·综述·

慢性腰痛运动性肌肉疲劳的研究进展*

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慢性腰痛是导致人们劳动能力下降及日常活动能力受限的主要原因之一[1]。运动性肌肉疲劳是生活中的常见现象,涉及心理、认知、身体功能等多方面。在运动性肌肉疲劳的发生和发展过程中,人体可出现本体感受器敏感性下降[2],姿势稳定性降低[3]及神经肌肉控制改变[4]等一系列变化,并且这些改变可能与慢性疼痛的发生存在密切相关[5]。研究表明,肌肉疲劳与慢性腰痛患者自我效能、抑郁状态、疼痛强度、恐惧情绪、残疾失能等因素相关,并且肌肉疲劳是慢性腰痛患者普遍存在的现象,其发生率约26%—69.7%不等,且女性更为常见[6—7]。运动性肌肉疲劳在慢性腰痛发病过程中的作用及机制仍不甚清楚,进一步探讨慢性腰痛与运动性肌肉疲劳之间的相互作用关系,将为理解慢性腰痛的发病机制及精准化康复治疗提供潜在的思路。本研究通过查阅近年来关于慢性腰痛运动性肌肉疲劳的研究进展,从运动性肌肉疲劳的概念与研究手段、运动性肌肉疲劳与慢性腰痛心理及姿势控制的相互关系、针对慢性腰痛运动性肌肉疲劳的康复训练治疗等方面,展开探讨。

1 运动性肌肉疲劳

1.1 运动性肌肉疲劳的概念

运动性肌肉疲劳,是指任何运动诱发的身体功能不能维持预期肌力及特定功能水平的身体现象,疲劳的发生和发展贯穿于整个运动程序期间,受到运动负荷强度、运动负荷类型、心理状况、能量供应、机体代谢等多因素影响[8]。

通常情况下,将发生在脊髓及以上部位的疲劳定义为中枢性疲劳,发生在周围神经肌肉等部位的疲劳定义为周围性疲劳。就疲劳发生的生理学机制来看,既往的研究表明,外周与中枢性疲劳并不独立存在,具有统一性与交互性的特点,且发生机制极其复杂[9]。从细胞生物学角度考虑,运动性肌肉疲劳是肌肉过度运动的症状,这涉及过度运动相关的糖原耗竭、细胞膜结构和功能受损、肌酸激酶外排、兴奋-收缩偶联下降、炎症、线粒体功能紊乱、活性氧激活、乳酸累积等生理过程[10—12]。从神经生理学因素来看,运动性肌肉疲劳涉及感觉输入、运动输出及中枢整合等整个神经回路调节过程,表现为脊髓及以上部位中枢运动神经元兴奋和驱动能力不足或外周执行中枢运动指令能力下降[13—14]。

1.2 运动性肌肉疲劳的试验范式

按照运动性疲劳的发生部位,运动性肌肉疲劳可以分为局部性疲劳与全身性疲劳。其中,可引起全身性疲劳的运动,包括平板跑步、划船、游泳、健身操、跳绳等全身性动作任务,而引起局部肌肉疲劳的运动主要是反复局部肌肉收缩,比如反复股四头肌自主收缩、反复膝关节屈伸、持续躯干肌背伸、平板支撑及卷腹等动作任务。在诱发全身性肌肉疲劳的众多实验范式中,划船测功仪通过使受试者手脚同时做功,被认为是诱发全身运动性疲劳的可靠方法[15]。在诱发局部肌肉疲劳试验范式中,Sorensen试验被证明具有较高的信度和效度,是诱发受试者腰背部局部伸肌疲劳的常用范式[16],此外,站立位双手持物(10%自身体重)诱发上肢肌肉疲劳[17]、重复深蹲诱发下肢肌肉疲劳[18]也是常用局部肌肉疲劳试验范式。根据疲劳程度,运动性肌肉疲劳可以分类部分程度的功能性肌肉疲劳诱发试验和力竭型肌肉疲劳诱发试验。在诱发不同程度肌肉疲劳的试验方法中,往往通过改变任务持续时间实现,如有学者让受试者站立位下双手自持10%自身体重负荷,持续1min来诱发以上肢为主功能性肌肉疲劳[17]。另外,通过让受试者在半蹲位下持举40%躯干最大伸肌力矩负荷(最大负荷值被限制在9kg)[19]、俯卧位下腰椎无支撑Sorensen试验(最长坚持测量时间为240s)[20]及Biodex等速测定仪上60%最大力量负荷反复背部屈伸[21]直到力量耗竭不能坚持等试验范式来诱发机体力竭型肌肉疲劳。

1.3 运动性肌肉疲劳的评估手段

在肌肉疲劳程度评估方法,有基于患者自我报告的主观疲劳程度评估,也有基于客观依据的量化评估。在主观评估方法方面,主观疲劳测试量表(rating of perceived exertion ,RPE)被广泛应用于肌肉疲劳后的主观疲劳程度自我报告[22]。近年来,有研究发现,面对极限负荷训练时,自我报告的RPE评分也低于最高值,而自我感觉可重复动作(repetitions in reserve,RIR)可更加准确地反映受试者极限负荷时的疲劳程度,RPE联合RIR可能更加有利于评估受试者的

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主观疲劳程度[23]。在客观评估方法方面,可利用表面肌电采集肌肉肌电中位频率、平均功率频率等指标作为量化肌肉疲劳程度的手段[24];也有研究者通过采用握力计、背力计和各种类型的拉力器等设备来评价手部肌肉、背部伸肌及其他相关部位反复运动所诱发的肌肉疲劳[25—27]。近年来,研究者尝试采用肌肉近红外功能检测进行肌肉氧含量检测,并提示该方法是检测运动性肌肉疲劳的可靠手段[28];此外,也有研究采用大脑功能性近红外[29]或功能性磁共振[30—31]来检测脑激活和功能变化而对运动性肌肉疲劳效应进行相应评价,这些方法可能是评估肌肉疲劳中枢效应的潜在手段。

2 运动性肌肉疲劳与慢性腰痛

2.1 运动性肌肉疲劳与慢性腰痛心理活动改变

研究发现,慢性腰痛容易出现运动性肌肉疲劳,同时,肌肉疲劳可能也是慢性腰痛持续和复发的诱因[32]。进一步,研究表明,慢性疼痛与心理关系密切[33],心理与疲劳联系也紧密[34]。然而,疼痛、心理与疲劳三者之间内在关系如何,目前仍不十分清楚,为此,一些学者也进行了相应探索。比如,Lariviere C等[35]研究发现,疼痛灾难化量表评分越低的慢性腰痛患者,表现出更加明显的抗肌肉疲劳表现,疼痛灾难化量表评分高的慢性腰痛患者,其预期肌肉耐力也会下降,这提示了慢性腰痛患者对于疼痛灾难化观念可能介导了慢性腰痛肌肉疲劳主观表现;进一步,研究认为,慢性腰痛患者消极心理信念和腰痛相关功能障碍及自我报告的疲劳主诉存在相关性[36];此外,Mehta RK[34]的研究也表明,与健康人群相比,慢性骨骼肌肉疼痛疾病患者的身体功能(易疲劳性和恢复能力)更易受到心理负荷的不利影响。

对于运动员而言,长期重复的疲劳训练可引起心理不安及心理疲劳感,这些负面情绪也会加重运动后疲劳感知[37]。对于成人慢性疲劳综合征患者,该类患者普遍存在疲惫感,而运动性肌肉疲劳会明显放大该类患者的疲惫感知[38]。另外,研究表明,纤维肌疼综合征患者容易出现运动性疲劳及疲劳后疼痛[39—40],随着病程的发展,患者会产生恐惧运动的心理[41]。在不同于慢性腰痛患者与其他慢性疼痛之间的心理活动改变方面,研究发现,慢性腰痛患者可存在不同程度的焦虑、抑郁等心理活动表现,患者往往认为是与久坐久站有关,因此慢性腰痛患者往往存在活动恐惧及避免特定久坐姿势的恐惧心理[42—44]。然而,纤维肌疼患者及慢性疲劳综合征患者,虽可以发展为不同程度的焦虑、抑郁等心理活动改变,但是这类患者往往主要表现为活动恐惧的心理活动改变[45—46]。此外,本课题组的前期研究也表明慢性腰痛患者静态姿势控制受损与疼痛灾难化程度相关[47],基于心理干预视角的正念冥想治疗能有效缓解慢性腰痛人群的疼痛症状,减轻背部残疾功能并提高运动耐力等表现[48]。以上研究表明,肌肉疲劳在一定程度上可受到主观心理因素影响。基于疼痛与心理、疼痛与肌肉疲劳也互为相关,如何解开它们之间的复杂关系,是未来需要特别关注的内容,这项工作对于从事慢性腰痛姿势控制的研究者来说,尤其具有价值意义。

2.2 运动性肌肉疲劳与慢性腰痛姿势控制改变

姿势控制改变与慢性腰痛关系密切[49]。研究表明,运动性肌肉疲劳可以通过影响感觉输入、运动指令传出、神经肌肉控制及中枢整合等方面而影响姿势控制[50—51]。也有研究认为,疲劳本身就相当于一种内部姿势扰动,也会影响姿势稳定性[9]。在运动性肌肉疲劳与姿势控制的相关研究中,Allison GT等[52]采用双臂快速前举的姿势干扰范式,予以背伸肌疲劳负荷,观察肌肉疲劳前后腹直肌、腹外斜肌、腹内斜肌、腹横肌与腰部竖脊肌的预激活时间点变化,结果发现疲劳后仅腹外斜肌预激活时间点显著提前,并认为面对姿势扰动时,疲劳效应引起的躯干姿势肌激活潜伏期的改变与腰痛发生有关;该团队的另外一项研究采用腹部肌肉疲劳作为诱发因素,结果也发现健康受试者腹直肌(发生疲劳)及竖脊肌(未发生疲劳)预期姿势调节强度下降20%[53],这提示可能发生了肌肉疲劳的中枢效应,也说明疲劳不独立产生并局限于中枢或者周围,两者的关系具有复杂的统一性和交互性。对于慢性腰痛患者,有研究表明,当发生核心躯干肌疲劳后,患者会限制躯干活动范围和活动强度来对疲劳的躯干肌肉进行保护,久之会导致腰背肌肌肉萎缩,功能弱化,活动受限,进而造成姿势控制能力下降[54]。另外,Tajali S等[55]研究也发现,腰部背伸肌及臀部外展肌疲劳后,慢性腰痛患者较无症状受试者在站立情况下表现出更加明显姿势控制能力下降。从肌电动力学相关研究来看,采用重复提物作为诱发肌肉疲劳方式,结果显示,慢性腰痛患者躯干肌肉共激活程度显著高于无症状受试者[56]。这些研究可说明与健康人相比,慢性腰痛患者在肌肉疲劳状态下的腰部神经肌肉控制模式发生了改变。此外,一份系统综述也表明,躯干肌疲劳后可以改变压力中心等姿势控制参数,并提示肌肉耐力训练可能是治疗慢性腰痛的重要手段[57]。因此,运动性肌肉疲劳可能是慢性腰痛姿势控制改变的重要诱因,慢性腰痛姿势控制改变也可能参与了运动性肌肉疲劳的发生与发展,两者存在着相互的关系。然而,我们在文献梳理过程中,也发现运动性肌肉疲劳诱发的慢性腰痛姿势控制改变与慢性腰痛持续、复发及腰痛相关功能障碍的关系,相关研究较少报道,值得进一步研究。

2.3 运动性肌肉疲劳相关的腰痛康复治疗

研究表明,以改善肌肉疲劳效应相关的姿势控制能力、肌肉力量与耐力表现的运动治疗有望成为改善慢性腰痛的潜在手段之一[57]。进一步,相关腰痛诊治专家共识及指南指出运动疗法(包括肌力训练、核心稳定/运动控制训练、耐力

训练、有氧训练等)可对慢性腰痛患者的疼痛程度、功能障碍指数、核心肌肉力量与耐力改善显示出积极作用(Ⅰ级证据,强推荐)[58—59],这些运动治疗方法可一定程度的增强肌肉抗疲劳能力。此外,一项有关于评估特定运动疗法对慢性腰痛有效性的高质量网状Meta分析也表明核心稳定/运动控制训练、普拉提、抗阻耐力训练和有氧训练是最有效的治疗方法[60](Ⅰ级证据),但不同的运动治疗形式证据等级不一致,目前对是否存在最佳运动治疗方法仍未定论。

有研究发现,渐进性抗阻力量训练在改善慢性腰痛症状的同时,也可改善患者消极情绪[61](Ⅱ级证据);进一步,Calatayud J等[62]通过对慢性腰痛患者实施小组治疗模式的渐进式力量训练,发现这种治疗不仅可以增强患者肌肉力量与耐力、减轻疼痛和功能残疾,还可以降低腰痛复发率,认为团队运动治疗模式会对患者的恐惧回避信念、灾难化和应对策略等心理认知产生积极作用,增强患者活动时无害体验感和背部功能信任度(Ⅰ级证据)。另外,一项系统评价显示,普拉提运动治疗可有效减轻非特异性慢性腰痛患者疼痛和功能残疾[63](Ⅰ级证据),连续给予8周的普拉提运动,可显著改善慢性腰痛患者腹部深层肌肉补偿姿势调节能力[64]。核心稳定/运动控制训练作为治疗慢性腰痛的常用方法,可增强患者肌肉力量与耐力表现、减轻疼痛与功能残疾、改善心理情绪与认知功能,提高姿势控制能力,可直接或间接地影响肌肉疲劳效应。比如,Shamsi MB等[65]通过对慢性腰痛患者给予核心稳定训练,治疗前后分别进行三项核心稳定耐力测试评估(躯干屈肌、躯干伸肌和侧桥测试),发现治疗后患者耐力表现增强(Ⅰ级证据);进一步,一项关于运动控制训练对非特异性慢性腰痛有效性的随机对照试验和荟萃分析也认为,运动控制训练可有效减轻患者疼痛,改善功能残疾状态,增强核心肌肉厚度形态学指标,在6个月随访期内的效果维持较其他保守治疗更好[66](Ⅰ级证据);但值得注意的是,另有一项高质量系统综述却表明,尽管核心稳定/运动控制训练对慢性腰痛疗效确切(Ⅰ级证据),但就随访期测试结果来看,核心稳定/运动控制训练并不优于其他形式的运动治疗[67]。另外,本课题前期在核心稳定/运动控制训练治疗慢性腰痛也积累了一些经验,比如,Zheng FM等[48]研究表明,核心稳定训练能改善慢性腰痛患者腰背部疼痛及身体功能,提升自我效能感和生存质量,同时也认为,基于正性心理关怀视角的核心稳定训练效果更好,远期疗效更易维持(Ⅰ级证据)。未来,进一步探讨核心稳定/运动控制训练与肌肉疲劳效应(姿势控制、心理认知及疼痛等)之间的潜在关系,也是值得深入研究的。

如前所述,通过各种康复治疗方法直接或间接地改善慢性腰痛患者的肌肉疲劳效应可显示出积极作用,然而,这些治疗作用与肌肉疲劳及姿势控制改变之间的潜在关系仍不明确。未来,进一步探讨肌肉疲劳效应所介导的姿势控制改变对慢性腰痛治疗的可能作用机制,将为优化慢性腰痛的各种运动训练方法及其治疗机制提供依据。

3 小结

慢性腰痛与运动性肌肉疲劳存在密切的关系。运动性肌肉疲劳是诱发慢性腰痛姿势控制改变的重要因素,同时可能也与慢性腰痛的发生与复发存在相关性,并受到患者疼痛相关消极信念影响。因此,针对改善慢性腰痛肌肉疲劳效应的运动训练也应该注意对心理的关注,探究其增强姿势控制系统应对运动疲劳负荷的能力,或许是治疗慢性腰痛的重要潜在手段之一。然而,肌肉疲劳在慢性腰痛发病过程中的可能机制仍不甚清楚。未来,开展针对慢性腰痛肌肉疲劳效应的机制探讨及康复手段研究,将有助于加深对慢性腰痛的全面理解。

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