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不同干预措施对兔抗谐振后血清标志物的影响 *

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摘要 目的: 探讨在 4 Hz 谐振频率下不同干预方式对兔抗谐振后血清代谢标志物特异性碱性磷酸酶 (BALP)、6- 酮前列腺素 1α (6-keto-PGF 1α)及丙二醛(MDA)含量的影响。**方法:** 75 只新西兰兔随机均分为正常对照组、模型对照组及 3 个谐振干预实验组,每组 15 只,分别于实验的 2、4、6 周从每组随机抽取 5 只在清晨空腹状态下经耳缘静脉穿刺抽取 5 mL 静脉血,测定血清 BALP、6-keto-PGF 1α 及 MDA 含量并观察其动态变化。**结果:** 与正常对照组和谐振干预 3 组比较,模型对照组、谐振干预 1、2 组血清 BALP、6-keto-PGF 1α 第 4 周开始升高,MDA 含量从第 6 周开始升高且差异显著(P<0.05)。与模型对照组相比,正常对照组、谐振干预 3 组血清 BALP、6-keto-PGF 1α 和 MDA 的含量在第 4、6 周降低且谐振干预 1、2 组与谐振干预 3 组同期相比差异显著(P<0.05)。**结论:** 不同干预对谐振引起的下腰痛早期防治具有重要参考价值,尤以 PEP 加工成大小不同空心棉球组成表面凹凸不平的座垫对于防治下腰痛发生具有重要意义。

关键词: 谐振;血清代谢标志物;下腰痛

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The Effects of Various Interventions of Syntony on the Serum Markers of Rabbits in the Forced Posture*

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ABSTRACT Objective: To investigate the effects of different interventions of syntony in 4 Hz on the serum markers such as alkaline phosphatase (levels of BALP), 6 fixed resonant frequency - keto prostaglandin 1α (6-keto-PGF 1α) and the malondialdehyde (MDA) content in the rabbits. **Methods:** Seventy-five New Zealand white rabbits were randomly divided into five groups: control group, matched model control group, model group I, model group II, and model group III. The activity of serum alkaline phosphatase (BALP), 6 - keto prostaglandin 1α (6-keto-PGF 1α) and malondialdehyde (MDA) were determined at the 2nd, 4th and 6th week after the treatment. **Results:** Compared with that of the control group and model group III, the serum BALP, 6-keto-PGF 1α and MDA content of model control group, model group I and model group II ascended significantly at the 4th and 6th week (P <0.05). Compared with that of the model control group, the serum BALP and 6-keto-PGF 1α content of control group and model group III were markedly reduced since the 4th week, and the serum MDA content reduced since the 6th week (P <0.05). **Conclusions:** The intervention of syntony had very important reference value for the early prevention of low back pain caused by syntony.

Key words: Syntony; Markers of blood metabolism; Low back pain

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前言

国内外研究普遍认为低频谐振是导致下腰痛发生的重要因素之一[1]。所谓的谐振总是指向平衡位置的力和振动位移下的对象的大小成正比[2]。流行病学调查表明下腰痛是仅次于呼吸系统疾病的常见临床症状[3]。在美国,约 1300 万人被腰背痛患困扰,每年住院治疗花费约 500 亿美元 [4-7]。腰椎的共振区(2-6 Hz)与汽车行驶时的振动频率(<50 Hz)相重叠,使腰椎产生机械振动的谐振,从而导致下腰痛的发生,以 4 Hz 的低频谐振损伤发生时间早且最为严重[8-11]。因此,如何干预谐振对下腰痛的发生尤为重要。目前有关谐振干预对强迫体位下动物血清中代谢标志物影响的研究尚未见报道。退行性脊柱退变性下腰痛的发病机制研究为本实验动物模型提供了基础[12]。本实验试图通过模拟驶乘人员接触振动,观察干预 4 Hz 低频振动对兔血清代谢标志物的影响,以期为下腰痛的早期预防治提供理论依据。

1 材料和方法

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1.1 实验动物

健康成年新西兰大白兔 75 只，雌雄不限，分笼饲养，体重 2.0± 0.18 kg，由解放军 150 医院动物中心提供。实验前适应性喂养 1 周，室温控制在 22± 1 ℃，饲养期间给予颗粒饲料，自由饮水。

1.2 试剂和仪器

兔 BALP、6-keto-PGF 1α、MDA 免疫试剂盒(均购于苏州美斯特贸易有限公司)。HDZDT-Ⅰ可调频振动台(振动范围：0-50 Hz，振幅 0.5± 0.2 mm)：天津市庆达试验仪器制造公司。KDC-1042 型离心机，由中佳公司提供；全自动快速立式洗板机，由基波科技提供；-20 ℃低温冰箱，由新飞公司提供；以及自制的固定笼。

1.3 动物分组与造模

动物适应性饲养 1 周后，随机均分为正常对照组、模型对照组和谐振干预 1、2、3 组，每组 15 只。模型对照组置于特制笼中，固定于臀坐位，确保臀部接触振动，给予 4 Hz 频率振动 2 h (相同强度 1.0 g 的振动)，每天 1 次，每周 5 天。谐振干预组置于特制笼中，臀部坐于不同介质的座垫上(干预 1 组为水垫，干预 2 组为海绵垫，干预 3 组座垫内充填 PEP 加工成大小不同的空心棉球)，振动频率和时间与造模对照组相同。正常对照组置于特制笼中自由活动。

1.4 标本的采集与处理

于第 2、4、6 周末，从每组中随机抽取 5 只在清晨空腹状态下经耳缘静脉穿刺抽取 5 mL(禁食 12 h，自由饮水))，置于真空清洁促凝管中，每分钟 3500 转离心机离心 15 min，并储存于 -20 ℃保存待测。

1.5 观察指标

BALP、6-keto-PGF 1α、MDA 的含量测定均采用酶联免疫吸附双抗夹心法(ELISA)，均严格按试剂盒说明操作。

1.6 统计学处理

数据结果以 $\bar{x}\pm s$ 表示，采用 SPSS19.0 软件进行单因素方差分析，多组间两两比较采用 LSD-t 检验，以 P<0.05 为差异有统计学意义。

2 结果

2.1 一般指标的观察

模型对照组和谐振干预 1、2 组动物造模 2 周后，食欲减退，精神差，皮毛失去光泽，体重开始下降，并呈进行性加重。正常对照组动物体重随实验进展逐渐增加。

2.2 各组不同时点兔血清 BALP、6-keto-PGF 1α、MDA 含量的比较

与正常对照组和谐振干预 3 组比较，模型对照组、谐振干预 1、2 组血清 BALP、6-keto-PGF 1α 第 4 周开始升高，MDA 含量从第 6 周开始升高且差异显著(P<0.05)。与模型对照组相比，正常对照组、谐振干预 3 组血清 BALP、6-keto-PGF 1α 和 MDA 的含量在第 4、6 周降低且谐振干预 1、2 组与谐振干预 3 组同期相比差异显著(P<0.05)。

3 讨论

近年来，我所进行的大量研究发现非特异性炎性反应和自身免疫性反应在下腰痛的发生过程中起着十分重要的作用，主要与以下因素有关，如机械力学、炎性因子、营养因素、凋亡因素、自身免疫、遗传因素等[13,14]。前期进行的大量动物实验表明低频谐振后椎体骨、肌肉和椎间盘发生了程度不同的损伤，损

表 1 各组不同时点兔血清 BALP 含量的比较($\bar{x}\pm s$)

Table 1 Comparison of the serum BALP content at different time points between different groups($\bar{x}\pm s$)

Group	2nd week	4th week	6th week
Control group	12.61± 0.32	12.84± 0.39(2)	12.94± 0.27(2)
Model control group	12.76± 0.36	13.21± 0.13(1)(3)	13.21± 0.13(1)(3)
I model group	12.32± 0.54	13.27± 0.12(1)(3)	13.24± 0.50(1)(3)
II model group	12.61± 0.44	13.24± 0.14(1)(3)	13.24± 0.14(1)(3)
III model group	12.47± 0.48	12.82± 0.18(2)	12.92± 0.17(2)

Note:(1)P<0.05 compared with control group; (2)P<0.05 compared with model control group;
(3)P<0.05 compared with III model group at the same time.

表 2 各组不同时点兔血清 6-keto-PGF 1α 含量的比较($\bar{x}\pm s$)

Table 2 Comparison of the serum 6-keto-PGF 1α content at different time points between different groups($\bar{x}\pm s$)

Group	2nd week	4th week	6th week
Control group	502.31± 58.35	500.40± 72.16(2)	545.45± 63.85(2)
Model control group	521.02± 52.51	587.80± 49.58(1)(3)	647.91± 84.13(1)(3)
I model group	487.88± 63.59	625.29± 69.22(1)(3)	651.48± 37.52(1)(3)
II model group	502.14± 55.28	625.67± 72.01(1)(3)	679.01± 59.55(1)(3)
III model group	528.25± 46.78	499.45± 62.28(2)	531.39± 72.40(2)

Note: (1)P<0.05 compared with control group; (2)P<0.05 compared with model control group;
(3)P<0.05 compared with III model group at the same time.

表 3 各组不同时点兔血清 MDA 含量的比较($\bar{x}\pm s$)

Table 3 Comparison of the serum MDA content at different time points between different groups($\bar{x}\pm s$)

Group	2nd week	4th week	6th week
Control group	4.63± 0.49	4.53± 0.63	4.51± 0.65(2)
Model control group	4.48± 0.78	4.92± 0.72	5.88± 0.53(1)(3)
I model group	4.31± 0.62	4.46± 0.77	5.47± 0.87(1)(3)
II model group	4.58± 0.60	4.64± 0.63	5.49± 0.57(1)(3)
III model group	4.52± 0.54(1)	4.71± 0.59	4.50± 0.65(2)

Note:(1)P<0.05 compared with control group; (2)P<0.05 compared with model control group; (3)P<0.05 compared with III model group at the same time.

伤发生时间早,并以 4 Hz 的谐振损伤最为严重。早期监测血清代谢指标可提高损伤风险的预测，应用于损伤进程的监测,防止进一步损伤的发生。研究发现,在退变或损伤中释放大量的化学物质包括特异性碱性磷酸酶、6- 酮前列腺素 1α、丙二醛、前列腺素等相关化学炎性因子,其中由成骨细胞产生的特异性碱性磷酸酶 BALP 的产生是成骨细胞成熟及活性的标志,是最常用于评价骨形成、了解成骨细胞骨形成和转化的最重要和最常用的评估指标;从椎间盘纤维环裂隙渗出 6- 酮前列腺素 1α 可刺激外部神经末梢引起下腰痛[15,16];丙二醛(MDA)含量可以间接反映细胞损伤的程度[17,18]。

本实验模型建立在兔的非自然体位下,局部组织的血液循环会受到肌肉所处的松弛或紧张状态的影响,在肌肉长期紧张得不到缓解状态下,从病理生理学角度而言,很容易导致局部组织的疲劳甚至损伤[19]。本研究中,通过连续对行驶时驾乘人员腰部振动频率测定结果显示多为 10 H z 以下的低频振动。腰椎的共振区(2-6 Hz)与汽车行驶时的振动频率(<50 Hz)相重叠,使腰椎产生机械振动的谐振，并以 4 Hz 的低频谐振损伤发生时间早且最为严重,谐振很容易再次增加腰部的损伤,极易发生下腰痛[20]。因此,长期在这种振动环境下工作对驾驶员的腰椎是非常不利的。如何保护驾乘人员的腰椎,防治下腰痛,已有大量学者做过相关的研究。充填 PEP 加工成大小不同的空心棉球做出的座垫无疑是一个尝试,不仅可以吸收机器振动对人们腰椎产生的动能量,而且改变了垂直和水平运动两方向的力学传导减轻腰椎间盘内压力,可减少前后纵韧带的剪切力等不利因素,且有可能因为座垫而改变了腰椎的共振特性,避开了共振频带,从而减轻共振对人们造成的伤害。

本研究中，由 PEP 加工成大小不同空心棉球组成的坐垫表面凹凸不平,可缓解车辆发动机所产生的垂直及水平方向作用力,有效避免与腰椎谐振频率的重叠,从而防止腰椎损伤。采用该种座垫进行干预的动物血清学指标 BALP、6-keto-PGF 1α 和 MDA 的含量在第 4、6 周时较为给予干预的动物有显著性差异,且优于采用水垫和海绵垫的干预组。因此,采用 PEP 加工成大小不同空心棉球组成表面凹凸不平的座垫可有效避免发动机振动频率与腰椎谐振频率区重叠,对于下腰痛的发生起到了延缓和防治的作用。

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