·综　述·

脑卒中心肺适能康复研究进展

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摘要：心肺适能被誉为“第五生命体征”，与多种常见病、慢性病的发病、进展及预后密切相关。作为我国成人致死、致残的首位病因，脑卒中常导致心肺适能下降等功能障碍，影响患者的康复预后，增加患者再发卒中风险。近年来，越来越多的康复医务工作者意识到心肺适能在脑卒中康复中的重要性。本文就脑卒中患者心肺适能下降的机制、心肺适能评估方法及训练方法作一介绍，为脑卒中综合康复提供参考。

关键词：脑卒中；心肺适能；心肺运动测试；有氧训练；抗阻训练；高强度间歇训练；吸气肌训练；普拉提

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Research progress on cardiorespiratory fitness rehabilitation in stroke

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Abstract: Cardiorespiratory fitness is known as the “fifth vital sign” and is closely related to the onset, progression, and prognosis of various common and chronic diseases. As the leading cause of adult mortality and disability in China, stroke often leads to dysfunction such as decreased cardiorespiratory fitness, which affects patients' rehabilitation prognosis and increases their risk of recurrent stroke. In recent years, more and more rehabilitation medical workers have realized the importance of cardiorespiratory fitness in stroke rehabilitation. This article introduces the mechanism of decreased cardiorespiratory fitness in stroke patients, as well as the evaluation and training methods for cardiorespiratory fitness, in order to provide reference for comprehensive rehabilitation of stroke.

Keywords: Stroke; Cardiorespiratory fitness; Cardiopulmonary exercise test; Aerobic training; Resistance training; High-intensity interval training; Inspiratory muscle training; Pilates

脑卒中是我国成人致死、致残的首位病因，具有高发病率、高致残率、高死亡率、高复发率和高经济负担五大特点[1]。推测我国 40 岁以上人群现患和曾患脑卒中人数约为 1 704 万[1]。其中，缺血性卒中后 1 年内复发率为 9%～15%[2-3]。

心肺适能(cardiorespiratory fitness，CRF)反映了循环系统和呼吸系统在持续的、中等到高强度的身体活动中为骨骼肌提供氧气的能力，以峰值摄氧量(peak oxygen uptake，VO_{2peak})表示，被誉为“第五生命体征”[4]。心肺适能因年龄、性别、身体活动水平、身体成分以及是否存在慢性疾病或残疾而不同。低心肺健康与心血管疾病风险增加相关，日常的心肺适能水平及其变化与卒中和死亡的长期风险相关[5]。中年时期低心肺适能与晚年脑卒中风险增加有关[6]。与年龄、性别相匹配的无卒中成年人相比，脑卒中患者的心肺适能下降 25%～45%，而心肺适能下降是已知的脑卒中复发危险因素[7-9]。

低心肺适能增加脑卒中风险，脑卒中后患者心肺适能下降，可能导致活动减少和久坐行为，不利于卒中恢复，更增加卒中复发概率。如此形成恶性循环，严重影响患者预后。近年来，人们逐渐意识到心肺适能的重要性，以及心肺适能训练对脑卒中患者整体康复的意义。结合药物、饮食调整的运动方案，可使脑卒中复发性血管事件的累积风险降低 80%[10]。本文就近些年相关研究进行综述。

1　脑卒中患者心肺适能下降的机制

相对于健康成年人，脑卒中患者发病前多存在相关基础疾病或危险因素。在国内，高血压是最常见的脑卒中危险因素，其次为超重或肥胖、血脂异常、吸烟、糖尿病、脑卒中家族史、体力活动不足、房颤[11]。这些疾病或危险因素通过各种途径影响着患者的心肺适能。伴有或不伴有左室肥大的高血压患者的心肺适能较血压正常人群显著降低[12]。与体重正常的同龄人相比，超重儿童的 VO_{2max} 较低[13]。新诊断的男性 2 型糖尿病患者的心肺耐力下降，且随着血糖水平和内脏脂肪水平的升高，VO_{2peak} 逐渐下降[14]。与低体力活动人群相比，中

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等强度和高强度的体力活动人群的心肺适能更好[15-16]。因此,相对于健康人群,脑卒中患者发病前可能已存在心肺适能损害。而患者卒中后易出现心脏损伤或心血管并发症,包括急性心肌损伤、心率失常、心脏衰竭等,被称之为脑心相互作用[17-18]。研究表明,1/4 的卒中急性期患者存在左心室收缩/舒张功能障碍,超过 1/2 的急性缺血性卒中患者肌钙蛋白 T 水平升高,提示心肌损伤[19-20]。此外,多达 1/3 的卒中患者患有肺炎,卒中幸存者的肺功能较正常人群降低[21-22]。这些都可能进一步损害了卒中后患者的心肺适能。

再者,脑卒中常导致偏瘫、平衡和协调能力受损、活动能力降低,以及本体感觉减弱等功能障碍,与患者体力活动减少和久坐行为、疲劳等有关,会对患者日常活动和运动表现产生负面影响[23-24]。此外,骨骼肌是全身代谢的重要决定因素,卒中后相关的病理生理改变,包括瘫痪侧肌肉萎缩和肌肉内脂肪增加、快速收缩肌纤维的比例显著上升、毛细血管数量减少以及胰岛素敏感性下降和葡萄糖耐受等与患者心肺适能下降密切相关[25-28]。相反,脑卒中患者的步行能耗比健康个体高 2~3 倍,这进一步加剧了患者的心肺适能失衡,影响患者生活质量[29]。

此外,脑卒中患者普遍存在睡眠呼吸障碍[30]。睡眠呼吸障碍与心肺适能下降、VO_{2peak}降低相关,且随着呼吸暂停/低通气指数的增加,有氧运动能力会逐渐下降[31-32]。卒中可能会增加各种精神疾病的风险,如抑郁、焦虑症、精神病和强迫症等,而单纯性焦虑或单纯性抑郁症患者的心肺适能有下降趋势[33-34]。

2　脑卒中患者心肺适能评估

2.1　心肺运动测试(cardiopulmonary exercise test, CPET)　CPET 是一种通过分析个体在运动期间的气体交换,以综合评估心血管、呼吸、代谢及神经肌肉系统功能能力的技术。通过 CPET,可得到 VO_{2peak}等反应个体心肺适能等功能能力的各种指标,是心肺适能评估的“金标准”。标准的 CPET 根据测试者的性别、年龄、身高、体重,结合测试者体力活动习惯和疾病状态等设定个体化测试方案,并依托运动平板或功率自行车,逐级递增速度和/或坡度或功率进行负荷测试。

Mustafa 等[35]对下肢 Brunnstrom 分期Ⅰ~Ⅵ期、功能性步行能力 3~5 级的脑卒中患者分别进行基于运动平板和功率车的 CPET。前者采用低水平 Bruce 方案,测得脑卒中患者 VO_{2peak}为(14.55±3.7) mL/(kg·min),健康对照人群为(23.5±4.2) mL/(kg·min);后者以10 W的阻力负荷进行热身,运动阶段以阻力负荷20 W起始,每 2 分钟增加 10 W,保持 60 转/min 的节奏直至疲劳或出现终止指征。脑卒中患者基于功率车的 CPET 所得 VO_{2peak}为(12.6±2.9) mL/(kg·min),而健康对照人群为(16.7±4.0) mL/(kg·min)。研究认为脑卒中患者可以安全地进行 CPET,基于运动平板的 CPET 更适合于脑卒中患者的心肺适能评估。

由于脑卒中患者常因偏瘫、平衡和协调能力受损、跌倒恐惧等原因,早期无法采用常规方式进行 CPET。研究者们设计、尝试了多种适应脑卒中人群的 CPET 方案。Saengsuwan 等[36]借助机器人辅助的倾斜台对功能性步行能力 0~5 级的脑卒中患者进行 CPET。整个测试包括 3 min 休息、5 min 零负荷被动运动热身、8~12 min 运动和 5 min 零负荷被动运动恢复等 4 个阶段。其中,倾斜台角度一般设置在 70°,运动阶段的负荷递增速度为 1.25~4.5 W/min,根据患者的性别、年龄、虚弱和共病等情况调整。所测脑卒中患者 VO_{2peak}为(15.7±4.7)~(16.2±5.0) mL/(kg·min)。2017 年日本学者 Oyake 等[37]采用健侧上肢曲柄运动测试对平均病程 101 d、能够无支持下保持坐位30 min的脑卒中患者进行心肺适能评估,验证其可行性和可靠性。受试者在 7 d 内随机分别进行基于单侧手臂曲柄和下肢运动测试。在单侧手臂曲柄运动测试中,测力计的旋转轴设置在受试者的肩膀高度,受试者肘部轻微弯曲,保持 50 转/min 的节奏,在 3 min 10 W 热身后,负荷以增加 5 W/min 递增直至出现终止症状或不能保持节奏。结果显示,基于健侧上肢的曲柄运动测试可独立于下肢运动障碍的严重程度来评估脑卒中偏瘫患者心肺适能,所得 VO_{2peak}为(13.0±4.6) mL/(kg·min)。Maryama 等[38]开发了一种斜坡划船方案,并对脑卒中患者进行心肺适能评估。研究结果表明斜坡划船方案作为脑卒中患者的 CPET 是可行的。Huang 等[39]研究基于卧式步进器的 CPET,脑卒中患者平均 VO_{2peak}为 15.6 mL/(kg·min),为预测值的 61.9%。研究还发现无论是健康受试者还是脑卒中患者,基于卧式步进器的 CPET 的 VO_2 轨迹呈非线性的增长。这可能与卧式步进器引起了一种不同的心肺适应模式有关。

2.2　6 min 步行测试(six-minute walk test, 6MWT)　考虑到 CPET 设备昂贵、测试费时,且需要训练有素的工作人员进行操作,找寻相对简单、易行的心肺适能评估方法具有重要意义。6MWT 是一项简单、实用的亚极量运动测试,易于进行,被试者耐受性良好,其 6 min 内的步行距离可作为其有氧耐力的评估指标。Liu 等[40]使用阻抗心电图研究卒中患者 6MWT 的心脏动力反应,发现 6 min 步行距离与患者心输出量、心脏指数高度相关。Laswati 等[41]研究发现,在亚急性卒中患者中,VO_{2max}与 6 min 步行距离呈正相关,认为步行测试可作为一种反映脑卒中患者功能状态和心肺适能的客观方法。Gunnes 等[42]研究在年龄、性别和功能依赖等因素之外,6MWT 是否增加了慢性卒中患者 VO_{2peak}的预测价值。他们对 92 例病程超过 3 个月的脑卒中患者进行基于运动平板的症状限制性 CPET 以获取 VO_{2peak},同时进行 6MWT。结果显示脑卒中患者 6 min 步行距离与 VO_{2peak}正相关;6MWT 结合年龄、性别和功能依赖性,对轻度卒中患者慢性期平均 VO_{2peak}的预测具有显著价值。

2.3　其他　增量穿梭行走测试(incremental shuttle walk test, ISWT)是一种模拟 CPET 的症状限制性步行试验。受试者在两个间距 9 m 的圆锥体障碍物之间往返步行,速度根据外部音频节奏每分钟增加,分 12 级,直至受试者喘不过气或再也保持不了音频节奏所需速度。测试结果为为行走的总距离。由于行走速度受外部音频节奏调控而非自定,ISWT 相对于

6MWT可获得的更高 VO_{2peak}[43]。在 COPD 患者中,相比 6MWT,ISWT 与 VO_{2peak}的相关性更强,并且具有极好的可靠性[44]。ISWT 在脑卒中患者中具有很高的重测信度和评估者间一致性,脑卒中亚急性期患者 ISWT 距离与 CPET 所获得的 VO_{2peak}之间存在一定的正相关[45]。ISWT 可能是卒中后运动能力和心肺适能评估的替代方法,但仍需进一步研究。

3　脑卒中患者心肺适能训练

3.1　有氧训练　有氧运动是指涉及较大的肌肉群、较长时间的、规律的、以有氧代谢供能为主的运动。有氧训练可以提高摄入的氧气从肺部和心脏经由血液运输供肌肉使用的速度。有氧训练有助于提升 VO_{2peak},增加 6 min 步行距离,改善脑卒中患者心肺适能[46]。那些基线 VO_{2peak}较低的患者可能从有氧训练中受益更大[47]。这种改善的趋势不受有氧训练形式、强度、时间及频率等因素的影响。Reynolds 等[48]对两组共 20 例病程 6~12 个月、至少能步行 100 m 的脑卒中患者进行单次训练时长渐进增加至 30 min,每周 5 次,持续 12 周的有氧训练。训练强度以储备心率(heart rate reserve,HRR)表示,干预组患者训练强度为 40%~59% HRR、BORG-RPE 11~13,对照组患者训练强度低于 40% HRR、BORG-RPE 小于 11。训练形式包括立式和卧式功率车、上肢测力计、步进器等。两组患者的 VO_{2peak}均有显著改善。Serra 等[49]对脑卒中患者进行基于运动平板的有氧训练,每周 3 次,训练时长由最初的 15 min 逐渐增加至50 min,训练强度由 40%~50% HRR 递增至 60%~70% HRR,持续 6 个月。结果显示,与对照组相比,6 个月的有氧训练使得慢性脑卒中患者 VO_{2peak}和 6 min 步行距离均有增加。Duran 等[50]探讨反重力跑步机训练和水下行走治疗对脑卒中患者心肺适能等功能能力的影响。所有患者均接受为期 4 周的常规康复治疗,反重力跑步机训练每周 3 次,共 12 次,单次训练包括热身 5 min[速度=0~2.0 mi/h(1 mi=1.609 km),反重力后体重=65%自身体重,倾斜角=0],步行 30 min(速度=2.0 mi/h,反重力后体重=65%自身体重,倾斜角=0),和冷却 5 min(速度=2.0~0 mi/h,反重力后体重=65%自身体重~100%自身体重,倾斜角=0)。而水下行走在治疗用水池中进行,水温约 29~30 ℃,水深达受试者的剑突和肚脐之间。水下行走治疗每周 3 次,共 12 次,单次训练包括热身 5 min,步行 30 min,冷却 5 min。结果显示治疗后,反重力跑步机组和水下行走治疗组患者 6 min 步行距离及最大心率、VO_{2max}均较前增加,但仅有反重力跑步机组患者心肺适能相关指标改善具有统计学意义。

3.2　抗阻训练　抗阻训练是一种使肌肉收缩以抵抗外部阻力的运动,以期增加力量、耐力和肌肉质量。外部阻力可来自哑铃、弹力带、自身体重或任何其他能导致肌肉收缩的物体,常以多次重复最大负荷(repetition maximum, RM)、自觉用力程度(rating of perceived exertion, RPE)表示。对于脑卒中患者来说,抗阻训练是一种经济有效,简单和安全的康复方法[51]。渐进式抗阻训练可改善急慢性卒中患者的步态性能和活动能力[52]。但有关抗阻训练对脑卒中患者心肺适能影响的近期报道较少。Kang 等[53]探讨结合高速抗阻训练的多组分运动计划对卒中后患者心肺适能、身体功能和肌肉力量的影响。多组分运动计划包括热身、有氧训练、抗阻训练、基于游戏的娱乐项目和冷却,每次 60 min,每周 3 次,共 8 周。其中,抗阻训练包括深蹲、弓步、硬举等 10 个动作,分为高速抗阻训练和低速抗阻训练。前者弹力带阻力 15 RM,每个动作重复 12~15 次为 1 组,每次训练完成 2~3 组,保持 RPE 12~13(有点吃力)。后者弹力带阻力 8~10 RM,每个动作重复 8~10 次为 1 组,每次训练完成 2~3 组,保持 RPE 15~16(吃力~非常迟力)。研究显示,高速抗阻训练和低速抗阻训练对脑卒中患者 VO_{2peak}均有显著临床改善;相比而言,高速抗阻训练对 VO_{2peak}的改善更大。

3.3　高强度间歇训练(high-intensity interval training, HIIT)　HIIT 是一种流行的和有效的运动方式,包括反复进行的高强度运动,其间穿插低强度运动或休息。强度通常以运动测试中最大心率(maximum heart rate, HR_{max})/峰值心率(peak heart rate, HR_{peak})、最大输出功率(peak power output, PPO)和 VO_{2peak}等的百分比表示。高强度要求开始运动后心率显著提高至 80% HR_{max}及以上。强度与运动恢复时间比等参数差异很大,从 30 s 恢复期 2 min 或更长时间的运动到 4 min 恢复期 3 min 运动等不一,总运动时间为 20~60 min。

更高的运动强度可以更好地刺激氧气运输和利用系统,从而诱导更大的 VO_{2peak}的改善。与 60% VO_{2peak}中等强度的持续有氧训练相比,5 次 3 min 80% VO_{2peak}高强度运动+3 min 40% VO_{2peak}恢复间歇的 HIIT 方案可通过增加脑卒中患者的全身组织氧气摄取来提高其有氧能力[54]。一项多中心随机对照试验涉及 70 例病程 3 个月~5 年的首次脑卒中患者,其中 36 名患者接受了每周 3 次,持续 8 周的 HIIT 方案(4 min 85%~95%峰值心率高强度运动+3 min 50%~70%峰值心率恢复间歇)。研究显示,HIIT 干预在功能良好的脑卒中患者中耐受性良好,干预后 VO_{2peak}有显著提升,且优于对照组[55]。

3.4　吸气肌训练(inspiratory muscle training, IMT)　脑卒中后偏瘫患者多存在呼吸肌无力和呼吸模式异常等功能障碍。与预测值相比,卒中后最大吸气压和最大呼气压测量值显著降低[56]。而“血液窃流”使得运动时呼吸肌血流量在心输出量中的占比显著增加,而骨骼肌血流量会相应减少,进而造成患者运动能力下降。IMT 是一种特殊形式的抗阻训练,目的是提高吸气肌的力量和耐力。IMT 有助于改善脑卒中患者呼吸功能、呼吸肌力、躯干控制和平衡能力,提高日常生活活动能力[57]。张玮淞等[58]使用 Power Breathe K5 吸气肌训练器对脑卒中患者进行吸气肌渐进抗阻训练,阻力值为 30%最大口腔吸气压,每周动态评估调整,对照组则予以无效阈值阻力。每组训练 30 次,每日 2 组,每周训练 6 d,持续 6 周。以踏车达到 RPE 16~18(非常吃力)的运动时间为运动耐力指标。结果显示 IMT 能够显著改善脑卒中患者运动耐力。另一项研究则显示,在康复计划中加入 IMT 可改善脑卒中患者吸气肌耐力,但不能进一步改善 6 min 步行距离等指标[59]。两项研究的结果差异可能与量化心肺适能的指标不同有关,也与纳入患者卒

中病程相差较大有关。前者纳入脑卒中患者平均病程不超过 2 个月,后者为 1 年以上。已知主要的神经可塑性和功能改善发生在卒中后的前几周,损伤 6 个月后恢复较慢。因此,与后遗症期相比,急性期和亚急性期的卒中患者进行 IMT 后,其心肺适能可能会有更明显的改善。

3.5 *其他* 普拉提是一种在垫子或其他设备上重复进行的,结合呼吸、运动、意识,以提高力量、耐力、稳定性和灵活性的低强度运动。经过每次 1 h,每周 3 次,持续 8 周的改良普拉提运动后,脑卒中患者静息心率下降,VO_{2max} 和每公斤 VO_{2max} 均较前治疗前提升,差异有统计学意义。此外,上述心肺适能相关指标在治疗后普拉提组和对照组差异有统计学意义[60]。

利益冲突 无

参考文献

[1] 王陇德,彭斌,张鸿祺,等.《中国脑卒中防治报告 2020》概要[J].中国脑血管病杂志,2022,19(2):136-144.
Wang LD, Peng B, Zhang HQ, et al. Brief report on stroke prevention and treatment in China, 2020[J]. Chin J Cerebrovasc Dis, 2022, 19(2): 136-144.

[2] Dawson J, Béjot Y, Christensen LM, et al. European Stroke Organisation(ESO) guideline on pharmacological interventions for long-term secondary prevention after ischaemic stroke or transient ischaemic attack[J]. Eur Stroke J, 2022, 7(3): Ⅰ-Ⅱ.

[3] Peng Y, Ngo L, Hay K, et al. Long-term survival, stroke recurrence, and life expectancy after an acute stroke in Australia and New Zealand from 2008-2017: a population-wide cohort study[J]. Stroke, 2022, 53(8): 2538-2548.

[4] Raghuveer G, Hartz J, Lubans DR, et al. Cardiorespiratory fitness in youth: an important marker of health: a scientific statement from the American heart association[J]. Circulation, 2020, 142(7): e101-e118.

[5] Prestgaard E, Mariampillai J, Engeseth K, et al. Change in cardiorespiratory fitness and risk of stroke and death[J]. Stroke, 2019, 50(1): 155-161.

[6] Pandey A, Patel MR, Willis B, et al. Association between midlife cardiorespiratory fitness and risk of stroke: the cooper center longitudinal study[J]. Stroke, 2016, 47(7): 1720-1726.

[7] MacKay-Lyons MJ, Makrides L. Exercise capacity early after stroke[J]. Arch Phys Med Rehabil, 2002, 83(12): 1697-1702.

[8] Billinger SA, Taylor JM, Quaney BM. Cardiopulmonary response to exercise testing in people with chronic stroke: a retrospective study[J]. Stroke Res Treat, 2012, 2012: 987637.

[9] Kleindorfer DO, Towfighi A, Chaturvedi S, et al. 2021 guideline for the prevention of stroke in patients with stroke and transient ischemic attack: a guideline from the American heart association/American stroke association[J]. Stroke, 2021, 52(7): e364-e467.

[10] Hackam DG, Spence JD. Combining multiple approaches for the secondary prevention of vascular events after stroke: a quantitative modeling study[J]. Stroke, 2007, 38(6): 1881-1885.

[11] Chen JY, Zhu QR, Yu LL, et al. Stroke risk factors of stroke patients in China: a nationwide community-based cross-sectional study[J]. Int J Environ Res Public Health, 2022, 19(8): 4807.

[12] 傅路红,叶萍仙,孙志凌,等.高血压及左心室肥厚患者的心肺运动功能[J].中华心血管病杂志,2008,36(8):718-721.
Fu LH, Ye PX, Sun ZL, et al. Reduced cardiopulmonary exercise capacity in patients with essential hypertension: impact of left ventrtcular hypertrophy[J]. Chin J Cardiol, 2008, 36(8):718-721.

[13] Borkertienė V, Valonytė-Burneikienė L. Normal weight 6-12 years boys demonstrate better cognitive function and aerobic fitness compared to overweight peers[J]. Medicina(Kaunas), 2022, 58(3): 423.

[14] Liu BB, Niu ZR, Jia XJ, et al. A correlational study on cardiopulmonary endurance in male patients with new-onset type 2 diabetes[J]. Diabetes Metab Syndr Obes, 2022, 15: 1365-1373.

[15] 陈泽刚,丁吉,万芹,等.中国儿童青少年体力活动与心肺耐力的相关性[J].中国学校卫生,2022,43(3):429-432.
Chen ZG, Ding J, Wan Q, et al. Association between physical activity and cardiopulmonary endurance of Chinese children and adolescents[J]. Chin J Sch Health, 2022, 43(3): 429-432.

[16] 郭小亚,吴雪娇,洪怡,等.不同性别、年龄及体力活动心脏康复患者心肺运动试验指标分析[J].实用心脑肺血管病杂志,2021,29(9):10-17.
Guo XY, Wu XJ, Hong Y, et al. Analysis of cardiopulmonary exercise test indexes of patients with different gender, age and physical activity in cardiac rehabilitation[J]. Pract J Cardiac Cereb Pneumal Vasc Dis, 2021, 29(9): 10-17.

[17] Meloux A, Rigal E, Rochette L, et al. Ischemic stroke increases heart vulnerability to ischemia-reperfusion and alters myocardial cardioprotective pathways[J]. Stroke, 2018, 49(11): 2752-2760.

[18] Zhao MX, Guan L, Collet JP, et al. Relationship between ischemic stroke locations, etiology subtypes, neurological outcomes, and autonomic cardiac function[J]. Neurol Res, 2020, 42(8): 630-639.

[19] Heuschmann PU, Montellano FA, Ungethüm K, et al. Prevalence and determinants of systolic and diastolic cardiac dysfunction and heart failure in acute ischemic stroke patients: the SICFAIL study[J]. ESC Heart Fail, 2021, 8(2): 1117-1129.

[20] Scheitz JF, Mochmann HC, Erdur H, et al. Prognostic relevance of cardiac troponin T levels and their dynamic changes measured with a high-sensitivity assay in acute ischaemic stroke: analyses from the TRELAS cohort[J]. Int J Cardiol, 2014, 177(3): 886-893.

[21] Sellars C, Bowie L, Bagg J, et al. Risk factors for chest infection in acute stroke: a prospective cohort study[J].Stroke, 2007, 38(8): 2284-2291.

[22] Ezeugwu VE, Olaogun M, Mbada CE, et al. Comparative lung function performance of stroke survivors and age-matched and sex-matched controls[J]. Physiother Res Int, 2013, 18(4): 212-219.

[23] Yeh IL, Holst-Wolf J, Elangovan N, et al. Effects of a robot-aided somatosensory training on proprioception and motor function in stroke

survivors[J]. J Neuroeng Rehabil, 2021, 18(1): 77.

[24] Mahmood W, Burq HSIA, Ehsan S, et al. Effect of core stabilization exercises in addition to conventional therapy in improving trunk mobility, function, ambulation and quality of life in stroke patients: a randomized controlled trial[J]. BMC Sports Sci Med Rehabil, 2022, 14(1): 62.

[25] Ishimoto T, Taniguchi Y, Akazawa N. Longitudinal relationship between intramuscular fat in the quadriceps and gait independence in convalescent stroke patients[J]. J Stroke Cerebrovasc Dis, 2020, 29(11): 105287.

[26] Nozoe M, Kubo H, Kanai M, et al. Peripheral motor nerve conduction abnormality, muscle strength, and muscle wasting in patients with acute stroke: a pilot study[J]. J Clin Neurosci, 2020, 75: 80-84.

[27] McDonald MW, Jeffers MS, Issa L, et al. An exercise mimetic approach to reduce poststroke deconditioning and enhance stroke recovery[J]. Neurorehabil Neural Repair, 2021, 35(6): 471-485.

[28] Flieh SM, Miguel-Berges ML, Huybrechts I, et al. Associations between food portion sizes, insulin resistance, VO_2 max and metabolic syndrome in European adolescents: the HELENA study[J]. Nutr Metab Cardiovasc Dis, 2022, 32(9): 2061-2073.

[29] Platts MM, Rafferty D, Paul L. Metabolic cost of over ground gait in younger stroke patients and healthy controls[J]. Med Sci Sports Exerc, 2006, 38(6): 1041-1046.

[30] Simonsen SA, Andersen AV, West AS, et al. Sleep-disordered breathing and cerebral small vessel disease: acute and 6 months after ischemic stroke[J]. Sleep Breath, 2022, 26(3): 1107-1113.

[31] Konecny T, Geske JB, Ludka O, et al. Decreased exercise capacity and sleep-disordered breathing in patients with hypertrophic cardiomyopathy[J]. Chest, 2015, 147(6): 1574-1581.

[32] Mansukhani MP, Allison TG, Lopez-Jimenez F, et al. Functional aerobic capacity in patients with sleep-disordered breathing[J]. Am J Cardiol, 2013, 111(11): 1650-1654.

[33] Lyu Y, Li W, Tang T. Prevalence trends and influencing factors of post-stroke depression: a study based on the national health and nutrition examination survey[J]. Med Sci Monit, 2022, 28: e933367.

[34] 庄洪波,陈静远,许丹焰.焦虑抑郁情绪对冠心病患者心肺运动试验的影响[J].中南大学学报(医学版),2020,45(11):1316-1325.
Zhuang HB, Chen JY, Xu DY. Effect of anxiety and depression on cardiopulmonary exercise test in patients with coronary artery disease [J]. J Central South Univ Med Sci, 2020, 45(11): 1316-1325.

[35] Mustafa E, Aytür YK. Assessment for cardiovascular fitness in patients with stroke: which cardiopulmonary exercise testing method is better? [J]. Top Stroke Rehabil, 2022, 29(5): 347-355.

[36] Saengsuwan J, Berger L, Schuster-Amft C, et al. Test-retest reliability and four-week changes in cardiopulmonary fitness in stroke patients: evaluation using a robotics-assisted tilt table [J]. BMC Neurol, 2016, 16(1): 163.

[37] Oyake K, Yamaguchi T, Oda C, et al. Unilateral arm crank exercise test for assessing cardiorespiratory fitness in individuals with hemiparetic stroke[J]. Biomed Res Int, 2017, 2017: 6862041.

[38] Maryama ADD. Rowing-ramp protocol as A cardiopulmonary exercise test for hemiparetic stroke survivors[J]. Med Health, 2019, 14(1): 157-171.

[39] Huang SC, Hsu CC, Fu TC, et al. Application of stepper in cardiopulmonary exercise test for patients with hemiplegia [J]. Medicine (Baltimore), 2020, 99(28): e21058.

[40] Liu F, Jones AYM, Tsang RCC, et al. Noninvasive investigation of the cardiodynamic response to 6MWT in people after stroke using impedance cardiography[J]. PLoS One, 2020, 15(6): e0233000.

[41] Laswati H, Putri CJE, Kurniawati PM. Relation between cardiorespiratory fitness measured with six-minute walk test and walking speed measured with 1-meter walk test in patients of post-subacute and chronic ischemic stroke [J]. Indian Journal of Forensic Medicine & Toxicology, 2022, 14(2): 2265-2270.

[42] Gunnes M, Aksetøy IL A, Follestad T, et al. Can functional walk tests add value to the prediction of cardiorespiratory fitness after stroke? A prospective cohort study [J]. PLoS One, 2021, 16(8): e0255308.

[43] Chae G, Ko EJ, Lee SW, et al. Stronger correlation of peak oxygen uptake with distance of incremental shuttle walk test than 6-Min walk test in patients with COPD: a systematic review and meta-analysis [J]. BMC Pulm Med, 2022, 22(1): 102.

[44] Ko EJ, Lee JH, Lee HY, et al. Correlation comparison and personalized utility of field walking tests in assessing the exercise capacity of patients with chronic obstructive pulmonary disease: a randomized controlled trial[J]. J Pers Med, 2022, 12(6): 40-52.

[45] Quintino LF, Aguiar LT, de Brito SAF, et al. Reliability and validity of the incremental shuttle walking test in individuals after stroke[J]. Top Stroke Rehabil, 2021, 28(5): 331-339.

[46] Brauer SG, Kuys SS, Paratz JD, et al. High-intensity treadmill training and self-management for stroke patients undergoing rehabilitation: a feasibility study[J]. Pilot Feasibility Stud, 2021, 7(1): 215.

[47] Linder SM, Davidson S, Rosenfeldt A, et al. Predictors of improved aerobic capacity in individuals with chronic stroke participating in cycling interventions[J]. Arch Phys Med Rehabil, 2020, 101(4): 717-721.

[48] Reynolds H, Steinfort S, Tillyard J, et al. Feasibility and adherence to moderate intensity cardiovascular fitness training following stroke: a pilot randomized controlled trial [J]. BMC Neurol, 2021, 21(1): 132.

[49] Serra MC, Accardi CJ, Ma CY, et al. Metabolomics of aerobic exercise in chronic stroke survivors: a pilot study[J]. J Stroke Cerebrovasc Dis, 2019, 28(12): 104453.

[50] Duran ÜD, Duran M, Tekin E, et al. Comparison of the effectiveness of anti-gravity treadmill exercises and underwater walking exercises on cardiorespiratory fitness, functional capacity and balance in stroke patients[J]. Acta Neurol Belg, 2023, 123(2): 423-432.

[51] Prabin B, Priyanka S, Deepak P. A Comparison of the effect of resistance training on upper extremity motor function, motor recovery, and quality of life in sub-acute stroke participants[J]. Med J Dr D Y Patil Vidyapeeth, 2021, 14(2): 219-225.

(下转第 1406 页)

Su Y, Qin MF, Wu Y, et al. Risk factors for biliary stent migration in patients with benign biliary strictures[J]. World Chin J Dig, 2011, 19(2): 192-195.

[36] He X, Zhu Y, Wang YN, et al. Advances in stent therapy for malignant biliary obstruction[J]. Abdom Radiol, 2021, 46(1): 351-361.

[37] Katsinelos P, Kountouras J, Paroutoglou G, et al. Migration of plastic biliary stents and endoscopic retrieval[J]. Surg Laparosc Endosc Percutaneous Tech, 2009, 19(3): 217-221.

[38] Cheruvu S, Kennedy R, Moshenyat Y, et al. Biliary stent migration[J]. Am J Ther, 2014, 21(5): e124-e129.

[39] Margulies C, Siqueira ES, Silverman WB, et al. The effect of endoscopic sphincterotomy on acute and chronic complications of biliary endoprostheses[J]. Gastrointest Endosc, 1999, 49(6): 716-719.

[40] Ding SM, Wu WL, Lu JF, et al. Migration of fully covered self-expandable metallic stents used to treat anastomotic strictures after orthotopic liver transplantation[J]. Medicine, 2022, 101(4): e28685.

[41] Bernardo S, Freitas C, Lopes J, et al. Endoscopic closure of a duodenal perforation caused by early migration of a biliary plastic stent with an over-the-scope-clip[J]. Gastroenterol Y Hepatol, 2021, 44(2): 139-140.

[42] Cakmak E. Endoscopic closure of a duodenal perforation secondary to a migrated biliary plastic stent by using hemoclips[J]. Rev Esp Enferm Dig, 2022, 114(5):295.

[43] Al Lehibi A, Al Mtawa A, Almasoudi T, et al. Removal of proximally migrated biliary stents by using single-operator cholangioscopy[J]. VideoGIE, 2020, 5(5): 213-216.

[44] Brown D, Naidu J, Thomas R. Bowel perforation: a 'not so rare' complication of biliary stent migration[J]. ANZ J Surg, 2021, 91(12): E784-E786.

[45] Ida Bagus B. A rare clinical presentation of third part duodenal perforation due to post-endoscopic retrograde cholangiopancreatography stent migration on advanced stage peri-ampullary tumor[J]. JGH Open, 2021, 5(8): 968-970.

[46] Fernández-Alvarez P, Cintas-Catena J, Jimenez-García VA, et al. Perforation of the capsule of Glisson by migration of a plastic biliary stent during a rendezvous and ERCP procedure[J]. Endoscopy, 2022, 54(8): E458-E459.

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(上接第 1401 页)

[52] Ain QU, Imran M, Bashir A, et al. Progressive resistance training improving gait performance and mobility in acute and chronic stroke patients[J]. J Pak Med Assoc, 2021, 71(1A): 140-142.

[53] Kang D, Park J, Jeong I, et al. Comparing the effects of multicomponent exercise with or without power training on the cardiorespiratory fitness, physical function, and muscular strength of patients with stroke: a randomized controlled trial[J]. J Sports Med Phys Fitness, 2022, 62(5): 722-731.

[54] Hsu CC, Fu TC, Huang SC, et al. Increased serum brain-derived neurotrophic factor with high-intensity interval training in stroke patients: a randomized controlled trial[J]. Ann Phys Rehabil Med, 2021, 64(4): 101385.

[55] Gjellesvik TI, Becker F, Tjønna AE, et al. Effects of high-intensity interval training after stroke(the HIIT stroke study) on physical and cognitive function: a multicenter randomized controlled trial[J]. Arch Phys Med Rehabil, 2021, 102(9): 1683-1691.

[56] Ramos SM, da Silva DM, Buchaim DV, et al. Evaluation of respiratory muscular strength compared to predicted values in patients with stroke[J]. Int J Environ Res Public Health, 2020, 17(3): 1091.

[57] 林夏妃,吴海霞,史静琴,等.吸气肌训练对脑卒中患者呼吸功能和下肢运动功能的影响[J].中国康复,2022,37(5):279-283.
Lin XF, Wu HX, Shi JQ, et al. Effects of inspiratory muscle training on respiratory function and lower limb motor function in patients with stroke[J]. Chin J Rehabil, 2022, 37(5): 279-283.

[58] 张玮淞,邢艳丽.吸气肌力量训练对脑卒中患者吸气肌功能及运动耐力的影响[J].中国康复医学杂志,2021,36(9):1123-1127.
Zhang WS, Xing YL. Effect of inspiratory muscle strength training on inspiratory muscle function and exercise endurance of stroke patients[J]. Chin J Rehabil Med, 2021, 36(9): 1123-1127.

[59] Vaz L, Almeida J, Froes K, et al. Effects of inspiratory muscle training on walking capacity of individuals after stroke: a double-blind randomized trial[J].Clin Rehabil,2021,35(9):1247-1256.

[60] Lim HS, Yoon S. The effects of Pilates exercise on cardiopulmonary function in the chronic stroke patients: a randomized controlled trials[J]. J Phys Ther Sci, 2017, 29(5): 959-963.

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