VOLUNTARY STRENGTH TRAINING AND RUNNING EXERCISE INDUCE SITE-SPECIFIC BONE ADAPTATION IN ADULT FEMALE RATS

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INTRODUCTION

Previous studies have confirmed that physical activity has a positive effect on morphological and mechanical properties of bones [1,2]. Nevertheless, one has to consider that different types of exercise affect specific bone adaptation [3,4]. The loading pattern of the mechanical stimulus, including strain rate, loading cycle frequency, strain direction and distribution, peak strain magnitude and number of cycles is of critical importance. Thereby, a high-frequency low-risk mechanical loading pattern turned out to be strongly osteogenic [5]. In addition, it was found that a low-frequency loading regime is osteogenic with a rest period between each loading cycle [6].

The purpose of the study was to analyze the effect of vibration strength training with a high frequency of 25 Hz in compared to running exercise with a low frequency of ca. 2 Hz [7] and rest between the loading cycles on bone mechanical and morphological properties in the adult female rat.

METHODS

Forty-two 11 weeks old (233 ± 20g) female Sprague-Dawley rats were randomly assigned to a basic control group (BC; n=10), a voluntary wheel running group (RUN; n=10), a vibration strength training group (VST; n=12) and a non-active age-matched control group (AMC; n=10). The RUN group had free access to a running wheel. The VST group trained voluntarily in a rat squat machine, where the rats had to lift a weight to reach special food. When the weight was lifted a vibration plate (25 Hz) under the feet was activated. The time of lifting the weight was monitored. After 12 weeks of exercise the rats were killed by decapitation and the right femur and tibia were dissected.

Peripheral quantitative computed tomography (pQCT) was performed by transverse image sets of multiple slices at 7%, 7% + 5mm from the proximal tibial plateau and at 50% the total tibial length. Femora were scanned at 5, 5.5 and 6 mm from the distal plateau and at 50% of the total bone length.

To determine the mechanical properties the bones were loaded until failure by a 3-point bending test using a material testing machine (Z2.5/TN1S, Zwick, Germany). The support distance was 15 mm for tibia and 16 mm for femur. The broadness of support points was 2 mm for tibia and 4 mm for femur. The crosshead speed during testing was 10 mm/min. The cross-sectional moment of inertia was calculated from the pQCT measurements at 50% of the total length of the bone.

The significance of difference between groups was determined by one-way ANOVA (α <0.05).

RESULTS AND DISCUSSION

Three rats of the VST group had to be excluded from the study, because they did not use the squat machine on a regular basis. The average running distance of the RT group was 9.6 ± 2.9km/day. The VST group lifted the weight (mass: 250-450g) for 161 ± 112s/day. At the end of the study animals of the AMC group (327 ± 31g) were significantly heavier than those of the RT group (283 ± 25g, p=0.010). The mechanical properties of tibia and femur in the different groups are summarized in table 1.

Tibia: The cancellous BMD was significantly (p=0.001) higher in the RUN group compared to the BC group. There were no significant effects of vibration strength training on the analyzed pQCT parameters. The BC group had always significantly (p<0.05) lower values in contrast to the AMC, RUN and VST group.

Femur: On the diaphyseal site the RUN group had a significantly lower cortical area (p=0.003), cortical (p=0.003) and total (p=0.011) BMC compared to the AMC group.

CONCLUSIONS

Mechanical stimulation by exercise with different frequency regimes affects site-dependent bone adaptation.

REFERENCES

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Table 1: Mechanical properties of tibia and femur. Values presented are means ± SD. *Values significantly (p<0.05) different to the BC group. $^{\#}$Values significantly (p<0.05) different to the RUN group. BM = bending moment; BS = bending stress

		F_{max} [N]	BM [Nmm]	Energy [mJ]	E-modulus [MPa]	BS [MPa]	Strain [%]
Tibia	**BC**	82 ± 7	315 ± 65	34.7 ± 8.3$^{\#}$	15.7 ± 33.3	218 ± 45	4.2 ± 0.9
	AMC	117 ± 21*	468 ± 83*	36.4 ± 9.9$^{\#}$	10.4 ± 23.8*	218 ± 28	4.2 ± 0.9
	RUN	127 ± 17*	506 ± 68*	46.5 ± 6.7	10.7 ± 22.2*	244 ± 24	4.6 ± 0.5
	VST	115 ± 16*	461 ± 62*	38.4 ± 8.0	11.2 ± 39.1*	221 ± 26	4.1 ± 0.6
Femur	**BC**	96 ± 9	358 ± 33	37.6 ± 15.6	33.4 ± 11.1	135 ± 13	4.5 ± 1.6
	AMC	130 ± 31*	487 ± 116*	42.1 ± 21.2	36.6 ± 14.9	137 ± 31	4.2 ± 1.6
	RUN	120 ± 22	450 ± 83	30.6 ± 16.0	43.5 ± 13.3	141 ± 28	3.6 ± 1.6
	VST	141 ± 25*	528 ± 95*	50.4 ± 17.2	30.9 ± 11.0	142 ± 17	5.1 ± 2.1