# 不同间动周期中频脉冲电流经皮刺激肝区对运动性疲劳士兵的抗疲劳作用观察

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[摘要] **目的** 探讨不同间动周期中频脉冲电流经皮刺激肝区对运动性疲劳士兵体能恢复的影响。**方法** 选择120名无训练史的健康男性新兵，随机均分为对照组及刺激A组、刺激B组、刺激C组，每组30名。4组均进行为期5周的强化训练(每周一至周六训练6d，周日休息1d)以建立运动性疲劳模型，刺激A、B、C组于每天训练结束后给予经皮肝区中频脉冲电流(频率1024Hz，电流强度≤80mA)康复治疗，间动周期分别为0.5、1.0、2.0s，对照组不进行脉冲电流刺激。4组均于第1、3、5周的周日在清晨空腹状态下采集静脉血，测定空腹血糖(FPG)、血乳酸(LAC)含量及丙氨酸转氨酶(ALT)、天冬氨酸转氨酶(AST)、乳酸脱氢酶(LDH)活性，并于同日测试各组士兵3000m跑步成绩。**结果** 第1周末4组FPG含量无显著差异($P$>0.05)，第3、5周末3个刺激组FPG含量均显著高于对照组($P$<0.01)，且刺激B组显著高于刺激A、C组($P$<0.01)，刺激A、C组之间比较无显著差异($P$>0.05)。第1、3、5周末各刺激组血清ALT、AST、LDH活性及LAC含量均显著低于对照组($P$<0.05，$P$<0.01)，且刺激B组显著低于刺激A、C组($P$<0.05，$P$<0.01)，而刺激A、C组之间比较无显著差异($P$>0.05)。第1周末4组3000m跑成绩无显著差异($P$＞0.05)，第3、5周末各刺激组3000m跑用时均短于对照组($P$<0.01)，且刺激B组短于刺激A、C组($P$<0.05，$P$<0.01)，而刺激A、C组之间比较无显著差异($P$>0.05)。**结论** 不同间动周期中频脉冲电流可明显减轻运动性疲劳所致的肝损伤，促进体内能量生成，加速乳酸清除，提高运动耐力，具有缓解运动性疲劳的作用，其中以频率1024Hz、间动周期1.0s的中频脉冲电流效果最佳。

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## Impact of mid-frequency pulse current in different diadynamic cycles to hepatic region on restorability of exercise-induced fatigue in soldiers

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[**Abstract**] **Objective** To investigate the anti-fatigue effect of percutaneous stimulation with the middle-frequency pulse current in different diadynamic cycles in the hepatic region in exercise-induced fatigued soldiers. **Methods** One hundred twenty healthy PLA recruits who did not have physical exercise were randomly divided into four groups with thirty recruits in each: control, stimulation group A, stimulation group B, and stimulation group C. All the subjects of four groups were given training with great intensity (exercise from Monday to Saturday, with rest on Sunday) for five weeks to establish the exercise-induced fatigue model. Each day after the exercise, the recruits of stimulation groups A, B, and C were treated immediately with middle-frequency (1,204Hz, current intensity ≤80mA) stimulation to the hepatic region with diadynamic cycles of 0.5, 1, and 2 seconds, respectively. No pulse current stimulation was given in the control group. Venous blood was collected before breakfast on Sundays to measure the fasting plasma glucose (FPG) and blood lactate (LAC) contents, and liver function was determined by determination of alanine aminotransferase (ALT), aspartate aminotransferase (AST), and lactate dehydrogenase (LDH). The scores of 3,000m race of the recruits in each group were recorded on same day. **Results** There was no significant difference among the four groups in terms of the FPG level at the end of the first week ($P$>0.05). At the end of the third and fifth weeks, the FPG level was significantly higher in the three stimulation groups than that of the control group ($P$<0.01). It was significantly higher in stimulation group B than in stimulation groups A and C, respectively ($P$<0.01), but there was no significant difference between stimulation groups A and

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C ($P$>0.05). At the end of the first , third, and fifth weeks, the ALT, AST, LDH, and LAC levels were significantly lower in every stimulation group compared with those in the control group ($P$<0.05, $P$<0.01). They were significantly lower in stimulation group B than in stimulation groups A and C, respectively ($P$<0.05, $P$<0.01), but there was no significant difference between stimulation groups A and C ($P$>0.05). At the end of the first week, there was no significant difference in scores of 3,000m racing ($P$>0.05) among 4 groups. At the end of the third and fifth weeks, the 3,000m racing score was significantly better in every stimulation group as compared with that of the control group ($P$<0.01). The score was significantly better in stimulation group B than in stimulation groups A and C, respectively ($P$<0.05, $P$<0.01), but there was no significant difference between stimulation groups A and C ($P$>0.05). **Conclusions** Percutaneous stimulation with middle-frequency pulse current in different diadynamic cycles in the hepatic region in recruits can reduce liver injury due to exercise-induced fatigue, promote the generation of energy source *in vivo*, accelerate the elimination of lactate, and improve the exercise endurance of recruits. It plays a role in relieving exercise-induced fatigue, and the efficacy of the middle frequency with 1,204 Hz and diadynamic cycles of 1 second is the best.

[**Key words**] electric stimulation therapy; fatigue; middle frequency pulse current

运动性疲劳是机体进行运动训练时不可避免的现象，也是限制训练效果的重要因素之一[1]。适度疲劳后经合理恢复可促进人体功能的提高，但过度的运动性疲劳不及时消除会引起疲劳积累，不仅无助于提高人体功能水平，而且可能形成过度训练症候群，最终损害机体健康[2]。本研究通过建立人运动性疲劳模型，观察不同间动周期中频脉冲电流经皮刺激肝区对士兵生化指标、肝功能及3000m跑成绩的影响，旨在为其应用于抗运动性疲劳提供理论依据。

## 1 资料与方法

**1.1** 研究对象 选择120名2010年度入伍新兵，均为健康男性，入伍前均无训练史，亦无由于生活环境而导致的运动性活动，以排除由此造成的训练初始水平差异。120名新兵随机分为对照组、刺激A组、刺激B组及刺激C组，每组30名。对照组年龄18.6 1.4岁，身高169.9 5.5cm，体重62.8 7.5kg；刺激A组年龄18.5 1.8岁，身高169.6 5.3cm，体重62.9 7.9kg；刺激B组年龄18.7 1.5岁，身高169.3 5.0cm，体重62.5 7.8kg；刺激C组年龄18.6 1.7岁，身高169.5 5.1cm，体重62.6 7.6kg。组间比较差异均无统计学意义($P$>0.05)。

**1.2** 研究方法 120名新兵均连续进行为期5周的强化训练(每天训练时间在原常规训练的基础上增加20%)，训练内容按照《陆军军事训练与考核大纲》进行并每日增加3000m跑1次，每周进行强化训练6d(周一至周六)，休息1d(周日)。训练地点在部队驻地训练场。强化训练期间，受试者作息时间、饮食条件及训练安排均保持一致。如遇气候和军事行动等不可抗拒的原因而停训，则择日补偿。所有研究对象均知情同意。刺激A、B、C组于每天强化训练结束后给予1024Hz的中频脉冲电流康复治疗，间动周期分别为0.5、1.0、2.0s，时间为20min，输出强度≤80mA，以机体不能耐受(肝区振动剧烈、似有撞击感)为准。

**1.3** 取材及指标检测 各组分别于第1、3、5周的周日清晨在静息30min后抽取空腹静脉血5ml，采用AU-640全自动生化分析仪检测空腹血糖(FPG)、血乳酸(LAC)含量及丙氨酸转氨酶(ALT)、天冬氨酸转氨酶(AST)、乳酸脱氢酶(LDH)活性，并于同日测定各组士兵3000m跑成绩。所有测试工作由固定的两名工作人员进行，以消除主观误差。

**1.4** 统计学处理 数据结果以$\bar{x}\pm s$表示，采用SPSS 17.0软件进行统计学分析。经正态性、方差齐性检验，组间比较采用单因素方差分析，进一步两两比较采用LSD-$t$检验，$P$<0.05为差异有统计学意义。

## 2 结 果

**2.1** 生化指标检测结果 第1周末4组FPG含量无显著差异($P$>0.05)，第3、5周末3个刺激组FPG含量均显著高于对照组($P$<0.01)，且刺激B组显著高于刺激A、C组($P$<0.01)，而刺激A、C组之间比较无显著差异($P$>0.05)。第1、3、5周末各刺激组LAC含量均显著低于对照组($P$<0.01)，且刺激B组显著低于刺激A、C组($P$<0.01)，而刺激A、C组之间比较无显著差异($P$>0.05，表1)。

**2.2** 肝功能指标检测结果 第1、3、5周末各刺激组血清ALT、AST活性均显著低于对照组($P$<0.05，$P$<0.01)，且刺激B组显著低于刺激A、C组($P$<0.05，$P$<0.01)，而刺激A、C组间比较无显著差异($P$>0.05)。第1周末刺激A、C组血清LDH活性显著低于对照组($P$<0.01)，但高于刺激B组($P$<0.05)，第3、5周末各刺激组血清LDH活性均显著低于对照组($P$<0.01)，且刺激B组显著低于刺激A、C组($P$<0.01)，而刺激A、C组之间比较无显著性差异($P$>0.05，表2)。

**2.3** 3000m跑成绩比较 第1周末4组3000m跑成绩无显著差异($P > 0.05$)，第3周末各刺激组3000m跑时间均短于对照组($P<0.01$)，且刺激B组短于刺激A、C组($P<0.05$)，第5周末各刺激组3000m跑时间均短于对照组($P<0.01$)，且刺激B组短于刺激A、C组($P<0.01$)，各时间点刺激A、C组之间比较均无显著性差异($P>0.05$，表3)。

## 3 讨 论

高强度运动可使体内能量耗竭，导致肌肉工作能力下降，不能完成预定的运动目标。糖是肌肉活动时能量的主要来源，长时间紧张运动中的体力衰

**表1** 各组士兵血FPG和LAC含量比较(mmol/L，$\bar{x}\pm s$，$n$=30)

**Tab. 1** Comparison of FPG and LAC levels in peripheral blood (mmol/L, $\bar{x}\pm s$, $n$=30)

| Item | Time (Weeks) | | |
|---|---|---|---|
| | 1 | 3 | 5 |
| FPG | | | |
| Control group | 5.71 0.34 | 4.30 0.37 | 3.39 0.32 |
| Stimulating group A | 5.69 0.38 | 4.61 0.34(1) | 3.89 0.28(1) |
| Stimulating group B | 5.73 0.40 | 4.99 0.36(1)(2) | 4.21 0.25(1)(2) |
| Stimulating group C | 5.66 0.41 | 4.73 0.38(1)(3) | 3.75 0.30(1)(3) |
| LAC | | | |
| Control group | 2.39 0.23 | 3.28 0.31 | 3.63 0.30 |
| Stimulating group A | 2.23 0.20(1) | 2.91 0.26(1) | 3.32 0.25(1) |
| Stimulating group B | 2.08 0.17(1)(2) | 2.57 0.21(1)(2) | 2.95 0.23(1)(2) |
| Stimulating group C | 2.26 0.19(1)(3) | 2.87 0.24(1)(3) | 3.37 0.27(1)(3) |

(1)$P$<0.01 compared with control group; (2)$P$<0.01 compared with stimulating group A; (3)$P$<0.01 compared with stimulating group B; FPG. fasting plasma glucose; LAC. lactic acid

**表2** 各组士兵血ALT、AST及LDH活性比较(U/L，$\bar{x}\pm s$，$n$=30)

**Tab. 2** Comparison of ALT, AST and LDH activity in peripheral blood (U/L, $\bar{x}\pm s$, $n$=30)

| Item | Time (Weeks) | | |
|---|---|---|---|
| | 1 | 3 | 5 |
| ALT | | | |
| Control group | 46.93 7.11 | 75.43 9.44 | 83.10 6.44 |
| Stimulating group A | 38.53 6.33(1) | 59.83 8.39(1) | 67.87 4.97(1) |
| Stimulating group B | 28.57 5.64(1)(3) | 45.80 5.09(1)(3) | 57.80 6.63(1)(3) |
| Stimulating group C | 41.60 6.14(1)(5) | 62.77 5.56(1)(5) | 68.67 4.21(1)(5) |
| AST | | | |
| Control group | 41.73 6.66 | 65.77 7.69 | 76.43 8.12 |
| Stimulating group A | 33.77 5.58(1) | 52.60 6.95(1) | 62.80 6.33(1) |
| Stimulating group B | 23.53 4.18(1)(3) | 35.57 5.73(1)(3) | 44.83 5.26(1)(3) |
| Stimulating group C | 36.30 5.75(1)(5) | 50.10 6.41(1)(5) | 59.83 4.95(1)(5) |
| LDH | | | |
| Control group | 416.00 18.98 | 493.33 21.23 | 523.20 19.14 |
| Stimulating group A | 379.30 16.96(1) | 451.07 18.02(1) | 475.77 17.58(1) |
| Stimulating group B | 367.90 15.64(1)(2) | 434.03 16.61(1)(3) | 455.97 16.32(1)(3) |
| Stimulating group C | 377.27 16.53(1)(4) | 446.67 17.33(1)(5) | 473.50 16.39(1)(5) |

(1)$P$<0.01 compared with control group; (2)$P$<0.05, (3)$P$<0.01 compared with stimulating group A; (4)$P$<0.05, (5)$P$<0.01 compared with stimulating group B; ALT. alanine aminotransferase; AST. aspartate aminotransferase; LDH. lactate dehydrogenase

**表3** 各组士兵3000m跑成绩比较(s，$\bar{x}\pm s$，$n$=30)

**Tab. 3** Comparison of time of 3000m running tests (s, $\bar{x}\pm s$, $n$=30)

| Group | Time (Weeks) | | |
|---|---|---|---|
| | 1 | 3 | 5 |
| Control group | 916.13 53.09 | 1053.03 51.11 | 1090.20 50.83 |
| Stimulating group A | 904.43 51.32 | 861.03 53.21(1) | 806.70 55.19(1) |
| Stimulating group B | 897.13 49.86 | 826.00 50.07(1)(2) | 769.67 50.89(1)(3) |
| Stimulating group C | 910.10 52.35 | 853.63 54.97(1)(4) | 816.13 58.35(1)(5) |

(1)$P$<0.01 compared with control group; (2)$P$<0.05, (3)$P$<0.01 compared with stimulating group A; (4)$P$<0.05, (5)$P$<0.01 compared with stimulating group B

竭是与肌糖原耗竭同时发生的，因此糖原含量能反映疲劳程度。体内肌糖原被消耗时，为了维持血糖水平，肝糖原储备量减少[3-4]，故运动性疲劳时机体肝糖原含量显著低于正常，血糖明显下降[5-6]。本研究结果显示，第1周末4组FPG含量无显著差异($P$>0.05)，第3、5周末各刺激组FPG含量显著高于对照组，且刺激B组明显高于刺激A、C组($P$<0.01)，而刺激A、C组无显著差异($P$>0.05)，提示不同间动周期中频脉冲电流经皮刺激运动性疲劳士兵肝区可增加其血糖含量，补充体内能源物质。

血乳酸是与疲劳相关的重要生化指标[7]。正常情况下，机体大多数组织依靠有氧代谢途径供能，只有少数组织依靠糖酵解供能，且其产生的乳酸迅速进入血液，使血乳酸浓度维持在一定水平。高强度运动时，机体利用糖酵解生成乳酸而获得能量的过程加强，造成乳酸堆积，肌肉中pH值下降[8]。Shanely等[9]研究证实，乳酸堆积与肌力呈显著负相关，pH值和疲劳恢复时间亦显著相关。研究显示，加速肝脏对乳酸的代谢可缓解运动性疲劳[10]。本研究结果表明，运动性疲劳士兵体内有大量乳酸堆积，血乳酸含量明显升高，而采用中频脉冲电流经皮刺激肝区能加速乳酸清除，与对照组比较差异有统计学意义($P$<0.01)。

血清ALT及AST活性升高在一定程度上反映了肝细胞的损伤程度[10]，而血清LDH活性升高可反映过度训练对肝脏等器官组织的损伤情况[11]。运动性疲劳可损伤肝脏等机体组织，促进细胞凋亡，致使血清ALT、AST及LDH活性升高[10,12-13]。本研究结果显示，自第1周起各刺激组血清ALT、AST及LDH活性均较对照组显著升高($P$<0.01)，提示中频脉冲电流经皮刺激肝区可减轻运动性疲劳所致的肝脏等机体组织损伤，促进疲劳恢复。

本研究还进行了3000m跑训练测试，发现强化训练3周后各刺激组3000m跑时间均短于对照组($P$<0.01)，且刺激B组短于刺激A、C组($P$<0.05)，第5周末各刺激组3000m跑时间均短于对照组($P$<0.01)，且刺激B组短于刺激A、C组($P$<0.01)，提示中频脉冲电流经皮刺激肝区可缓解运动性疲劳士兵的疲劳程度，提高训练成绩。

综上所述，本研究结果表明，不同间动周期中频脉冲电流经皮刺激肝区可明显减轻运动性疲劳所致的肝脏损伤，促进体内能量生成，加速乳酸清除，提高运动耐力，具有缓解运动性疲劳的作用，其中以频率1024Hz、间动周期1.0s的中频脉冲电流效果为最佳。

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