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跑台运动训练和停训对去卵巢大鼠体成分和骨密度的影响 *

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摘要 目的:研究中等强度跑台运动训练和停训对去卵巢大鼠骨密度和体成分的影响。**方法**:将 60 只成年雌性 SD 大鼠按体重分层后随机分为假手术组、去卵巢静止组和去卵巢运动组,每组 20 只。去卵巢运动组大鼠每周进行 4 次时间 45min、速度 18m/min、跑道倾角 5℃的跑台训练，持续训练 14 周时，将各组大鼠又随机分为两个亚组，即：假手术 -16 周 (Sham-16) 和假手术 32 周 (Sham-32)组、去卵巢 -16 周(OVX-16)和去卵巢 -32 周(OVX-32)组以及去卵巢运动(EX)和停训组(DEX)。分别在末次训练结束 36-48 小时内或停训 16 周时,用双能 X 线骨密度仪检测各组大鼠体成分和骨密度的变化。**结果**:(1)训练结束时,OVX-16 组大鼠体脂重量和含量显著高于 Sham-16 和 EX 组,而瘦体含量、全身骨密度和腰椎骨密度显著低于 Sham-16 和 EX 组,各组其他检测指标无显著变化。(2)停训 16 周时,OVX-32 组大鼠体重、脂肪重量和体脂含量显著高于 Sham-32 组,而全身、腰椎和左右股骨骨密度以及瘦体含量显著低于 Sham-32 组;DEX 组大鼠脂肪重量和体脂含量显著高于 OVX-32 组，而瘦体含量显著低于 OVX-32 组。**结论**:跑台运动对去卵巢大鼠体成分和骨密度的改善效应在停训 16 周时均未能被保持。

关键词:去卵巢大鼠;体成分;运动训练和停训;骨密度

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Effects of Treadmill Training and Detraining on Whole-body Bone Mineral Density and Body Composition in Ovariectomized Rats*

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ABSTRACT Objective: To investigate the effects of treadmill training and detraining on whole-body bone mineral density (WBMD) and body composition of ovariectomized rats. **Methods:** Sixty female SD rats were randomly divided into three groups: sham-operation group (Sham), ovariectomized group (OVX), ovariectomized and exercise group (EX, 18 m/min, 45 min/day, 5 uphill, 4 times/week). After 14 weeks of regular exercise, the three groups were randomly divided into two subgroups namely: sham-16 and Sham-32, OVX-16 and OVX-32 as well as EX and DEX. At the end of regular training or 16 weeks of detraining, the WBMD and body composition were both detected by dual energy X-ray absorptiometry. **Results:** (1) At the end of treadmill training, both the fat mass and fat mass content in OVX-16 group were significantly higher than those in the other two groups whereas the content of lean mass, the WBMD and lumbar vertebrae BMD were significantly lower than those in the other two groups. (2) After 16 weeks of detraining, the body mass, the fat mass and the fat mass content in OVX-32 group were significantly higher than those in the Sham-32 group whereas the content of lean mass as well as the WBMD, lumbar vertebrae BMD, and left and right femur BMD were significantly lower than those in the Sham-32 group. The fat mass and the fat mass content in DEX group were significantly higher than those in OVX-32 group whereas the content of lean mass was significantly lower than that in the OVX-32 group. **Conclusion:** The benefit effects of treadmill training on whole-body composition and WBMD in OVX rats could not be preserved after 16 weeks of detraining.

Key words: Ovariectomized rats; Body composition; Training and detraining; BMD

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前言

向心性肥胖、骨质疏松症、心血管疾病等是妇女绝经后经常面临的严重健康问题[1,2]。近年来,体成分和骨密度的相关性研究备受国内外学者的关注[3-5],运动既能改变绝经后妇女的体成分[6],又能减缓绝经后妇女骨量的丢失[7],是调节人体和动物体成分和骨密度的双刃剑。前期研究表明,瘦体含量可能是影响大鼠骨密度的重要因素之一,中等强度跑台运动减缓去卵巢大鼠骨量丢失的效应可能与其能增加去卵巢大鼠的瘦体含量有关[8]。但跑台运动的这种积极效应在停训后会怎样,目前还不清楚。因此本实验采用能精确无创测量人体和小动物骨密度和体成分的双能 X 线骨密度仪(DEXA)[9],检测了中等强度跑台运动训练和停训对去卵巢大鼠体成分和骨密度的影响,旨在为临床采用运动疗法防治绝经后代谢综合症提供理论参考依据。

1 材料和方法

1.1 实验动物

60 只健康 3 月龄性成熟未孕雌性 SD 大鼠,体重(235 ± 8)

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1.2 动物手术和分组

动物手术和分组同前期报道[10]。将适应饲养 1 周的大鼠按体重分层后,随机分为手术组(40 只)和假手术组(20 只)两组。手术前,两组大鼠均禁食 12 h,按体重腹腔注射 10 %水合氯醛麻醉,注射计量为 3 mL/kg,假手术组不切除卵巢,只切除卵巢附近与卵巢等大的一块脂肪组织,而手术组则需从背部切除双侧卵巢。手术后恢复 1 周,将手术组大鼠按体重分层后又随机分为去卵巢运动和去卵巢静止两个组,每组 20 只。实验进行中,有 7 只大鼠因手术感染而死亡,最后纳入实验的各组大鼠的数目分别为:去卵巢静止组 16 只、去卵巢运动组 18 只、假手术组 19 只。

1.3 运动训练方案和运动后分组

运动训练方案和运动后分组同前期报道 [10]。手术后第 2 周,去卵巢运动组大鼠开始在小动物跑台上适应训练 1 周,训练时间从 30 min 逐渐增加到 45 min,跑速从 12 m/min 逐渐增加到 18 m/min。正式运动训练时,跑速为 18 m/min,跑台坡度为 5°,时间为 45 min,每周 4 次,共运动训练 14 周。训练结束后,将各组大鼠按体重分层后随机分为两个亚组,其中假手术组分为假手术 -16 周组(Sham-16, 9 只)和假手术 -32 周组(Sham-32, 10 只),去卵巢组分为去卵巢 -16 周组(OVX-16, 8 只)和去卵巢 -32 周组(OVX-32, 8 只),去卵巢运动组分为运动组(EX, 9 只)和停训组(DEX, 9 只)。

1.4 骨密度和体成分的检测

骨密度和体成分的检测方法同前期报道[8,10]。在末次运动的 36-48 小时内或在停训 16 周时,将大鼠按体重腹腔注射 10% 水合氯醛麻醉,注射剂量为 3 mL/kg。然后将大鼠俯卧在 DPX-Q 型双能 X 线吸收测量平台下进行扫描。扫描后,在小动物软件模式下,计算每只大鼠的骨密度和体成分。

1.5 统计学处理

各组数据以均数± 标准差表示,采用单因素方差分析比较数据,用 SPSS17.0 软件进行统计检验。

2 结果

2.1 各组大鼠体成分的比较

运动训练结束时,与 Sham-16 组比较,OVX-16 组体脂重量、总体重量和体脂含量显著增加,而瘦体含量显著下降;与 OVX-16 组比较,EX 组脂肪重量和体脂含量显著下降,而瘦体含量显著增加。三组大鼠瘦体重量差异无显著性(见表 1)。停训 16 周时,与 Sham-32 组比较,OVX-32 组体脂重量、总体重量和体脂含量显著增加,而瘦体含量显著下降;与 OVX-32 组比较,D-EX 组大鼠脂肪重量和体脂含量显著增加,而瘦体含量显著下降。三组大鼠瘦体重量差异无显著性(见表 1)。

表 1 各组大鼠体成分的比较

Table 1 Comparison of body composition in all groups

Group	Lean mass(g)	Body mass(g)	Fat mass(g)	Fat content %	Lean content %
Sham-16	260.10± 16.92	312.51± 22.64	52.41± 16.98	16.63± 4.76	83.38± 4.76
OVX-16	270.16± 51.51	415.55± 68.04***	145.45± 36.59***	34.97± 6.56***	65.03± 6.56***
EX	279.48± 18.87	367.25± 18.03	85.27± 23.23##	23.07± 5.41###	76.94± 5.41###
Sham-32	263.97± 25.80	346.66± 13.29	82.69± 26.44	23.82± 7.32	76.18± 7.32
OVX-32	268.47± 42.62	455.40± 76.988***	224.32± 39.85**	38.89± 19.37*	61.11± 19.37*
D-EX	279.95± 18.62	526.99± 54.87	247.04± 66.10##	46.22± 7.68##	53.78± 7.68##

注:**P< 0.01, ***P< 0.001,**与假手术组比较**; ##P< 0.01, ###P< 0.001,**与去卵巢组比较。**

Note: **P< 0.01, ***P< 0.001 vs Sham group; ##P< 0.01, ###P< 0.001 vs OVX group.

2.2 各组大鼠全身骨密度和主要部位骨密度的比较

运动训练结束时,与 Sham-16 组比较,OVX-16 组大鼠腰椎和全身骨密度显著下降,而左、右股骨骨密度差异无显著性;与 OVX-16 组比较,EX 组大鼠腰椎和全身骨密度显著增加,而左、右股骨骨密度差异无显著性(见表 2)。停训 16 周时,与 Sham-32 组比较,OVX-32 组大鼠腰椎、全身和左、右股骨骨密度均显著下降;与 OVX-32 组比较,D-EX 组大鼠腰椎、全身和左、右股骨骨密度差异均无显著性(见表 2)。

表 2 各组大鼠全身和主要部位骨密度的比较

Table 2 Comparison of whole-body and major position bone mineral density in all groups

Group	Lumbar density	Whole bone density	Femur density	
			Left	Right
Sham-16	0.179± 0.004	0.142± 0.007	0.162± 0.009	0.167± 0.005
OVX-16	0.155± 0.053**	0.134± 0.005*	0.156± 0.008	0.155± 0.008
EX	0.168± 0.075##	0.142± 0.003#	0.165± 0.004	0.165± 0.005
Sham-32	0.188± 0.008	0.148± 0.004	0.177± 0.008	0.178± 0.008
OVX-32	0.159± 0.015**	0.133± 0.010*	0.155± 0.020*	0.163± 0.012*
D-EX	0.160± 0.003	0.144± 0.001	0.167± 0.003	0.166± 0.003

注:*P< 0.05, **P< 0.01,**与假手术组比较**; #P< 0.05, ##P< 0.01,**与去卵巢组比较。**

Note: *P< 0.05, **P< 0.01 vs Sham group; #P<0.05, ##P< 0.01 vs OVX group.

3 讨论

妇女绝经后,体脂含量不仅增加,而且分布会发生向心性转移,脂肪积聚在内脏易诱发心血管、糖尿病等疾病[11]。众所周知,有氧运动是一种方便易行的减肥方法。本研究发现运动处理 16 周时,运动组大鼠脂肪含量显著低于去卵巢组大鼠,而瘦

体含量却显著高于去卵巢大鼠;停训 16 周时,运动组脂肪含量不仅不低于去卵巢组,而且还显著高于去卵巢组。同样,运动组大鼠的瘦体重量也显著低于去卵巢组大鼠。结果提示,14 周的中等强度跑台运动对去卵巢大鼠脂肪含量增加的抑制效应在停训 16 周时不仅不能被保持,而且发生逆转。可见,采用运动减肥,如果不坚持,后果比不采用运动疗法还严重,其机制还有待实验进一步证实。

小鼠和人体实验已表明[12,13],过度的肥胖能降低骨密度。本研究中,运动处理 16 周时,运动组大鼠全身骨密度和腰椎骨密度均显著高于去卵巢组大鼠,但运动这种减缓骨丢失的效应在停训 16 周时未能被保持。此结果与 Iwamoto 等人的人体实验结果相似[14]。由于停训后,去卵巢运动组大鼠的体脂含量显著高于去卵巢静止组,那么运动组大鼠停训后骨密度的下降是由于体重增加造成的还是运动的效应在随着时间的推移逐渐消失,或是二者兼而有之,需要进一步的研究去证实。Umemura 等人报道,8 周跳跃运动对去卵巢大鼠骨骼的改善效应虽然在停止训练 24 周时还能被保持下来,但跳跃运动对骨骼的改善效应也在逐渐丢失[15]。可见运动虽不像激素替代疗法等药物处理具有增加子宫内膜癌、血管栓等的副作用[16],但其需要人持之以恒,甚至终身坚持。

去卵巢大鼠是目前国内外通用的模拟绝经后骨质疏松的动物模型[17,18],已有实验结果表明[19],大鼠在去卵巢 8 周后骨量开始出现下降。虽然 DEXA 既能检测人体和动物的在体骨密度,也能检测人体和动物的离体骨密度[9],但本实验中,去卵巢 16 周时,在体检测的去卵巢组大鼠股骨骨密度与假手术组大鼠的差异不显著,此结果与我们前期用同一台骨密度仪检测的股骨离体骨密度结果不吻合[20]。就其原因可能与在体检测时,包裹在股骨外面的肌肉等软组织的掩盖有关。这可从去卵巢 32 周时,去卵巢组和假手术组股骨骨密度的差异才开始出现显著性而得到证实。可能此时两组大鼠股骨骨密度的差异已远大于软组织的影响。提示,虽然 DEXA 是诊断骨质疏松的金标准,但采用其系统默认的方式测量小动物在体骨密度还是有一定的误差的。

综上所述,中等强度跑台运动对去卵巢大鼠骨密度和体成分的改善效应在停训 16 周时已不能被保持。

参 考 文 献(References)

[1] Duque G, Li W, Adams M, et al. Effects of risedronate on bone marrow adipocytes in postmenopausal women [J]. Osteoporos Int., 2011, 22(5): 1547-1553

[2] Yang R, Ma X, Pan X, et al. Serum osteocalcin levels in relation to metabolic syndrome in Chinese postmenopausal women [J]. Menopause, 2013, 20(5): 548-553

[3] Morcov C, Vulpoi C, Branis teanu D. Correlation between adiponectin, leptin, insulin growth factor-1 and bone mineral density in pre and postmenopausal women[J]. Rev Med Chir Soc Med Nat Iasi., 2012, 1 16(3): 785-789

[4] Song GE, Kim K, Lee DJ, et al. Whole body vibration effects on body composition in the postmenopausal korean obese women [J]. Korean J Fam Med., 2011, 32(7): 399-405

[5] Elabd C, Basillais A, Beaupied H, et al. Oxytocin controls differentiation of human mesenchymal stem cells and reverses osteoporosis [J]. Stem Cells., 2008, 26(9): 2399-2407

[6] Kim JW, Kim DY. Effects of aerobic exercise training on serum sex hormone binding globulin, body fat index, and metabolic syndrome factors in obese postmenopausal women [J]. Metab Syndr Relat Disord., 2012, 10(6): 452-457

[7] Schmitt NM, Schmitt J, D?ren M. The role of physical activity in the prevention of osteoporosis in postmenopausal women-An update [J]. Maturitas, 2009, 63(1): 34-38

[8] 卜淑敏, 沈晶, 谢金珍. 中等强度跑台运动对去卵巢大鼠全身骨密度和身体成分的影响 [J]. 中国老年学杂志, 2012, 32(19): 4182-4183
Bu Shu-min, Shen Jing, Xie Jin-zhen. Effects of treadmill exercise with moderate intensity on whole body bone mineral density and body composition in ovariectomized rats. Chinese Journal of Gerontology, 2012, 32(19): 4182-4183

[9] Lochmü ller EM, Jung V, Weusten A, et al. Precision of high resolution dual energy X-ray absorptiometry measurements of bone mineral status and body composition in small animal models [J]. Eur Cell Mater, 2001, 1: 43-51

[10] 魏祥,卜淑敏,汪建红. 跑台运动训练和停训对去卵巢大鼠腰椎骨密度和骨髓脂肪细胞数目的影响[J].中国运动医学杂志, 2012, 31(3): 240-243
Wei Xiang, Bu Shu-min, Wang Jian-hong. Effects of Treadmill Training and Detraining on Bone Mineral Density and Bone Marrow Adipocytes in Lumbar Vertebrae of Ovariectomized Rats [J]. Chinese Journal of Sports Medicine, 2012, 31(3): 240-243

[11] Franz R, Maturana MA, Magalhães JA, et al. Central adiposity and decreased heart rate variability in postmenopause: a cross-sectional study[J]. Climacteric, 2013, 16(5): 576-583

[12] Nú ñez NP, Carpenter CL, Perkins SN, et al. Extreme obesity reduces bone mineral density: complementary evidence from mice and women[J]. Obesity (Silver Spring)., 2007,15(8): 1980-1987

[13] Tanaka S, Kuroda T, Saito M, et al. Overweight/obesity and underweight are both risk factors for osteoporotic fractures at different sites in Japanese postmenopausal women[J]. Osteoporos Int., 2013, 24(1): 69-76

[14] Iwamoto J, Takeda T, Ichimura S. Effect of exercise training and detraining on bone mineral density in postmenopausal women with osteoporos[J]. J Orthop Sci., 2001, 6(2): 128-132

[15] Umemura Y, Nagasawa S, Sogo N, et al. Effects of jump training on bone are preserved after detraining, regardless of estrogen secretion state in rats[J]. J Appl Physiol., 2008, 104(4): 1116-1120

[16] Wang L, Wang YD, Wang WJ, et al. Differential regulation of dehydroepiandrosterone and estrogen on bone and uterus in ovariectomized mice[J]. Osteoporosis Int., 2009, 20: 79-92

[17] Kalu DN. The ovariectomized rat model of postmenopausal bone loss [J]. Bone Miner., 1991, 15(3): 175-191

[18] Lelovas PP, Xanthos TT, Thoma SE, et al. The laboratory rat as an animal model for osteoporosis research [J]. Comp Med, 2008, 58(5): 424-430

[19] Yoon KH, Cho DC, Yu SH, et al. The Change of Bone Metabolism in Ovariectomized Rats: Analyses of MicroCT Scan and Biochemical Markers of Bone Turnover[J]. J Korean Neurosurg Soc., 2012, 51 (6): 323-327

[20] 陈永杰,沈红,卜淑敏. 17β-雌二醇和运动对去卵巢大鼠后肢骨组织 PPARγ 蛋白表达的影响 [J]. 中国药理学通报, 2010, 26 (5): 421-425
Chen Yong-jie, Shen Hong, Bu Shu-min. Effects of 17β-estradiol and exercise on bone PPARγ expression of hinder limb in ovariectomized rats[J]. Chinese Pharmacological Bulletin, 2010, 26 (5): 421-425