)^[57]。PRIME-HF 研究数据显示,8 周 PRIME 训练方案显著提升 VO_2peak $2.4\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ($P=0.004$),该方案较传统干预手段展现更优效能^[57]。近年研究进展表明,基于抗阻训练体系,结合有氧运动强度分级标准筛选低强度、MICT 或 HIIT 等多维干预策略逐步发展为新兴康复模式,为临床实践开拓了综合治疗方案选择空间^[7-9]。

运动干预并非联合训练的唯一核心,营养管理与心理支持的系统整合成为优化康复多维效果的关键路径。抑郁在 AMI 患者中发病率显著高于普通人群(15%~20%比 4.8%),且干预不足会加重心血管不良预后,认知行为疗法(cognitive behavioral therapy, CBT)已被证实可缓解 25%~30% 的抑郁症状并提高康复依从性^[58];饮食策略层面,地中海饮食可使心血管高危人群的主要心血管事件风险分别下降 31% ($RR=0.69$, $95\%CI=0.53\sim0.91$) 和 28% ($RR=0.72$, $95\%CI=0.54\sim0.95$)^[59]。心理支持与营养干预的协同作用使 EBCR 方案在 HRQoL 改善和远期预后优化中呈现多维度获益。基于 EBCR 框架拓展多维干预模式成为优化心肺耐力与肌肉功能协同发展的必然趋势,其内在机制涉及生物-心理-社会医学模型的多维整合效应。

3 EBCR 中的个性化路径

3.1 定制化运动干预:精准运动方案设计

在 EBCR 中,个性化路径的精细设计则是其成功实施的关键因素。老年 AMI 患者接受个体化运动训练后,心率恢复、 VO_2peak 及通气效率均呈现显著改善($P<0.001$),而单纯接受常规运动建议者未见类似益处^[60]。美国运动医学会力荐老年患者采用循序渐进的个性化运动策略,旨在增强肌力与耐力,并最大限度降低受伤风险、提升依从性^[61]。8 周综合 CR 后,老年患者低密度脂蛋白胆固醇(LDL-C)水平显著下降($P<0.001$),运动能力提升($P<0.001$),生活质量评分改善,其中身体维度和情绪维度评分均显著下降^[62]。即使老年患者的 CR 参与率偏低,个体化训练能带来媲美年轻患者的健康益处:显著优化整体健康状况^[63]。针对身体状况较佳的年轻人群,HIIT 在 VO_2max 增益方面展现出独特优势。研究结果显示,8 周 HIIT 干预可使 VO_2max 平均提升($6.5\%\pm2.4\%$) ($P<0.001$),增幅超过冲刺间歇训练(SIT) $8\times20\text{ s}$ 方案的($3.3\%\pm2.4\%$) ($P<0.001$),但与 SIT $10\times30\text{ s}$ 组差异不显著;3 000 m

耐力测试中,HIIT 组获得($5.9\%\pm3.2\%$)的提升幅度($P<0.001$),显著高于 SIT $10\times30\text{ s}$ 组的($2.2\%\pm2.2\%$) ($P<0.05$),为 HIIT 在提升心肺耐力方面的临床应用提供依据^[64]。纵向研究揭示,16 周有氧间歇训练后,受试者 VO_2peak 提升伴随内脏脂肪组织减少($P<0.01$),两者变化呈负相关;代谢综合征核心指标(腰围、舒张压、三酰甘油水平)的改善与 VO_2peak 增幅、内脏脂肪减少量均存在负向关联($P<0.05$)^[64-65],证实心肺功能优化对代谢调节具有协同效应。对比持续适度运动,间歇训练 HIIT 与 MICT 在代谢敏感性、BMI 调控及胰岛素抵抗缓解方面表现出更优的生物效应,为制订年轻个体 EBCR 方案提供了循证支持。

对于代谢综合征及心力衰竭患者,HIIT 与 MICT 在 EBCR 中的作用也受广泛关注。一项荟萃分析表明,HIIT 改善 VO_2peak ($MD=1.78$, $95\%CI=0.80\sim2.76$)、左心室射血分数(LVEF, $MD=3.13$, $95\%CI=1.25\sim5.02$)、6 min 步行距离($MD=28.13$, $95\%CI=14.56\sim41.70$) 及 HRQoL ($MD=-4.45$, $95\%CI=-6.25\sim-2.64$) 方面优于 MICT^[66]。TAYLOR 等^[67]的研究显示,4 周 HIIT 训练可显著改善血流介导的扩张(1.5%比 0.1%, $P=0.004$),揭示其在短期血管功能改善方面的潜力,但是经过 12 个月的随访,HIIT 与 MICT 在血管功能、动脉硬化及血压改善方面无显著差异,说明 HIIT 在短期内具有一定优势,故短期康复方案设计需考虑时效性特征,而长期管理策略应建立动态评估机制。针对 AMI 女性患者的康复困境,心理因素被证实为影响预后的关键变量。JUG 等^[68]的研究指出,女性患者对心理支持的需求显著高于男性,增加心理干预可有效提升 CR 参与率。TURNER 等^[69]的研究进一步证实,针对性心理辅导与同伴支持可增强患者战胜疾病的信心,并改善心血管疾病的长期预后。EBCR 方案与心理干预的协同作用,本质上构建了生物-心理双重作用靶点的新型治疗范式。

3.2 心理与行为因素的整合:提升康复依从性与效果

心理与行为因素在 AMI 患者的康复过程中发挥着至关重要的作用。心脏病患者中运动恐惧症的总体患病率高达 61.0% ($95\%CI=49.4\%\sim72.6\%$),其中 CHD 患者的患病率为 63.2% ($95\%CI=45.2\%\sim81.3\%$),显著影响其运动依从性,凸显了早期心理干预在 CR 中的临床重要性^[70]。AMI 患者急性期后普遍存在抑郁焦虑等共病心理问题,不仅加重疾病负担,更可能形成制约康复进程的关键阻力^[5]。CBT 通过修正错误信念、建立积极应对机制显著改善患者自我效能;动机访谈技术借助目标导向对话模式增强个体行为改变的内在驱动力^[71-72]。从行为医学视角分析,运动回避行为常源于风险认知偏差及康复知识匮乏,这要求干预方案需兼顾生理

与心理维度。系统化健康教育策略通过解析康复机制、澄清认知误区等途径显著提升患者对运动疗法的接受度。研究证实结构化教育干预使受试者运动恐惧量表评分下降,且规律参与康复训练的比例提升2倍^[73-74]。构建整合心理与行为维度的干预体系,已成为突破传统CR模式瓶颈的重要研究方向。

3.3 技术的整合与创新:推动个性化康复的精准性

EBCR因技术革新而日趋成熟,个性化康复方案得以实现。医疗团队凭借智能手表等可穿戴设备实时监测到的心率、步数、运动强度等详实数据,得以优化康复方案,智能设备的应用使康复过程更趋精准且易于掌控。研究表明^[75],基于智能设备的远程康复方案可使AMI患者的 VO_{2peak} 在干预3个月后提升 $1.56\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$,其疗效与传统线下康复相当。对于基线功能能力较差的患者, VO_{2peak} 提升更显著,达 $2.46\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$,并使6 min步行距离增加60 m($P=0.045$),进一步验证了远程个性化CR在高风险亚群中的临床价值。技术赋能使康复流程具备数据化特征,患者自主决策权与安全感增强直接推动治疗依从性提升。远程医疗体系打破地理屏障,优质资源可覆盖偏远地区、医疗资源匮乏区域,实现康复服务的普惠化,远程监测结合实时指导构建起连续性管理闭环。一项荟萃分析显示,远程CR可显著提升患者 VO_{2peak} 和HRQoL,干预完成率达80%,显示出优良的可行性与依从性^[76]。疫情防控期间,低接触式康复方案有效规避院内感染风险,持续性的居家干预缓解了受试者的医疗环境焦虑^[77]。人工智能(artificial intelligence, AI)的时代浪潮奔涌而来,正深刻变革着CR领域。心血管事件的发生风险评估,以往常受限于传统手段,AI凭借海量数据的深度挖掘和先进算法模型的构建,实现了风险的精准预测和个性化干预。通过机器学习(machine learning, ML)技术优化后的运动处方,能够大幅提高患者的治疗配合度以及康复的成效^[78]。家庭场景下的康复模式,因专业指导和即时反馈的缺位,长期面临困境;远程医疗与AI的有机融合,催生了“医院指导+家庭康复”这一创新路径,在提高患者心肺耐力之外,也为患者行为管理和治疗依从带来了新的曙光,EBCR的长期管理迎来了发展的新阶段^[79]。

3.4 社会经济与文化适配:提高康复可及性与参与率

社会资源配置格局与文化认知模式共同塑造着CR服务的可及性特征。经济欠发达区域普遍存在医疗资源结构性失衡现象,亟待建立基于社区生态的差异化干预框架。经济支持的精准投放必须与文化适配机制协同推进,整合社区医疗资源网络,构建覆盖不同社会阶层的CR服务输送体系。经济资源匮乏群体面临双重困境:CR参与直接影响健康重建进程,医疗支出压力可

能加剧家庭经济脆弱性。文化观念层面的认知偏差则表现为部分患者将康复训练等同于“虚弱标识”,这种符号化认知导致服务利用率呈现显著地域差异。经济激励措施将低社会经济地位患者的CR完成率从11%提高至42%,联合干预下更升至62%,显著改善依从性^[80]。偏远地区受限于交通条件与医疗资源不足,CR实施效果长期停滞于11.2%。远程医疗显著降低了CR未完成风险($OR=0.26$),而完成康复者的再入院及死亡风险在12个月内下降约35%($HR=0.65$),显示科技手段在提升依从性与改善结局方面具有重要潜力^[81]。经济援助与科技手段的协同应用不仅突破地域性医疗资源限制,更通过双重路径缓解经济压力并拓展服务可及性,有效提升CR实施效果。文化背景差异直接制约着CR方案的临床采纳深度。文化适应性CR计划已被证实具有良好可接受性与安全性,能有效改善心血管危险因素,其成功依赖于社区主导的设计、文化敏感性培训与传统实践的有机融合^[82]。针对少数族裔社群的文化适应性CR干预有助于提高患者的参与度和计划完成率,康复环境中融入宗教和文化元素可增强传统社区患者对治疗方案的情感认同和接受意愿^[83]。居住地距康复中心超过16 km是患者不参与EBCR的最强预测因素($OR=1.75$),吸烟、合并慢性病、男性及退休状态亦为显著影响因素,提示优化资源布局与社会文化适配是提升康复可及性与参与率的关键路径^[84]。医疗体系的文化包容性重构和社会经济支持正在成为优化CR结局的关键路径。

4 EBCR:未来发展的多维路径

4.1 填补研究空白:优化实践与探索长期效益

4.1.1 个性化启动时间的优化策略:EBCR能显著降低AMI患者全因死亡与再发梗死风险^[6, 26, 85]。在延长随访周期时全因死亡率未呈现统计学差异($RR=0.91$, $95\%CI=0.75\sim1.10$),但该干预策略对心血管特异性死亡率($RR=0.58$, $95\%CI=0.43\sim0.78$)和心肌梗死发生率($RR=0.67$, $95\%CI=0.50\sim0.90$)方面均表现出显著效果^[85]。确定最佳启动时机直接影响干预效果,促使学界致力于构建精准化个体实施模型。AMI后2周内启动EBCR是安全有益的,不仅不会损害左心室射血分数及心肌功能,还能够促进心脏功能恢复^[86]。早期运动介入的可行性也在其他研究中得到佐证,在一项6周随访的研究中,接受运动干预的患者LVEF显著提升,且未观察到运动相关不良事件^[87]。左心室收缩与舒张功能也能在AMI后1周内开始的运动训练中获得显著改善。另有回顾性分析发现,相对于常规康复,早期家庭运动干预使术后并发症发生率更低(3.45%比17.54%, $P<0.05$),LVEF、HRQoL评分也有显著提高^[88]。现

有证据揭示早期 EBCR 对心脏结构重塑与功能恢复具有积极作用^[89]。后续荟萃分析验证该结论,发现急性期(1周内)进行 EBCR 干预在提升 LVEF、改善左心室收缩末期直径及增加 VO_{2peak} 方面较恢复期(2~4周)更具优势^[89]。但心肌愈合进程伴随康复效益衰减现象,超过4周实施 EBCR 不仅降低心功能恢复幅度,还可能引发心脏适应性障碍^[86]。临床观察显示早期 EBCR 未显著提升心血管不良事件风险^[90];年龄、合并症与经济因素限制导致部分群体错过最佳干预窗口,持续终生 EBCR 训练可有效维持左心室收缩功能、延缓 AMI 后结构异常进展^[91]。ZHANG 等^[92]的荟萃分析发现,AMI 患者康复需突破单一运动训练模式,整合生理状态评估、心理适应度分析与个性化目标设定形成多维干预体系,提示临床需建立动态化 EBCR 执行框架,依据病理分期与耐受阈值精准调控介入时机,在保障安全性的前提下通过依从性管理实现远期预后优化。

4.1.2 运动模式与强度的最佳组合探索:运动模式与强度的优化是 EBCR 研究和实践的重要方向。不同实施模式干预对患者健康结局产生多维影响。EBCR 方案将明尼苏达心力衰竭问卷评分提升 7.11 分(95%CI=-10.49~-3.73),全因住院风险相对降低 30%(RR=0.70, 95%CI=0.60~0.83)^[93],其临床价值体现在生存质量优化与医疗资源消耗降低的双重维度。中心康复、家庭场景及数字化平台实施路径在 HRQoL 改善效应上呈现趋同性,这为个性化康复模式选择提供了实证依据。运动处方的强度控制存在显著个体差异:HIIT 策略使 VO_{2peak} 提升达 25%^[66, 76, 93],但在心力衰竭群体中训练负荷较高可能引发心理压力及依从性下降问题^[94];MICT 方案因强度可控性优势,运动耐力提升幅度相对较低,但长期参与率相对较高,可达 80%^[65, 93]。两种策略的互补性特征提示需根据患者心肺功能基线水平动态调整训练参数。在 EBCR 模式选择过程中,需综合考虑患者体能状态、心理适应水平及康复进程实施精准干预策略。MICT 具有普适性优势,HIIT 则针对性提升心肺功能储备较高者的康复效果。融合 HIIT 高效性与 MICT 依从性优势的混合运动模式正成为 EBCR 领域新兴方向。通过动态调节运动负荷,该方案能匹配不同耐受阈值人群的康复需求,在保证训练安全性的基础上增强康复信心,实现中长期运动处方的持续性执行^[95]。远程监测与智能设备让 EBCR 在个体化康复中的精细化实施迈进了一大步。有研究表明,远程 CR 监测与个性化反馈结合,患者依从率从 29.2% 提升至 80.8%,干预还显著改善了代谢指标,包括高密度脂蛋白水平升高和 BMI 下降,同时焦虑与抑郁水平也有所缓解,显示出远程 CR 在提升多维健康指标方面的综合潜力^[96]。

4.1.3 长期依从性与行为改变的挑战与对策:EBCR 成

效的关键在于患者长期依从,实践中患者长期面临诸多挑战。即使短期康复的确使 HRQoL 大幅提高,12 个月仅 30%~50% 的患者维持初始运动量^[97]。治疗依从性降低受多重因素制约:患者对康复价值认知薄弱、社会支持网络不完善以及复杂心理机制干扰;经济资源匮乏群体与女性患者受经济负担、家庭照护需求及社会角色冲突三重压力影响,康复计划持续性面临显著挑战^[98];运动处方同质化严重与个性化指导缺失导致患者参与积极性持续衰减,这种现象在长期康复过程中尤为突出。智能监测设备与远程支持系统协同应用能有效克服传统康复模式局限,研究证实该策略为无法参与线下 CR 的群体提供了替代路径,不仅提升了治疗依从性,更显著改善了多项生理指标^[27, 30]。实时数据追踪结合动态激励机制突破地理限制,辅助患者建立持续康复行为模式。结合 CBT 策略与社区支持的干预模式,为改善老年患者及社会支持薄弱人群的长期依从性提供了切实可行的方向^[71, 98]。

4.2 技术创新驱动:实现智能化和精准化

心血管疾病诊疗正经历智能精准化转型,AI 与 ML 技术推动个性化康复体系构建。虚拟现实(VR)、增强现实(AR)等数字疗法突破传统 CR 模式,实现治疗过程动态优化,ML 系统整合电子病历、心电信号、新型生物标志物等多维度数据,构建风险评估框架支持临床决策。CCHIA 数据库研究证实,集成随机森林与 XGBoost 算法显著提升预后评估效能,随机森林模型 C 统计量达 0.83,较 Logistic 回归基线提升 12%;引入射血前期、肱射血时间等血流动力学指标后,算法灵敏度提高至 91%,推动 CR 的二级预防策略前移,在疾病早期阶段实施综合干预^[99]。

在 CR 领域,AI 技术显著提升了患者康复体验的个性化程度。AI 算法实时监测患者心率、呼吸及运动状态,并依此动态调整康复强度,保障安全并优化康复效果。SmartCare-CAD 研究证实了这一点:利用可穿戴设备的远程康复模式改善了患者体力活动与 HRQoL,降低了医疗资源消耗,对于受地理位置或经济条件限制而无法参与传统康复的患者而言,这种模式带来了极大便利^[100]。尽管如此,EBCR 过程中心理因素不容忽视,特别是运动恐惧症成为患者参与康复的一大障碍。54%~70% 的心力衰竭患者存在不同程度的运动恐惧,这一心理障碍与运动能力下降、情绪障碍和康复依从性差密切相关,可能在患者康复过程中持续存在较长时间^[71, 101]。VR 与 AR 技术的应用为康复医学领域提供了创新性解决方案。沉浸式虚拟环境能够模拟现实运动场景,使患者在安全受控条件下开展步态协调性训练、平衡功能恢复及心肺耐力提升,直接促进运动系统功能重建,针对中、低风险患者群体,三维空间中的交互式

训练模式可显著优化运动功能表现^[102-103]。

荟萃分析表明,VR辅助的EBCR在焦虑抑郁干预方面较常规疗法呈现显著优势,其沉浸式场景构建能力正推动传统CR体系迭代升级^[104]。智能可穿戴装置通过多模态传感技术持续捕获心电信号、血氧浓度及体表温度等参数,依托ML模型实现生理指标的动态解析,监测数据一旦超过安全阈值,设备端即时触发预警机制引导患者及时干预或联系医护人员。这种融合边缘计算与移动医疗的创新模式,为精准化CR指导提供了新的技术范式。一项对16 741名老年女性开展的前瞻性队列研究表明,每日步数越多,全因死亡风险越低;当步数达到约7 500步时,健康益处趋于稳定,继续增加步数所带来的额外收益有限^[105]。有研究人员利用腕戴式心率监测器、三轴加速度计对患者活动进行持续监测并提供个性化反馈,这种远程康复计划在改善低风险CHD患者体力活动、HRQoL方面取得成效,效果堪比传统康复,且实施成本更低^[106]。若患者活动减少50%,监测系统能触发警报并及时干预^[100, 107]。AI、ML、AR及智能可穿戴设备融合,不断促进CR领域的智能化与精准化发展,为实现更高效、更科学的心血管疾病康复目标奠定了基础。

4.3 整体范式转型:迈向多学科与全生态康复

4.3.1 心理支持与营养干预的整合:CHD患者中抑郁症、焦虑症较为普遍,增加了患者的死亡概率,降低了HRQoL^[108-109]。CBT能显著改善CHD、心力衰竭、心房颤动患者的心理健康,给予患者康复的正向支持,相关的系统荟萃证实了这一点^[110-111]。心理健康与营养干预的整合是未来EBCR发展的关键。CBT康复模式能有效减轻患者抑郁、提升HRQoL^[112]。重度抑郁患者应接受定期的抑郁筛查,依据基层诊疗指南,在必要时可采用CBT联合选择性5-羟色胺再摄取抑制剂的干预策略,以改善其心理状态,提升康复依从性和远期疗效^[113-114]。此外,个体化营养干预在心血管健康改善中同样具有重要意义。相关研究表明,增加膳食纤维摄入可有效降低心血管风险,而补充 ω -3脂肪酸则有助于减缓炎症反应、稳定心律,对预防及辅助治疗心血管疾病具有显著效果^[115-116]。虽然EBCR改善心理健康与生活品质方面效果显著,目前EBCR相关的研究依然不够,许多领域有待深入。

4.3.2 精准医疗与分子诊断的结合:基因组学与代谢组学的快速发展,为心血管疾病患者康复干预策略的个体化、精准化提供了新的技术支撑。研究显示,PNPLA3 I148M(rs738409)等基因变异不仅与代谢紊乱密切相关,还可能增加个体的心血管死亡风险,对康复路径的设计具有重要参考价值^[117]。与此同时,代谢组层面的研究表明,短链脂肪酸(如丙酸、丁酸等)在维持心血管系

统稳态、调控免疫功能方面发挥着关键作用,其水平的动态变化可作为衡量康复进展和效果的重要指标^[118]。基于多组学联合分析的研究进一步揭示了运动干预在多个组织层面的广泛作用,例如骨骼肌、肝脏及心肌等在蛋白表达、代谢途径和线粒体功能方面均出现系统性改变。这类多维度生物学数据的整合提升了康复效果预测的准确性,为精准制订个体运动处方提供了理论基础^[119]。此外,针对慢性炎症、病毒感染等复杂病理状态,氨基酸代谢异常被认为是关键的干预靶点,特别是色氨酸、谷氨酰胺和精氨酸等代谢通路在免疫调节、黏膜修复和细胞应激中的作用日益受到关注,对推进精准康复干预模式具有重要意义^[120]。

4.3.3 生态系统式康复模式的构建:生态系统康复模式在CR中的应用日益受到重视。该模式强调多学科协同与个体-环境互动,整合生理、心理及社会因素,构建以患者为中心的康复路径^[121]。数字化手段,特别是严肃游戏在提升康复依从性方面显示出良好效果,在低资源环境中亦具备可行性与推广价值^[121]。基于使用依赖性可塑性机制的干预策略,有助于改善慢性肌肉骨骼疼痛患者的运动功能。研究发现,长期运动经验可减轻持续性疼痛对运动皮质的抑制作用,为个体化康复提供了神经调控依据^[122]。此外,融合健康科技的心脏康复模式被证实可在提高HRQoL与实现远程干预方面提供有效支持,并有助于改善康复服务可及性^[123]。在家庭康复场景中,生态系统视角强调持续性与适应性,通过多元主体协作及环境因子整合,推动康复资源的优化配置,实现康复管理的可持续发展^[124]。这一成果进一步佐证了生态系统模式的适用性,特别是在资源受限或患者需求多样化的情况下,或许会成为EBCR有效构建的路径。

综上所述,AMI治疗研究的逐步深入推动康复模式发生动态调整与革新。多学科交叉融合、个性化与精准化发展趋势促使当前康复体系向系统化、整体化方向持续优化。这一转型进程既体现临床实践中干预策略的升级,更反映医学界对疾病康复机制认知水平的实质性突破。

5 结语与展望

EBCR作为AMI患者长期管理的核心干预手段,在降低心血管事件再发风险、改善心肺功能储备及提高HRQoL等方面具有显著效果。然而,在临床实践中,其推广应用仍面临多重挑战,包括患者治疗依从性不足、医疗资源配置不均以及社会经济条件制约等,在LMICs尤为突出。随着康复医学研究的深入,个体化运动处方已成为该领域的重要研究方向,其中以有氧运动强度分级与抗阻训练相结合的多维度干预方案,为不同临床特征患者提供了更为精准的康复策略。值得注意的是,心

理干预与营养支持的协同应用进一步提升了整体康复效果。与此同时,技术创新正在重塑传统康复模式,可穿戴设备与远程监测技术的应用显著提高了康复服务的可及性与患者依从性。

展望未来,EBCR的发展将着重于精准化康复、资源整合与智能化应用三个维度。通过制订个体化康复方案、构建多学科协作体系以及应用数字健康工具,将有力推动EBCR的广泛普及。从本质上而言,EBCR已超越单纯的医学干预范畴,发展成为主动健康管理的重要模式。通过持续优化康复策略,整合科技创新与医疗资源,将为AMI患者提供更优质的康复服务,从而有效降低心血管疾病的全球疾病负担。

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参考文献

- [1] UTHMAN O A, HARTLEY L, REES K, et al. Multiple risk factor interventions for primary prevention of cardiovascular disease in low- and middle-income countries [J]. *Cochrane Database Syst Rev*, 2015, 2015 (8): CD011163. DOI: 10.1002/14651858.CD011163.pub2.
- [2] ANDERSON L, OLDRIDGE N, THOMPSON D R, et al. Exercise-based cardiac rehabilitation for coronary heart disease: cochrane systematic review and meta-analysis [J]. *J Am Coll Cardiol*, 2016, 67 (1): 1-12. DOI: 10.1016/j.jacc.2015.10.044.
- [3] PIEPOLI M F, HOES A W, AGEWALL S, et al. 2016 European Guidelines on cardiovascular disease prevention in clinical practice [J]. *Rev Esp Cardiol (Engl Ed)*, 2016, 69 (10): 939. DOI: 10.1016/j.rec.2016.09.009.
- [4] MCDONAGH S T, DALAL H, MOORE S, et al. Home-based versus centre-based cardiac rehabilitation [J]. *Cochrane Database Syst Rev*, 2023, 10 (10): CD007130. DOI: 10.1002/14651858.CD007130.pub5.
- [5] GRACE S L, TURK-ADAWI K I, CONTRACTOR A, et al. Cardiac rehabilitation delivery model for low-resource settings: an international council of cardiovascular prevention and rehabilitation consensus statement [J]. *Prog Cardiovasc Dis*, 2016, 59 (3): 303-322. DOI: 10.1016/j.pcad.2016.08.004.
- [6] LAWLER P R, FILION K B, EISENBERG M J. Efficacy of exercise-based cardiac rehabilitation post-myocardial infarction: a systematic review and meta-analysis of randomized controlled trials [J]. *Am Heart J*, 2011, 162 (4): 571-584.e2. DOI: 10.1016/j.ahj.2011.07.017.
- [7] RAMOS J S, DALLECK L C, TJONNA A E, et al. The impact of high-intensity interval training versus moderate-intensity continuous training on vascular function: a systematic review and meta-analysis [J]. *Sports Med*, 2015, 45 (5): 679-692. DOI: 10.1007/s40279-015-0321-z.
- [8] KILPATRICK M W, JUNG M E, LITTLE J P. High-intensity interval training [J]. *ACSM'S Health Fit J*, 2014, 18 (5): 11-16. DOI: 10.1249/fit.0000000000000067.
- [9] CHEN N, HE X F, FENG Y W, et al. Effects of resistance training in healthy older people with sarcopenia: a systematic review and meta-analysis of randomized controlled trials [J]. *Eur Rev Aging Phys Act*, 2021, 18 (1): 23. DOI: 10.1186/s11556-021-00277-7.
- [10] DIBBEN G O, FAULKNER J, OLDRIDGE N, et al. Exercise-based cardiac rehabilitation for coronary heart disease: a meta-analysis [J]. *Eur Heart J*, 2023, 44 (6): 452-469. DOI: 10.1093/eurheartj/ehac747.
- [11] WU M, LUO J. Wearable technology applications in healthcare: a literature review [J]. *Online J Nurs Inform*, 2019, 23 (3): 8.
- [12] LI L X, LIANG H, FAN Y, et al. Development of intelligent monitoring system based on Internet of Things and wearable technology and exploration of its clinical application mode [J]. *J Biomed Eng*, 2023, 40 (6): 1053-1061. DOI: 10.7507/1001-5515.202211047.
- [13] ZHAO H Y, ZHOU L, HU L, et al. Summary of best evidence for rehabilitation management of patients with motor dysfunction after stroke [J]. *Zhong Nan Da Xue Xue Bao Yi Xue Ban*, 2024, 49 (4): 497-507. DOI: 10.11817/j.issn.1672-7347.2024.240006.
- [14] LIU Y, GUO S X, YANG Z Y, et al. A home-based tele-rehabilitation system with enhanced therapist-patient remote interaction: a feasibility study [J]. *IEEE J Biomed Health Inform*, 2022, 26 (8): 4176-4186. DOI: 10.1109/JBHI.2022.3176276.
- [15] AL-SADI H I, RAZZAQ A, GABER M, et al. The association between perceived social support and adherence to cardiac rehabilitation in patients with myocardial infarction [J]. *Int J Body Mind Culture*, 2024, 10 (Special Issue): 28-39. DOI: 10.22122/ijbmc.v11isp.736.
- [16] RAUCH B, DAVOS C H, DOHERTY P, et al. The prognostic effect of cardiac rehabilitation in the era of acute revascularisation and statin therapy: a systematic review and meta-analysis of randomized and non-randomized studies - The Cardiac Rehabilitation Outcome Study (CROS) [J]. *Eur J Prev Cardiol*, 2016, 23 (18): 1914-1939. DOI: 10.1177/2047487316671181.
- [17] TURK-ADAWI K, SARRAFZADEGAN N, GRACE S L. Global availability of cardiac rehabilitation [J]. *Nat Rev Cardiol*, 2014, 11 (10): 586-596. DOI: 10.1038/nrcardio.2014.98.
- [18] TAYLOR R S, DALAL H M, ZWISLER A D. Cardiac rehabilitation for heart failure: 'Cinderella' or evidence-based pillar of care? [J]. *Eur Heart J*, 2023, 44 (17): 1511-1518. DOI: 10.1093/eurheartj/ehad118.
- [19] SHANMUGASEGARAM S, OH P, REID R D, et al. Cardiac rehabilitation barriers by rurality and socioeconomic status: a cross-sectional study [J]. *Int J Equity Health*, 2013, 12: 72. DOI: 10.1186/1475-9276-12-72.

- [20] World Health Organization. Rehabilitation: Key facts [EB/OL]. (2024-04-22) [2025-06-22]. <https://www.who.int/news-room/fact-sheets/detail/rehabilitation>.
- [21] NEUBECK L, BEN FREEDMAN S, CLARK A M, et al. Participating in cardiac rehabilitation: a systematic review and meta-synthesis of qualitative data [J]. Eur J Prev Cardiol, 2012, 19 (3) : 494-503. DOI: 10.1177/1741826711409326.
- [22] GRACE S L, TURK-ADAWI K, SANTIAGO DE ARAÚJO PIO C, et al. Ensuring cardiac rehabilitation access for the majority of those in need: a call to action for Canada [J]. Can J Cardiol, 2016, 32 (10 Suppl 2) : S358-364. DOI: 10.1016/j.cjca.2016.07.001.
- [23] ADES P A, KETEYIAN S J, WRIGHT J S, et al. Increasing cardiac rehabilitation participation from 20% to 70%: a road map from the million hearts cardiac rehabilitation collaborative [J]. Mayo Clin Proc, 2017, 92 (2) : 234-242. DOI: 10.1016/j.mayocp.2016.10.014.
- [24] CIEZA A, CAUSEY K, KAMENOV K, et al. Global estimates of the need for rehabilitation based on the global burden of disease study 2019: a systematic analysis for the global burden of disease study 2019 [J]. Lancet, 2021, 396 (10267) : 2006-2017. DOI: 10.1016/S0140-6736(20)32340-0.
- [25] MANSOUR A I, NULIYALU U, THOMPSON M P, et al. Out-of-pocket spending for cardiac rehabilitation and adherence among US adults [J]. Am J Manag Care, 2024, 30 (12) : 651-657. DOI: 10.37765/ajmc.2024.89637.
- [26] DUSCHA B D, ROSS L M, HOSELTON A L, et al. A detailed analysis of cardiac rehabilitation on 180-day all-cause hospital readmission and mortality [J]. J Cardiopulm Rehabil Prev, 2024, 44 (2) : 99-106. DOI: 10.1097/HCR.0000000000000835.
- [27] ZHANG L X, ZHANG L, WANG J, et al. Community health service center-based cardiac rehabilitation in patients with coronary heart disease: a prospective study [J]. BMC Health Serv Res, 2017, 17 (1) : 128. DOI: 10.1186/s12913-017-2036-3.
- [28] ZHANG Z G, JIANG H Y, WANG Y H, et al. Exploration and implementation of management path of community/home-based cardiac rehabilitation [J]. Chinese General Practice, 2019, 22 (31) . DOI: 10.12114/j.issn.1007-9572.2019.00.355.
- [29] World Health Organization. Regional Office for Africa. Assessing the impact of COVID-19 on older people in the African Region: a study conducted by the World Health Organisation Regional Office for Africa [EB/OL]. [2025-06-22]. <https://iris.who.int/handle/10665/351134>.
- [30] TUMWESIGYE R, AINOMUGISHA L, MIREMBE A, et al. Telemedicine and healthcare delivery: a case study of Mbarara Regional Referral Hospital [J]. Metropolitan Journal of Medical and Health Research, 2024, 3 (10) : 172-183.
- [31] WOHLFAHRT P, JENČA D, MELENOVSKÝ V, et al. Remote, smart device-based cardiac rehabilitation after myocardial infarction: a pilot, randomized cross-over SmartRehab study [J]. Mayo Clin Proc Digit Health, 2024, 2 (3) : 352-360. DOI: 10.1016/j.mcpdig.2024.06.001.
- [32] BOURKE A, NIRANJAN V, O'CONNOR R, et al. Barriers to and motives for engagement in an exercise-based cardiac rehabilitation programme in Ireland: a qualitative study [J]. BMC Prim Care, 2022, 23 (1) : 28. DOI: 10.1186/s12875-022-01637-7.
- [33] ANTONIOU V, DAVOS C H, KAPRELI E, et al. Effectiveness of home-based cardiac rehabilitation, using wearable sensors, as a multicomponent, cutting-edge intervention: a systematic review and meta-analysis [J]. J Clin Med, 2022, 11 (13) : 3772. DOI: 10.3390/jcm11133772.
- [34] KHALIQ A, MUZZAM A, RAFIQUE R, et al. A feasibility randomized controlled trial of culturally adapted Getting Better Bite-by-Bite (Ca-GBBB) intervention for individuals with eating disorders in Pakistan [J]. J Eat Disord, 2024, 12 (1) : 100. DOI: 10.1186/s40337-024-01038-4.
- [35] RAUCH B, DAVOS C H, DOHERTY P, et al. The prognostic effect of cardiac rehabilitation in the era of acute revascularisation and statin therapy: a systematic review and meta-analysis of randomized and non-randomized studies - The Cardiac Rehabilitation Outcome Study (CROS) [J]. Eur J Prev Cardiol, 2016, 23 (18) : 1914-1939. DOI: 10.1177/2047487316671181.
- [36] RODRIGUES B, LIRA F S, CONSOLIM-COLOMBO F M, et al. Role of exercise training on autonomic changes and inflammatory profile induced by myocardial infarction [J]. Mediators Inflamm, 2014, 2014 : 702473. DOI: 10.1155/2014/702473.
- [37] TAYLOR R S, BROWN A, EBRAHIM S, et al. Exercise-based rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized controlled trials [J]. Am J Med, 2004, 116 (10) : 682-692. DOI: 10.1016/j.amjmed.2004.01.009.
- [38] LA ROVERE M T, BERSANO C, GNEMMI M, et al. Exercise-induced increase in baroreflex sensitivity predicts improved prognosis after myocardial infarction [J]. Circulation, 2002, 106 (8) : 945-949. DOI: 10.1161/01.cir.0000027565.12764.e1.
- [39] MARTINEZ D G, NICOLAU J C, LAGE R L, et al. Effects of long-term exercise training on autonomic control in myocardial infarction patients [J]. Hypertension, 2011, 58 (6) : 1049-1056. DOI: 10.1161/HYPERTENSIONAHA.111.176644.
- [40] SUZUKI K. Cytokine response to exercise and its modulation [J]. Antioxidants, 2018, 7 (1) : 17. DOI: 10.3390/antiox7010017.
- [41] FLETCHER G F, ADES P A, KLIGFIELD P, et al. Exercise standards for testing and training: a scientific statement from the American heart association [J]. Circulation, 2013, 128 (8) : 873-934. DOI: 10.1161/CIR.0b013e31829b5b44.
- [42] GILLINOV S, ETIWIY M, WANG R, et al. Variable accuracy of wearable heart rate monitors during aerobic exercise [J]. Med Sci Sports Exerc, 2017, 49 (8) : 1697-1703. DOI: 10.1249/MSS.0000000000001284.
- [43] SUMIDE T, SHIMADA K, OHMURA H, et al. Relationship between exercise tolerance and muscle strength following cardiac rehabilitation: comparison of patients after cardiac surgery and patients with myocardial infarction [J]. J Cardiol, 2009, 54 (2) : 273-281. DOI: 10.1016/j.jjcc.2009.05.016.
- [44] YAMAMOTO S, HOTTA K, OTA E, et al. Effects of resistance training on muscle strength, exercise capacity, and mobility in

- middle-aged and elderly patients with coronary artery disease: a meta-analysis [J]. *J Cardiol*, 2016, 68 (2): 125-134. DOI: 10.1016/j.jcc.2015.09.005.
- [45] BJARNASON-WEHRENS B, MAYER-BERGER W, MEISTER E R, et al. Recommendations for resistance exercise in cardiac rehabilitation. Recommendations of the German Federation for Cardiovascular Prevention and Rehabilitation [J]. *Eur J Cardiovasc Prev Rehabil*, 2004, 11 (4): 352-361. DOI: 10.1097/01.hjr.0000137692.36013.27.
- [46] CAI H, CAO P Y, ZHOU W Q, et al. Effect of early cardiac rehabilitation on prognosis in patients with heart failure following acute myocardial infarction [J]. *BMC Sports Sci Med Rehabil*, 2021, 13 (1): 139. DOI: 10.1186/s13102-021-00368-z.
- [47] AISPURU-LANCHE G R, GALLEGO-MUÑOZ M, JAYO-MONTOYA J A, et al. Low-volume and high-intensity aerobic interval training may attenuate dysfunctional ventricular remodeling after myocardial infarction: data from the INTERFARCT study [J]. *Rev Cardiovasc Med*, 2023, 24 (1): 20. DOI: 10.31083/j.rcm.2401020.
- [48] MCLEOD K A, JONES M D, THOM J M, et al. Resistance training and high-intensity interval training improve cardiometabolic health in high risk older adults: a systematic review and meta-analysis [J]. *Int J Sports Med*, 2022, 43 (3): 206-218. DOI: 10.1055/a-1560-6183.
- [49] LAZAR J M, KHANNA N, CHESLER R, et al. Swimming and the heart [J]. *Int J Cardiol*, 2013, 168 (1): 19-26. DOI: 10.1016/j.ijcard.2013.03.063.
- [50] ADSETT J A, MUDGE A M, MORRIS N, et al. Aquatic exercise training and stable heart failure: a systematic review and meta-analysis [J]. *Int J Cardiol*, 2015, 186: 22-28. DOI: 10.1016/j.ijcard.2015.03.095.
- [51] YADAV R, YADAV R K, SARVOTTAM K, et al. Framingham risk score and estimated 10-year cardiovascular disease risk reduction by a short-term Yoga-based LifeStyle intervention [J]. *J Altern Complement Med*, 2017, 23 (9): 730-737. DOI: 10.1089/acm.2016.0309.
- [52] CHRISTA E, SRIVASTAVA P, CHANDRAN D S, et al. Effect of Yoga-based cardiac rehabilitation on heart rate variability: randomized controlled trial in patients post-MI [J]. *Int J Yoga Therap*, 2019, 29 (1): 43-50. DOI: 10.17761/2019-00019.
- [53] MARZOLINI S, OH P I, THOMAS S G, et al. Aerobic and resistance training in coronary disease: single versus multiple sets [J]. *Med Sci Sports Exerc*, 2008, 40 (9): 1557-1564. DOI: 10.1249/MSS.0b013e318177eb7f.
- [54] MARZOLINI S, OH P I, BROOKS D. Effect of combined aerobic and resistance training versus aerobic training alone in individuals with coronary artery disease: a meta-analysis [J]. *Eur J Prev Cardiol*, 2012, 19 (1): 81-94. DOI: 10.1177/1741826710393197.
- [55] SCHROEDER E C, FRANKE W D, SHARP R L, et al. Comparative effectiveness of aerobic, resistance, and combined training on cardiovascular disease risk factors: a randomized controlled trial [J]. *PLoS One*, 2019, 14 (1): e0210292. DOI: 10.1371/journal.pone.0210292.
- [56] TOFAS T, FATOUROS I G, DRAGANIDIS D, et al. Effects of cardiovascular, resistance and combined exercise training on cardiovascular, performance and blood redox parameters in coronary artery disease patients: an 8-month training-detraining randomized intervention [J]. *Antioxidants (Basel)*, 2021, 10 (3): 409. DOI: 10.3390/antiox10030409.
- [57] GIULIANO C. Optimising clinical and functional outcomes in older adults with chronic heart failure [D]. Melbourne: Victoria University, 2020.
- [58] LICHTMAN J H, JR J T B, BLUMENTHAL J A, et al. Depression and coronary heart disease: recommendations for screening, referral, and treatment: a science advisory from the American heart association prevention committee of the council on cardiovascular nursing, council on clinical cardiology, council on epidemiology and prevention, and interdisciplinary council on quality of care and outcomes research: endorsed by the American psychiatric association [J]. *Circulation*, 2008, 118 (17): 1768-1775. DOI: 10.1161/CIRCULATIONAHA.108.190769.
- [59] ESTRUCH R, ROS E, SALAS-SALVADÓ J, et al. Retraction and republication: primary prevention of cardiovascular disease with a Mediterranean diet. *N engl J med* 2013; 368: 1279-90 [J]. *N Engl J Med*, 2018, 378 (25): 2441-2442. DOI: 10.1056/NEJMc1806491.
- [60] GIALLAURIA F, LUCCI R, PIETROSANTE M, et al. Exercise-based cardiac rehabilitation improves heart rate recovery in elderly patients after acute myocardial infarction [J]. *J Gerontol A Biol Sci Med Sci*, 2006, 61 (7): 713-717. DOI: 10.1093/gerona/61.7.713.
- [61] MEDICINE A C O S. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults [J]. *Med Sci Sports Exerc*, 2009, 41 (3): 687-708. DOI: 10.1249/MSS.0b013e3181915670.
- [62] ADIWINATA S, POETRA B, LAMPUS N S, et al. Comprehensive cardiac rehabilitation in elderly patients with heart failure: age is just a number? Free [J]. *Eur J Prev Cardiol*, 2024, 31 (Supplement_1): zwae175.155. DOI: 10.1093/eurjpc/zwae175.155.
- [63] MIAO X, JIANG H, HUANG X F, et al. Randomized trial of early exercise rehabilitation and its effects on patients with acute coronary syndrome [J]. *Sci Rep*, 2024, 14 (1): 26289. DOI: 10.1038/s41598-024-77108-z.
- [64] HOV H, WANG E, LIM Y R, et al. Aerobic high-intensity intervals are superior to improve $\dot{V}O_{2\max}$ compared with sprint intervals in well-trained men [J]. *Scand J Med Sci Sports*, 2023, 33 (2): 146-159. DOI: 10.1111/sms.14251.
- [65] TJØNNA A E, LEE S J, ROGNMO Ø, et al. Aerobic interval training versus continuous moderate exercise as a treatment for the metabolic syndrome: a pilot study [J]. *Circulation*, 2008, 118 (4): 346-354. DOI: 10.1161/CIRCULATIONAHA.108.772822.
- [66] YANG C R, ZHANG L Z, CHENG Y, et al. High intensity interval training vs. moderate intensity continuous training on aerobic

- capacity and functional capacity in patients with heart failure: a systematic review and meta-analysis [J]. *Front Cardiovasc Med*, 2024, 11: 1302109. DOI: 10.3389/fcvm.2024.1302109.
- [67] TAYLOR J L, KEATING S E, HOLLAND D J, et al. Comparison of high intensity interval training with standard cardiac rehabilitation on vascular function [J]. *Scand J Med Sci Sports*, 2022, 32 (3): 512–520. DOI: 10.1111/sms.14106.
- [68] JUG B, SEDLAR KOBE N, STOJINIC D, et al. Cardiac rehabilitation patient perspectives during COVID-19 pandemic: quantitative and qualitative study [J]. *Front Cardiovasc Med*, 2024, 11: 1373684. DOI: 10.3389/fcvm.2024.1373684.
- [69] TURNER E A. Understanding the Multi-faceted Patient Experience after Spontaneous Coronary Artery Dissection (SCAD) [D]. Sydney: University of Technology Sydney (Australia), 2024.
- [70] LIU L, YANG Q, LI T L, et al. Prevalence and influencing factors of kinesiophobia in patients with heart disease: a meta-analysis and systematic review [J]. *Sci Rep*, 2024, 14 (1): 18956. DOI: 10.1038/s41598-024-69929-9.
- [71] XIANG Q, XIONG X Y, ZHANG M J, et al. Incidence and influencing factors of kinesiophobia in patients with chronic heart failure: a scoping review [J]. *Front Psychol*, 2024, 15: 1395199. DOI: 10.3389/fpsyg.2024.1395199.
- [72] WALTON L, DE MENDONCA J, PRESTON E, et al. Transient ischemic attack and mild stroke participant perspectives on barriers and enablers to participation in cardiovascular rehabilitation: a qualitative study guided by the theoretical domains framework and capability, opportunity, motivation and behavior model [J]. *Journal of Cardiovascular Nursing*, 2024: 10.1097. DOI: 10.1097/JCN.0000000000001155.
- [73] MOLOS I, KLEISIARIS C, PATELAROU A, et al. Evaluation of a specialist nurse-led post-coronary heart disease support program: a prospective pre-post interventional study [J]. *Healthcare (Basel)*, 2024, 12 (24): 2497. DOI: 10.3390/healthcare12242497.
- [74] DE MELO GHISI G L, AULTMAN C, OH P. Characterizing health literacy in cardiac rehabilitation patients: a decade of multinational data (2014–2024) [J]. *Health Lit Commun Open*, 2025, 3 (1): 2446620. DOI: 10.1080/28355245.2024.2446620.
- [75] WOHLFAHRT P, JENCA D, MRAZKOVA J, et al. Abstract 13995: remote, smart device based cardiac rehabilitation after myocardial infarction – smart rehab study [J]. *Circulation*, 2023, 148 (Suppl_1): A13995–A. DOI: 10.1161/circ.148.suppl_1.13995
- [76] ZHONG W, LIU R, CHENG H X, et al. Longer-term effects of cardiac telerehabilitation on patients with coronary artery disease: systematic review and meta-analysis [J]. *JMIR Mhealth Uhealth*, 2023, 11: e46359. DOI: 10.2196/46359.
- [77] BORGHI-SILVA A, GOULART C D L, SILVA R N, et al. Impact of COVID-19 on exercise-based pulmonary rehabilitation: what lessons have we learned? [J]. *J Cardiopulm Rehabil Prev*, 2024, 44 (6): 409–416. DOI: 10.1097/HCR.0000000000000916.
- [78] DE ABREU R M, CAIRO B, KARSTEN M, et al. Editorial: Innovative approaches to exercise assessment and prescription in non-communicable diseases [J]. *Front Sports Act Living*, 2025, 7: 1560372. DOI: 10.3389/fspor.2025.1560372.
- [79] CHEN W P, FENG Y, YU M L, et al. Effects of different rehabilitation modality on cardiopulmonary function in patients with acute coronary syndrome after revascularization [J]. *Front Cardiovasc Med*, 2024, 10: 1120665. DOI: 10.3389/fcvm.2023.1120665.
- [80] GAALEMA D E, KHADANGA S, SAVAGE P D, et al. Improving cardiac rehabilitation adherence in patients with lower socioeconomic status: a randomized clinical trial [J]. *JAMA Intern Med*, 2024, 184 (9): 1095–1104. DOI: 10.1001/jamainternmed.2024.3338.
- [81] BELEIGOLI A, DAFNY H A, PINERO DE PLAZA M A, et al. Clinical effectiveness of cardiac rehabilitation and barriers to completion in patients of low socioeconomic status in rural areas: a mixed-methods study [J]. *Clin Rehabil*, 2024, 38 (6): 837–854. DOI: 10.1177/02692155241236998.
- [82] MARCHAND M, MCCALLUM R K, MARCHAND K, et al. Indigenizing cardiac rehabilitation: the role for cultural adaptation [J]. *Can J Cardiol*, 2024, 40 (6): 1069–1076. DOI: 10.1016/j.cjca.2023.12.006.
- [83] MIDENCE L, MOLA A N, TERZIC C M, et al. Ethnocultural diversity in cardiac rehabilitation [J]. *J Cardiopulm Rehabil Prev*, 2014, 34 (6): 437–444. DOI: 10.1097/HCR.0000000000000089.
- [84] BORG S, ÖBERG B, LEOSDOTTIR M, et al. Factors associated with non-attendance at exercise-based cardiac rehabilitation [J]. *BMC Sports Sci Med Rehabil*, 2019, 11: 13. DOI: 10.1186/s13102-019-0125-9.
- [85] DIBBEN G, FAULKNER J, OLDRIDGE N, et al. Exercise-based cardiac rehabilitation for coronary heart disease [J]. *Cochrane Database Syst Rev*, 2021, 11 (11): CD001800. DOI: 10.1002/14651858.CD001800.pub4.
- [86] KIM C, KIM D Y, LEE D W. The impact of early regular cardiac rehabilitation program on myocardial function after acute myocardial infarction [J]. *Ann Rehabil Med*, 2011, 35 (4): 535–540. DOI: 10.5535/arm.2011.35.4.535.
- [87] HAYKOWSKY M, SCOTT J, ESCH B, et al. A meta-analysis of the effects of exercise training on left ventricular remodeling following myocardial infarction: start early and go longer for greatest exercise benefits on remodeling [J]. *Trials*, 2011, 12: 92. DOI: 10.1186/1745-6215-12-92.
- [88] YU H Q, YANG H E. Effect of early home-based exercise for cardiac rehabilitation on the prognosis of patients with acute myocardial infarction after percutaneous coronary intervention [J]. *Am J Transl Res*, 2021, 13 (7): 7839–7847.
- [89] GIALLAURIA F, ACAMPA W, RICCI F, et al. Exercise training early after acute myocardial infarction reduces stress-induced hypoperfusion and improves left ventricular function [J]. *Eur J Nucl Med Mol Imaging*, 2013, 40 (3): 315–324. DOI: 10.1007/s00259-012-2302-x.
- [90] ZHANG Y M, LU Y, TANG Y, et al. The effects of different initiation time of exercise training on left ventricular remodeling and cardiopulmonary rehabilitation in patients with left ventricular dysfunction after myocardial infarction [J]. *Disabil Rehabil*, 2016, 38 (3): 268–276. DOI:

- 10.3109/09638288.2015.1036174.
- [91] MARCHIONNI N, FATTIROLI F, FUMAGALLI S, et al. Determinants of exercise tolerance after acute myocardial infarction in older persons [J]. J Am Geriatr Soc, 2000, 48 (2) : 146–153. DOI: 10.1111/j.1532-5415.2000.tb03905.x.
- [92] ZHANG S S, LIN Y H. Advancements, challenges, and innovative strategies in cardiac rehabilitation for patients with acute myocardial infarction: a systematic review [J]. Curr Probl Cardiol, 2025, 50 (2) : 102934. DOI: 10.1016/j.cpcardiol.2024.102934.
- [93] LONG L, MORDI I R, BRIDGES C, et al. Exercise-based cardiac rehabilitation for adults with heart failure [J]. Cochrane Database Syst Rev, 2019, 1: CD003331. DOI: 10.1002/14651858.cd003331.pub5.
- [94] MARTLAND R, KORMAN N, FIRTH J, et al. Can high-intensity interval training improve mental health outcomes in the general population and those with physical illnesses? A systematic review and meta-analysis [J]. Br J Sports Med, 2022, 56 (5) : 279–291. DOI: 10.1136/bjsports-2021-103984.
- [95] NICHOLS S, MCGREGOR G, BRECKON J, et al. Current insights into exercise-based cardiac rehabilitation in patients with coronary heart disease and chronic heart failure [J]. Int J Sports Med, 2021, 42 (1) : 19–26. DOI: 10.1055/a-1198-5573.
- [96] LI P R, ZHANG W J, WU B B. Adherence to cardiac rehabilitation in patients with acute myocardial infarction after PCI: a scoping review [J]. J Multidiscip Healthc, 2024, 17: 4165–4176. DOI: 10.2147/JMDH.S483512.
- [97] TAYLOR R S, SAGAR V A, DAVIES E J, et al. Exercise-based rehabilitation for heart failure [J]. Cochrane Database Syst Rev, 2014, 2014 (4) : CD003331. DOI: 10.1002/14651858.CD003331.pub4.
- [98] GUNN E, BRAY S R, MATASEJE L, et al. Psychosocial outcomes and adherence in a women's only exercise and education cardiac rehabilitation program [J]. J Cardiopulm Rehabil Prev, 2007, 27 (5) : 345. DOI: 10.1097/01.her.0000291377.52385.9d.
- [99] ROUDINI B, KHAJEHPURI B, MOGHADDAM H A, et al. Machine learning predicts long-term mortality after acute myocardial infarction using systolic time intervals and routinely collected clinical data [J]. Intell Med, 2024, 4 (3) : 170–176. DOI: 10.1016/j.imed.2024.01.001.
- [100] BROUWERS R W M, KRAAL J J, REGIS M, et al. Effectiveness of cardiac telerehabilitation with relapse prevention: SmartCare-CAD randomized controlled trial [J]. J Am Coll Cardiol, 2021, 77 (21) : 2754–2756. DOI: 10.1016/j.jacc.2021.03.328.
- [101] LLOYD-JONES D M, ALLEN N B, ANDERSON C A M, et al. Life's essential 8: updating and enhancing the American Heart Association's construct of cardiovascular health: a presidential advisory from the American heart association [J]. Circulation, 2022, 146 (5) : e18–43. DOI: 10.1161/CIR.0000000000001078.
- [102] RUIVO J M A D S, KARIM K, O'U02BCSHEA R, et al. In-class active video game supplementation and adherence to cardiac rehabilitation [J]. J Cardiopulm Rehabil Prev, 2017, 37 (4) : 274–278. DOI: 10.1097/HCR.0000000000000224.
- [103] CACAU LDE A, OLIVEIRA G U, MAYNARD L G, et al. The use of the virtual reality as intervention tool in the postoperative of cardiac surgery [J]. Rev Bras Cir Cardiovasc, 2013, 28 (2) : 281–289. DOI: 10.5935/1678-9741.20130039.
- [104] BASHIR Z, MISQUITH C, SHAHAB A, et al. The impact of virtual reality on anxiety and functional capacity in cardiac rehabilitation: a systematic review and meta-analysis [J]. Curr Probl Cardiol, 2023, 48 (5) : 101628. DOI: 10.1016/j.cpcardiol.2023.101628.
- [105] LEE I M, SHIROMA E J, KAMADA M, et al. Association of step volume and intensity with all-cause mortality in older women [J]. JAMA Intern Med, 2019, 179 (8) : 1105–1112. DOI: 10.1001/jamainternmed.2019.0899.
- [106] BROUWERS R W M, VAN DER POORT E K J, KEMPS H M C, et al. Cost-effectiveness of cardiac telerehabilitation with relapse prevention for the treatment of patients with coronary artery disease in the Netherlands [J]. JAMA Netw Open, 2021, 4 (12) : e2136652. DOI: 10.1001/jamanetworkopen.2021.36652.
- [107] MEIJER A, CONRADI H J, BOS E H, et al. Prognostic association of depression following myocardial infarction with mortality and cardiovascular events: a meta-analysis of 25 years of research [J]. Gen Hosp Psychiatry, 2011, 33 (3) : 203–216. DOI: 10.1016/j.genhosppsych.2011.02.007.
- [108] POGOSOVA N, SANER H, PEDERSEN S S, et al. Psychosocial aspects in cardiac rehabilitation: from theory to practice. a position paper from the cardiac rehabilitation section of the European association of cardiovascular prevention and rehabilitation of the European society of cardiology [J]. Kardiologia, 2015, 55 (10) : 96–108. DOI: 10.18565/cardio.2015.10.96–108.
- [109] CANDELARIA D, RANDALL S, LADAK L, et al. Health-related quality of life and exercise-based cardiac rehabilitation in contemporary acute coronary syndrome patients: a systematic review and meta-analysis [J]. Qual Life Res, 2020, 29 (3) : 579–592. DOI: 10.1007/s11136-019-02338-y.
- [110] VERSCHUEREN S, ESKES A M, MAASKANT J M, et al. The effect of exercise therapy on depressive and anxious symptoms in patients with ischemic heart disease: a systematic review [J]. J Psychosom Res, 2018, 105: 80–91. DOI: 10.1016/j.jpsychores.2017.11.018.
- [111] ZAMBRANO J, CELANO C M, JANUZZI J L, et al. Psychiatric and psychological interventions for depression in patients with heart disease: a scoping review [J]. J Am Heart Assoc, 2020, 9 (22) : e018686. DOI: 10.1161/JAHA.120.018686.
- [112] SCHOLZ U, KNOLL N, SNIEHOTTA F F, et al. Physical activity and depressive symptoms in cardiac rehabilitation: long-term effects of a self-management intervention [J]. Soc Sci Med, 2006, 62 (12) : 3109–3120. DOI: 10.1016/j.socscimed.2005.11.035.
- [113] 中华医学会, 中华医学杂志社, 中华医学会全科医学分会, 等. 抑郁症基层诊疗指南 (2021 年) [J]. 中华全科医师杂志, 2021, 20 (12) : 1249–1260. DOI: 10.3760/cma.j.cn114798-20211020-00778.

(下转第 4647 页)

- [26] AVILA A, CLAES J, GOETSCHALCKX K, et al. Home-based rehabilitation with telemonitoring guidance for patients with coronary artery disease (short-term results of the TRiCH study): randomized controlled trial [J]. J Med Internet Res, 2018, 20(6): e225. DOI: 10.2196/jmir.9943.
- [27] BATALIK L, PEPERA G, PAPATHANASIOU J, et al. Is the training intensity in phase two cardiovascular rehabilitation different in telehealth versus outpatient rehabilitation? [J]. J Clin Med, 2021, 10(18): 4069. DOI: 10.3390/jcm10184069.
- [28] BATALIK L, DOSBABA F, HARTMAN M, et al. Long-term exercise effects after cardiac telerehabilitation in patients with coronary artery disease: 1-year follow-up results of the randomized study [J]. Eur J Phys Rehabil Med, 2021, 57(5): 807-814. DOI: 10.23736/s1973-9087.21.06653-3.
- [29] PFAEFFLI DALE L, WHITTAKER R, JIANG Y N, et al. Text message and Internet support for coronary heart disease self-management: results from the Text4Heart randomized controlled trial [J]. J Med Internet Res, 2015, 17(10): e237. DOI: 10.2196/jmir.4944.
- [30] LAO S S W, CHAIR S Y. The feasibility of smartphone-based application on cardiac rehabilitation for Chinese patients with percutaneous coronary intervention in Macau: a qualitative evaluation [J]. Int J Qual Stud Health Well-being, 2022, 17(1): 2023940. DOI: 10.1080/17482631.2021.2023940.
- [31] MADDISON R, RAWSTORN J C, ROLLESTON A, et al. The remote exercise monitoring trial for exercise-based cardiac rehabilitation (REMOTE-CR): a randomised controlled trial protocol [J]. BMC Public Health, 2014, 14: 1236. DOI: 10.1186/1471-2458-14-1236.
- [32] BREWER L C, KAIHOI B, ZARLING K K, et al. The use of virtual world-based cardiac rehabilitation to encourage healthy lifestyle choices among cardiac patients: intervention development and pilot study protocol [J]. JMIR Res Protoc, 2015, 4(2): e39. DOI: 10.2196/resprot.4285.
- [33] 王子涵, 岳雯静, 张向毅, 等. 心脏康复患者运动恐惧形成与消退质性研究的Meta整合 [J]. 中国护理管理, 2024, 24(5): 725-730.
- [34] 孙爱萍, 丁雯, 王斐, 等. 中青年慢性心力衰竭病人运动康复影响因素的质性研究 [J]. 循证护理, 2023, 9(6): 1080-1085. DOI: 10.12102/j.issn.2095-8668.2023.06.026.
- [35] 刘欣源, 陈素琿, 文红, 等. 专科护理门诊开展经皮冠状动脉介入治疗术后患者运动康复的实践 [J]. 中国护理管理, 2025, 25(1): 6-11.
- [36] YU K H, HEALEY E, LEONG T Y, et al. Medical artificial intelligence and human values [J]. N Engl J Med, 2024, 390(20): 1895-1904. DOI: 10.1056/NEJMra2214183.
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(上接第4639页)

- [114] ZAMBRANO J, CELANO C M, JANUZZI J L, et al. Psychiatric and psychological interventions for depression in patients with heart disease: a scoping review [J]. J Am Heart Assoc, 2020, 9(22): e018686. DOI: 10.1161/JAHA.120.018686.
- [115] FU L M, ZHANG G B, QIAN S S, et al. Associations between dietary fiber intake and cardiovascular risk factors: an umbrella review of meta-analyses of randomized controlled trials [J]. Front Nutr, 2022, 9: 972399. DOI: 10.3389/fnut.2022.972399.
- [116] LI J J, DOU K F, ZHOU Z G, et al. Role of omega-3 fatty acids in the prevention and treatment of cardiovascular diseases: a consensus statement from the Experts' Committee of National Society Of Cardiometabolic Medicine [J]. Front Pharmacol, 2022, 13: 1069992. DOI: 10.3389/fphar.2022.1069992.
- [117] WIJARNPREECHA K, SCRIBANI M, RAYMOND P, et al. PNPLA3 gene polymorphism and overall and cardiovascular mortality in the United States [J]. J Gastroenterol Hepatol, 2020, 35(10): 1789-1794. DOI: 10.1111/jgh.15045.
- [118] CHEN X F, CHEN X Q, TANG X Q. Short-chain fatty acid, acylation and cardiovascular diseases [J]. Clin Sci (Lond), 2020, 134(6): 657-676. DOI: 10.1042/CS20200128.
- [119] GROUP M S, ANALYSTS L, GROUP M S. Temporal dynamics of the multi-omic response to endurance exercise training [J]. Nature, 2024, 629(8010): 174-183. DOI: 10.1038/s41586-023-06877-w.
- [120] ZHENG X W, ZHU Y, ZHAO Z H, et al. The role of amino acid metabolism in inflammatory bowel disease and other inflammatory diseases [J]. Front Immunol, 2023, 14: 1284133. DOI: 10.3389/fimmu.2023.1284133.
- [121] DEREJE D, LAMBA D, ABESSA T G, et al. Unlocking the potential of serious games for rehabilitation in low and middle-income countries: addressing potential and current limitations [J]. Front Digit Health, 2025, 7: 1505717. DOI: 10.3389/fdgh.2025.1505717.
- [122] ZAMORANO A M, KLEBER B, DE MARTINO E, et al. Prior use-dependent plasticity triggers different individual corticomotor responses during persistent musculoskeletal pain [J]. bioRxiv, 2025: 2025.01.15.633250. DOI: 10.1101/2025.01.15.633250.
- [123] BHATLA A, KIM C H, NIMBALKAR M, et al. Cardiac rehabilitation enabled with health technology: innovative models of care delivery and policy to enhance health equity [J]. J Am Heart Assoc, 2024, 13(2): e031621. DOI: 10.1161/JAHA.123.031621.
- [124] ELF M, NORIN L, MEIJERING L, et al. Rehabilitation at home with the development of a sustainable model placing the person's needs and environment at heart: protocol for a multimethod project [J]. JMIR Res Protoc, 2024, 13: e56996. DOI: 10.2196/56996.
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