

• 基础研究 •

基于“三法三穴”探讨推拿对坐骨神经损伤大鼠小腿肌肉生物力学特性的影响及其作用机制

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摘要 **目的** 基于“三法三穴”探讨推拿对坐骨神经损伤(SNI)大鼠小腿肌肉生物力学的影响,进一步阐释推拿恢复SNI运动功能的机制。**方法** 将21只雄性SPF级SD大鼠采用随机数字表法分为假手术组、模型组和推拿组,每组7只。模型组和推拿组建立SNI模型,假手术组仅暴露坐骨神经挑起后不夹持。推拿组在造模后7 d使用课题组自研“按摩推拿手法模拟仪”进行推拿干预,选取殷门穴、阳陵泉穴和承山穴,3个穴位都予以拨法、点法和揉法刺激,设置频率为60次/min,力量为4 N。每穴每法1 min,每只动物总计干预9 min/次,持续治疗20 d,1次/d,每10 d休息1次。假手术组和模型组只抓握束缚相同时间不干预。采用测力计对大鼠后肢抓力进行评估;采用超声剪切波弹性成像技术(SWE)检测腓肠肌、比目鱼肌、胫前肌的最大杨氏模量($E_{\max}$)和最大剪切波速度($S_{\max}$);采用精密电子秤进行称重并计算腓肠肌湿重比;采用Masson染色对腓肠肌形态学进行观察并计算腓肠肌肌纤维横截面积。**结果** 与假手术组比较,模型组、推拿组后肢抓力均降低($P<0.05$);与模型组比较,推拿组后肢抓力升高($P<0.05$)。与假手术组比较,模型组腓肠肌、比目鱼肌、胫前肌 $E_{\max}$ 、 $S_{\max}$ 均升高($P<0.05$),推拿组腓肠肌、胫前肌 $E_{\max}$ 、 $S_{\max}$ 和比目鱼肌 $E_{\max}$ 均升高($P<0.05$);与模型组比较,推拿组腓肠肌、比目鱼肌、胫前肌 $E_{\max}$ 、 $S_{\max}$ 均下降($P<0.05$)。与假手术组比较,模型组、推拿组腓肠肌湿重比均降低($P<0.05$);与模型组比较,推拿组腓肠肌湿重比升高($P<0.05$)。Masson染色结果显示:假手术组腓肠肌纤维细胞形态正常,边界清楚;模型组肌束间胶原纤维增多;推拿组肌纤维细胞形态趋于恢复,边界较清晰,胶原纤维减少。与假手术组比较,模型组和推拿组肌纤维横截面积减少($P<0.05$);与模型组比较,推拿组肌纤维横截面积增加($P<0.05$)。**结论** “三法三穴”可有效缓解坐骨神经,恢复SNI支配肌肉的肌力及弹性,减轻肌肉萎缩,恢复肌肉力学特性以改善运动功能障碍。

关键词 坐骨神经损伤;“三法三穴”;推拿;剪切波弹性成像;生物力学特性

周围神经损伤(peripheral nerve injury, PNI)后神经支配区域会出现疼痛、感觉障碍等感觉功能异常和自主功能异常,以及运动功能障碍的发生率高且严重影响日常生活^[1]。其中坐骨神经损伤(sciatic nerve injury, SNI)是最常见的一种。尽管周围神经

具有较强的组织再生能力,但是神经组织损伤和去神经支配时间过长都会导致靶器官不可逆的病理改变,从而导致SNI后运动功能障碍^[2]。肌力下降、靶器官的生物力学特性变化是运动功能障碍的主要原因。SNI发生后靶肌肉的弹性、硬度改变,弹性

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XU Y, NARENTUYA, YU T Y, et al. Effects of Tuina on calf muscle biomechanical properties and underlying mechanisms in sciatic nerve injury rats: a study based on the "three-manipulations and three-acupoints" protocol [J]. Rehabil Med, 2026, 36(7): 526-533.

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的减少会引起肌肉组织张力、兴奋性降低,减少局部血液微循环,最终使运动功能减弱或消失^[3-4]。超声剪切波弹性成像技术(shear wave elastography, SWE)是一种安全、无创的检测方法,能够对肌肉、肌腱、神经等组织的硬度进行定量评价^[5]。推拿是临床常见的一种治疗PNI的有效方式,且治疗成本较低、舒适度高。“三法三穴”是通过前期Meta分析以及中医理论得出的治疗SNI的有效方法^[6]。其中三法为点、拨、揉,三穴为殷门穴、承山穴、阳陵泉穴,“三法三穴”合用发挥温通经络、活血强筋的治疗作用。课题组前期研究发现“三法三穴”可以通过促进神经、脊髓处凋亡、自噬等细胞活动促进受损神经的修复,治疗PNI后运动功能障碍^[6-7]。但PNI后运动功能障碍与肌肉的生物力学变化直接相关。因此,本次研究通过建立SNI模型,结合SWE技术探究“三法三穴”对SNI大鼠肌肉生物力学特性的影响,进一步阐释推拿恢复PNI后运动功能的机制。

1 材料和方法

1.1 实验动物与分组

21只雄性SPF级SD大鼠,体质量(200 ± 10)g,由北京斯贝福动物公司提供[实验动物生产许可证号:SCXK(京)2019-0010]。实验室条件:温度(23 ± 2)℃,湿度(45 ± 5)%,12 h明暗交替。该研究已由北京中医药大学实验动物伦理委员会批准(审批号:BUCEM-2023121601-4205)。采用随机数字表法将实验动物分为假手术组、模型组和推拿组,每组7只。

1.2 主要实验仪器

气体麻醉机(型号:ABM)购自北京众实迪创科技发展有限公司;超声诊断仪(型号:AixPlore)、线阵探头(型号:SLH15-4)均购自法国声科影像公司;爪抓力测试仪(型号:BIO-GS3)购自深圳市瑞沃德生命科技有限公司;推拿按摩手法模拟仪(自制,中国发明专利号:ZL202320511277.5);精密电子秤(型号:TC6KA)购自双杰电子水平(美国)有限公司;ZEISS显微镜(型号:DP74型)购自日本奥林巴斯公司;石蜡包埋机(型号:JB-P5)购自武汉俊杰电子有限公司;石蜡切片机(型号:RM2245)、组织摊片机(型号:HI1210)均购自于德国Leica公司。

1.3 主要实验试剂

异氟烷(货号:R510-22-10)购自深圳市瑞沃德生命科技有限公司;戊巴比妥钠(货号:57-33-0)购自北京偶合科技有限公司;医用超声耦合剂

(货号:20140008)购自山东朱氏药业集团;4%多聚甲醛固定液(货号:G1101)、Masson三色染色液(货号:G1006-100ML)均购自武汉赛维尔生物科技有限公司。

1.4 实验方法

1.4.1 SNI造模方法

使用气体麻醉机对大鼠进行气体麻醉。将大鼠俯卧位固定,于患侧(右侧)后肢股骨中部的手术区域剃毛。用碘伏由内而外环形常规消毒3次,于患侧股骨干中部下方,沿股骨干长轴方向作0.5 cm切口,钝性分离肌层后暴露坐骨神经。模型组和推拿组用10号持针钳于坐骨神经处进行夹持,要求持针钳3扣,夹持5 s,造成约2 mm长的损伤点。假手术组只暴露神经,挑起后不夹持。然后逐层消毒、局部给予消炎药后缝合。

1.4.2 干预方法

推拿组造模后7 d进行推拿干预。使用课题组自研“按摩推拿手法模拟仪”进行干预^[8-9]。根据临床治疗时的循经取穴、局部取穴原则选取殷门穴、阳陵泉穴和承山穴。依据《实验针灸学》^[10]、《实验动物常用穴位名称与定位第2部分:大鼠》^[11]结合比较解剖学法进行取穴。3个穴位都予以拨法、点法和揉法刺激。设置参数:频率为60次/min,力量为4 N。每穴每法1 min,每只动物总计干预9 min/次,持续治疗20 d,1次/d,每10 d休息1次。假手术组和模型组只抓握束缚相同时间不干预。

1.4.3 观察指标

1.4.3.1 后肢抓力评估 用黑色袜子套住大鼠头部,将大鼠抓握至与测力计水平方向,使大鼠抓住测力计上的单杠,向上向后轻轻拉动大鼠,使之产生拉力,直至大鼠松开单杠,读取测力计上的数值并记录。每只大鼠后肢抓力测试3次取平均值。

1.4.3.2 腓肠肌、比目鱼肌、胫前肌肌肉硬度评估 采用SWE检测腓肠肌、比目鱼肌、胫前肌的杨氏模量最大值(maximum Young's modulus, $E_{\max}$)和剪切波速度最大值(maximum shear wave velocity, $S_{\max}$)。使用Aixplorer超声诊断仪,15 MHz线阵探头(SLH15-4),中心频率8.5 MHz。采用1%戊巴比妥钠剂量50 mg/kg将大鼠麻醉后,取俯卧位,麻醉成功标准为痛觉反射、眼睑反射等消失^[12]。在大鼠小腿上涂抹耦合剂,利用常规灰阶超声先与胫骨垂直,分别确定腓肠肌、比目鱼肌、胫前肌的位置。进而选择

剪切波成像模式,先选择感兴趣区与目标肌肉方向平行,尽量避开血管和筋膜边界,设置一个定量分析圆形取样框,直径为2 mm,当色彩稳定后确定图像^[13]。图中颜色蓝表示弹性软,红色表示弹性硬。每个肌肉测量3次取平均值。

1.4.3.3 腓肠肌湿重比计算 SWE检测结束后处死大鼠,解剖分离剪取两侧腓肠肌,剪取位置两侧尽量保持一致,判断手术侧萎缩程度,用精密电子秤进行称重并计算腓肠肌湿重比。

腓肠肌湿重比=手术侧腓肠肌湿重/健康侧腓肠肌湿重

1.4.3.4 腓肠肌形态学观察 采用Masson染色对腓肠肌形态学进行观察。腓肠肌称重后取患侧腓肠肌于4%多聚甲醛中固定48 h。经脱水、透明后包埋做石蜡切片。切片厚度为8 μm,切片脱蜡至水,浸入Masson A液中,在65℃烤箱中恒温浸泡30 min,拿出后纯水冲洗至组织上黄色褪去,同时Masson D液与Masson F液入55℃水浴锅预热。切片浸入Masson B液及Masson C液等比混合的染液中(现配现用,不可提前配制保存)浸染1 min,纯水冲洗。切片经1%盐酸酒精(浓盐酸:无水乙醇=1:100)分化1 min,至细胞核呈灰黑色,纯水冲洗。将切片放入Masson D液浸染6 min,组织应呈现亮红色,如果红色过浅可适当延长染色时间,纯水冲洗至流水无色。将切片放入Masson E液浸泡1 min,分化到胶原纤维呈浅红色,纤维呈红色即可。稍微沥干Masson E液后不水洗,直接放入Masson F液染色30 s。切片将放入1%冰醋酸水溶液中漂洗分化,重复3次,每次5 s。脱水透明,用中性树胶封片,在光学显微镜下观察并拍照。每组切片随机选3个视野,用ImageJ测量每个样本中腓肠肌肌纤维横截面积并统

计分析。

1.5 统计学方法

所有数据用SPSS 20.0软件进行统计分析。计量资料服从正态分布以($\bar{x}\pm s$)表示,组间比较采用单因素分析,方差齐组间两两比较采用LSD-*t*法;若方差不齐两两比较使用Tamhane's T2检验。以*P*<0.05为差异有统计学意义。

2 结 果

2.1 3组后肢抓力比较

与假手术组比较,模型组、推拿组后肢抓力均降低(*P*<0.05);与模型组比较,推拿组后肢抓力升高(*P*<0.05)。见表1。

表1 3组后肢抓力比较($\bar{x}\pm s$)N

Table 1 Comparison of hindlimb grip strength in three groups ($\bar{x}\pm s$)N

组别	<i>n</i>	后肢抓力/N
假手术组	7	78.54±3.45
模型组	7	49.26±5.69 ¹⁾
推拿组	7	65.29±3.72 ¹⁾²⁾

注:与假手术组比较,1) *P*<0.05;与模型组比较,2) *P*<0.05。

Note: compared with the sham operation group, 1) *P*<0.05; compared with the model group, 2) *P*<0.05.

2.2 3组腓肠肌、比目鱼肌、胫前肌E_{max}、S_{max}比较

与假手术组比较,模型组腓肠肌、比目鱼肌、胫前肌E_{max}、S_{max}均升高(*P*<0.05),推拿组腓肠肌、胫前肌E_{max}、S_{max}和比目鱼肌E_{max}均升高(*P*<0.05);与模型组比较,推拿组腓肠肌、比目鱼肌、胫前肌E_{max}、S_{max}均下降(*P*<0.05)。见图1~3,表2。

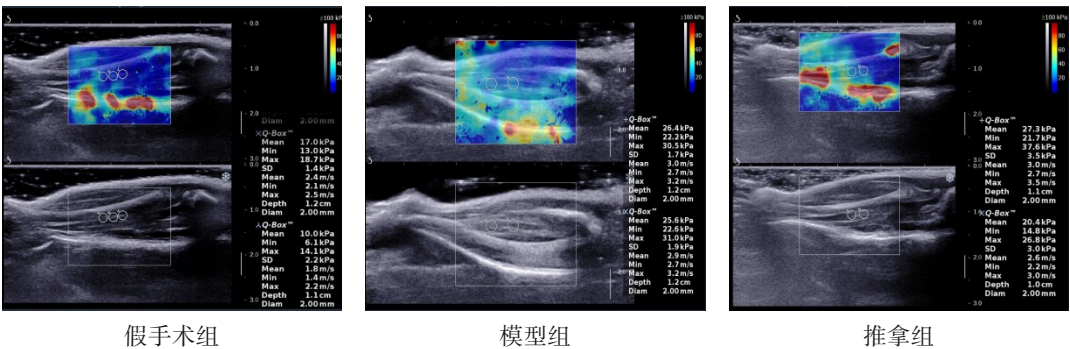


图1 腓肠肌弹性模量
Figure 1 Shear modulus of the gastrocnemius muscle

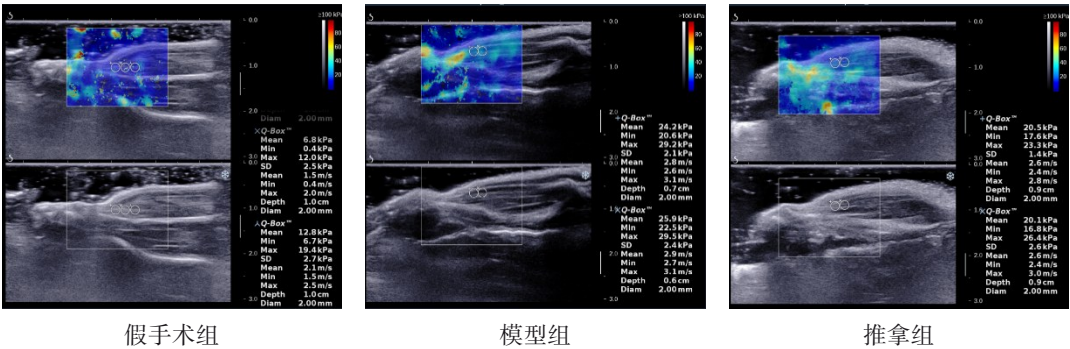


图2 比目鱼肌弹性模量

Figure 2 Shear modulus of the soleus

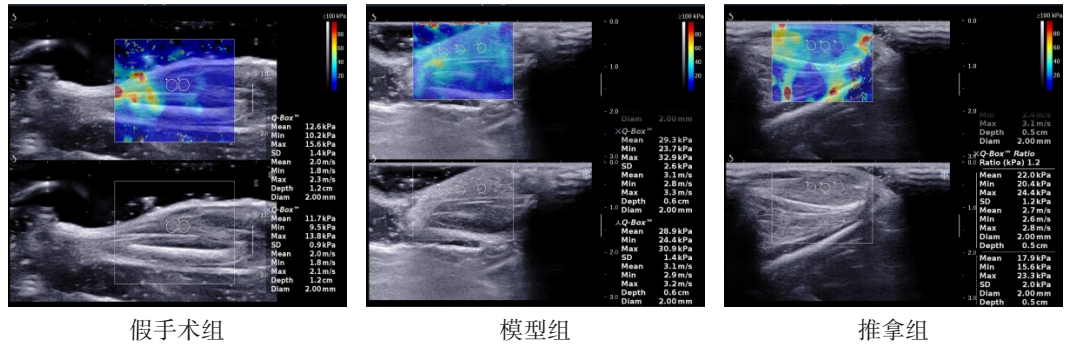


图3 胫前肌弹性模量

Figure 3 Shear modulus of the tibialis anterior muscle

表2 3组腓肠肌、比目鱼肌、胫前肌E_{max}、S_{max}比较($\bar{x}\pm s$)

Table 2 Comparison of E_{max} and S_{max} of gastrocnemius, soleus and tibialis anterior muscles in three groups ($\bar{x}\pm s$)

组别	n	腓肠肌		比目鱼肌		胫前肌	
		E _{max} /kPa	S _{max} /(m/s)	E _{max} /kPa	S _{max} /(m/s)	E _{max} /kPa	S _{max} /(m/s)
假手术组	7	18.41±2.42	1.99±0.28	19.03±1.95	2.29±0.14	16.57±2.07	1.77±0.20
模型组	7	32.30±1.71 ¹⁾	3.04±0.33 ¹⁾	33.96±4.47 ¹⁾	3.24±0.31 ¹⁾	27.51±3.70 ¹⁾	2.81±0.41 ¹⁾
推拿组	7	23.37±4.77 ¹⁾²⁾	2.57±0.29 ¹⁾²⁾	24.61±2.31 ¹⁾²⁾	2.51±0.22 ²⁾	21.60±2.38 ¹⁾²⁾	2.26±0.22 ¹⁾²⁾

注:与假手术组比较,1) $P<0.05$;与模型组比较,2) $P<0.05$ 。

Note: compared with the sham operation group, 1) $P<0.05$; compared with the model group, 2) $P<0.05$.

2.3 3组腓肠肌湿重比比较

与假手术组比较,模型组、推拿组腓肠肌湿重比均降低($P<0.05$);与模型组比较,推拿组腓肠肌湿重比升高($P<0.05$)。见表3。

2.4 3组腓肠肌肌纤维横截面积比较

Masson 染色结果显示:假手术组腓肠肌纤维细胞形态正常,边界清楚;模型组肌束间胶原纤维增多;推拿组肌纤维细胞形态趋于恢复,边界较清晰,胶原纤维减少。见图4。

与假手术组比较,模型组和推拿组肌纤维横截面积减少($P<0.05$);与模型组比较,推拿组肌纤维

横截面积增加($P<0.05$)。见表4。

表3 3组腓肠肌湿重比比较($\bar{x}\pm s$)

Table 3 Comparison of gastrocnemius wet weight ratios among three groups ($\bar{x}\pm s$)

组别	n	腓肠肌湿重比
假手术组	7	0.997±0.006
模型组	7	0.883±0.019 ¹⁾
推拿组	7	0.937±0.024 ¹⁾²⁾

注:与假手术组比较,1) $P<0.05$;与模型组比较,2) $P<0.05$ 。

Note: compared with the sham operation group, 1) $P<0.05$; compared with the model group, 2) $P<0.05$.

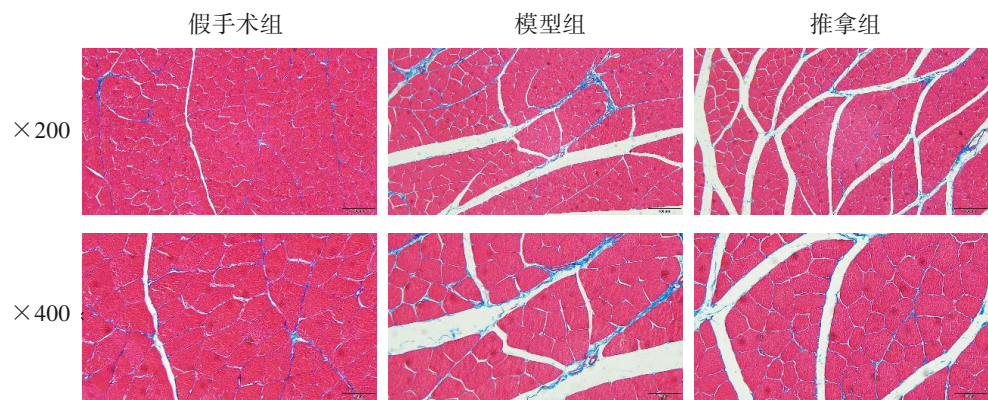


图4 3组 Masson 染色图

Figure 4 Three groups of masson staining images

表4 3组腓肠肌肌纤维横截面积比较($\bar{x}\pm s$) μm^2

Table 4 Comparison of cross-sectional area of gastrocnemius muscle fibers in three groups ($\bar{x}\pm s$) μm^2

组别	<i>n</i>	肌纤维横截面积
假手术组	4	2 003.92±86.27
模型组	4	1 096.50±49.81 ¹⁾
推拿组	4	1 673.83±68.62 ¹⁾²⁾

注:与假手术组比较,1) $P<0.05$;与模型组比较,2) $P<0.05$ 。

Note: compared with the sham operation group, 1) $P<0.05$; compared with the model group, 2) $P<0.05$.

3 讨 论

推拿可以改善PNI后运动功能障碍,但其科学机制需进一步阐明。PNI后肌肉运动功能障碍发生率高且严重,属中医学“痿证”范畴,认为其病因病机与筋骨失养有关。推拿具有舒筋活络、强肌生新的作用,可缓解肌萎缩,恢复肌肉的生物力学特性^[14-15]。多项临床研究表明,推拿可以治疗PNI导致的运动功能丧失^[16-18]。SNI是目前最常用的研究PNI的模型,“三法三穴”是安全有效的治疗SNI的推拿处方^[19]。其中三穴包括殷门、承山、阳陵泉,三穴位于足阳明和足少阳经上,符合中医理论中循经选穴和局部选穴原则。从解剖角度分析,三穴都位于坐骨神经上且位于坐骨神经支配的肌肉上,构成了“穴位-神经-肌肉”区域,是能够同时刺激神经和肌肉的最佳选穴。三法为点法、拨法、揉法,其中点法属于温通类手法,拨法、揉法属于放松类手法。“三法三穴”合用,具有温经通络、强筋生新的治疗作用。同时,课题组前期研究证明了“三法三穴”可以调节脊髓、背根神经节环磷酸腺苷(cyclic adenosine monophosphate, cAMP)、蛋白激酶A(protein kinase A, PKA)、神经营养因子(neurotrophic factor,

NTF)等蛋白表达,可以促进局部损伤神经轴突再生和髓鞘形成,促进感觉和运动功能恢复^[6,20]。

SWE能够定量评估组织的生物力学特征,且安全无创。SWE通过测量声波在组织结构中的传播速度来量化组织的力学性能,而且在传统超声图像基础上显示组织硬度的信息,可以选择感兴趣区评估组织硬度^[21]。周围神经所支配的骨骼肌,其生物力学特性与神经的支配状态及肌肉的功能完整性密切相关。研究表明,SWE在临床及基础研究中已广泛应用于周围神经病变后靶肌肉结构损伤与功能修复的动态评估^[22-23]。本研究结果从多维度证实了SNI后靶肌肉生物力学特性的显著改变。后肢抓力的结果直接反映了肌力下降;腓肠肌湿重比的降低则提示神经损伤后靶肌肉出现了明显的萎缩与蛋白质分解代谢增强;Masson染色结果从微观组织学角度验证了SNI后肌肉间质中胶原纤维沉积增多,即肌纤维化进程加速;而SWE检测结果进一步表明,坐骨神经支配的小腿三头肌硬度显著增加。在神经系统的支配下骨骼肌收缩,引起相应部位的运动,因此运动功能的正常运行需要骨骼肌具有正常的形态、结构以及功能^[24]。神经损伤后轴突再生速度缓慢,由于神经支配的丧失,靶肌肉就失去了“泵”肌肉的能力,靶肌肉的微循环相对减少,组织缺血缺氧状态持续存在。这种微环境改变一方面激活了TGF- β 1/Smad等促纤维化信号通路,促进成纤维细胞增殖与胶原蛋白过度沉积,从而导致肌肉硬度上升、弹性下降^[25-26]。另一方面,去神经支配导致肌卫星细胞增殖受阻,肌纤维类型发生转化,肌节结构紊乱,肌球蛋白与肌动蛋白含量比例失调,最终表现为肌肉湿质量减少与最大肌力下降,同时肌肉形态结构与生物力学特性改变又进一步降低

了肌肉组织的张力及兴奋性,形成恶性循环,最终导致严重的运动功能障碍^[27-28]。

本研究结果显示,与模型组比较,推拿组腓肠肌、胫前肌、比目鱼肌的 $E_{\max}$ 均降低,肌力逐渐恢复,萎缩情况明显改善,对其深层作用机制的推测可从力学传导的直接效应及生物学信号的级联放大2个方面进行阐释。①推拿是一种节律性的机械力学刺激,所选穴位均位于坐骨神经及其支配的肌肉区域,三法是轻柔、有序、有效的力学刺激,这种力学刺激直接作用于穴区局部的神经末梢与肌梭感受器,通过筋膜及肌外膜的网状结构将机械力迅速传导至整个肌束,直接改变局部组织黏弹性,松解粘连的胶原纤维,降低异常增高的肌张力^[29]。②在分子层面,这种力学信号级联通过PI3K/Akt信号通路改善微循环,影响肌卫星细胞的增殖分化,调节肌肉 α -肌动蛋白的表达等方式抑制肌蛋白的过度降解、促进蛋白质合成,从而减轻萎缩,改善肌肉的生物力学特性^[30-32]。同时力学刺激可通过促进坐骨神经局部的cAMP/PKA信号通路活化,促进轴突生长锥延伸,显著增强损伤近端神经营养因子的合成与逆向轴浆运输效率,从而为受损神经的髓鞘修复和突触重塑提供必需的营养支持,加速运动终板的功能重建^[20,33]。③机械力可调控肌肉细胞膜和神经细胞膜的机械敏感性离子通道如压电型机械门控离子通道组件1(piezo-type mechanosensitive ion channel component 1, Piezo1),引起 Ca^{2+} 等离子浓度变化,从而引起YAP/TAZ等力学信号通路改变,推拿可以修复损伤的神经,减少肌肉萎缩和纤维化改变,从而将物理力学信号转化为胞内电化学信号达到“强筋”的目的^[34-36]。当然,本研究也存在一定的局限性,如SWE虽然反映了组织的弹性特征,但是如果所测量部位有钙化、出血等病理特征,就可能导致假阳性结果。

综上,“三法三穴”干预可以恢复损伤神经支配肌肉的肌力及弹性,减轻肌肉萎缩,从而改善运动功能障碍。

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Effects of Tuina on Calf Muscle Biomechanical Properties and Underlying Mechanisms in Sciatic Nerve Injury Rats: A Study Based on the "Three-Manipulations and Three-Acupoints" Protocol

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ABSTRACT Objective This study aimed to investigate the effects of Tuina based on the "three-manipulations and three-acupoints" protocol on the biomechanical properties of calf muscles in rats with sciatic nerve injury (SNI), and to further elucidate the mechanism underlying Tuina-mediated recovery from motor dysfunction after SNI. **Methods** Twenty-one male specific pathogen-free (SPF) Sprague-Dawley rats were randomly divided into the sham operation group, the SNI group, and the Tuina group using a random number table, with 7 rats in each group. The SNI model was established in the SNI and Tuina groups by crushing the sciatic nerve, while the sham operation group underwent only exposure of the nerve without clamping. At 7 days after modeling, the Tuina group received Tuina intervention using a self-developed "massage manipulation simulator" at three acupoints: Yinmen (BL37), Yanglingquan (GB34), and Chengshan (BL57). Each acupoint was treated with three manipulations—Bo fa, Dian fa, and Rou fa—at a frequency of 60 times/min and a force of 4 N. Each manipulation was applied for 1 minute per acupoint, resulting in a total of 9 minutes intervention per session per animal. The treatment was given once daily for 20 consecutive days, with a one-day rest after 10 days of treatment. The sham operation and SNI groups were only restrained for the same duration without any intervention. Hindlimb grip strength was evaluated using a dynamometer. The maximum Young's modulus (E_{max}) and maximum shear wave velocity (S_{max}) of the gastrocnemius, soleus, and tibialis anterior muscles were measured by shear wave elastography (SWE). The wet weight ratio of the gastrocnemius was calculated using a precision electronic balance. Morphological changes of the gastrocnemius were observed by Masson staining, and the cross-sectional area of muscle fibers was measured. **Results** Compared with the sham operation group, hindlimb grip strength significantly decreased in both the SNI and Tuina groups ($P<0.05$); compared with the SNI group, the Tuina group showed a significant increase in grip strength ($P<0.05$). Compared with the sham operation group, the E_{max} and S_{max} of the gastrocnemius, soleus, and tibialis anterior muscles significantly increased in the SNI group ($P<0.05$), and in the Tuina group, the E_{max} and S_{max} of the gastrocnemius and tibialis anterior muscles as well as the E_{max} of the soleus muscle also significantly increased ($P<0.05$); compared with the SNI group, the Tuina group exhibited significant decreases in both E_{max} and S_{max} in all three muscles ($P<0.05$). Compared with the sham operation group, the wet weight ratio of the gastrocnemius was significantly reduced in both the SNI and Tuina groups ($P<0.05$); compared with the SNI group, the Tuina group had a significantly higher wet weight ratio ($P<0.05$). Masson staining revealed that in the sham operation group, the gastrocnemius muscle fibers displayed normal morphology and clear boundaries; in the SNI group, there was an increased deposition of collagen fibers between muscle bundles; in the Tuina group, the morphology of muscle fibers tended to recover, with clearer boundaries and reduced collagen fibers. Compared with the sham operation group, the cross-sectional area of muscle fibers in the SNI group and the Tuina group decreased ($P<0.05$); compared with the SNI group, the cross-sectional area of muscle fibers in the Tuina group increased ($P<0.05$). **Conclusion** The "three-manipulations and three-acupoints" intervention could effectively alleviate SNI, restore muscle strength and elasticity of sciatic nerve innervated muscles, attenuate muscle atrophy, and recover muscle biomechanical properties, thereby improving motor dysfunction.

KEY WORDS sciatic nerve injury; three-manipulations and three-acupoints; Tuina; shear wave elastography; biomechanical properties

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