UNIVERSITEIT GENT

Faculty of Medicine and Health Sciences
Department of Movement and Sports Sciences

WHOLE BODY VIBRATION: TRAINING AND DETRAINING IN STRENGTH

Report on behalf of Body Coach®

Renaat Philippaerts
Matthieu Lenoir

GENT 2005

Abstract

Purpose: To determine the training and detraining effects of a whole body vibration strength training programme.

Methods: In total 41 young adult subjects participated, in 3 groups. The training group participated in a 10 week exercise programme (three times per week) on the vibration platform (Body Coach®), followed by a second training period of 6 weeks (once a week). The detraining group only participated in the 10 week vibration programme. A control group did not participate in any exercise programme during the study. Subjects had to perform a dynamic squat movement (lower limbs) and a push up movement (upper limbs) on the platform during vibration. The intensity and the duration of the vibration programme increased systematically by changing the amplitude, frequency and duration of the vibration periods. Pre and post tests for maximal strength, explosive strength (power), flexibility and some anthropometric measures were taken. Four subjects dropped out, resulting in a total sample of 37 subjects.

Results: Maximal strength increased with 8,1% to 16,1% in the training group, and with 9,0% to 23,5% in the detraining group after 10 weeks of exercising. After 6 weeks of detraining, some detraining effects, although not statistically significant, were observed (0.7% to 6.7%) in the detraining group. Detraining was observed in 7 out of 10 strength measures after ending the exercise programme. The training group however showed a persistent increase in strength on 9 out of 10 tests.

Conclusion: This whole body vibration programme showed an increase in strength in upper and lower limbs. Moderate detraining effects were observed after a detraining period of 6 weeks in a sample of young adult males and females. A stabilisation or maintenance programme (once a week) seems to be sufficient to keep the gained strength by using the whole body vibration method.

Study of the literature:
Detraining effects in conventional strength training

1. Detraining effects on maximal isometric strength.

In 1975 Shaver et al. (1975) investigated the detraining effects after a 6 weeks training programme. Detraining in maximal isometric strength after one week was not significant (-0,8%). However, after 4, 6 and 8 weeks of inactivity, maximal isometric strength was decreased significantly (respectively -2,0%, -3,1%, -3,2%). No further significant decrease in strength has been observed between week 6 and week 8. The decrease in strength was more pronounced between week 2 and week 6. Shaver and colleagues noted that the magnitude of detraining strongly depends on strength increase during the preceding exercise programme. The higher the increase, the higher the reconditioning conform the reversibility principle (Waldman et al., 1969). Häkkinen et al. (1981) found a much larger decrease in isometric strength (12,0 ± 6,0%) in trained strength athletes after 8 weeks of detraining, due to a partial atrophy of the fast twitch muscle fibres. During a detraining period, especially the fast twitch fibres will experience atrophy. During moderate physical activity, fast twitch fibres are less recruited compared to the slow twitch fibres (Henneman et al., 1965). Häkkinen et al. (1983a) observed two years later a 12,0 ± 1,6% decrease in maximal strength after 8 weeks of detraining. The initial decrease has been attributed to less neural activity, while the more latent decrease in strength was due to muscle atrophy (Häkkinen et al., 1981). In another study (Häkkinen et al., 1983b) the researchers described a similar detraining effect in maximal isometric strength after 8 weeks of detraining (12,0 ± 6%). Again, two years later they studied training and detraining effects in 11 male strength athletes. The exercise programme consisted of 24 weeks of training followed by 12 weeks of detraining (Häkkinen et al, 1985). The maximal isometric knee extension strength increased with 11,4%. This decreased involved a significant decrease in EMG activity and muscle atrophy. The association between the diminished EMG activity and the strength decrease supports the importance of neural activity for strength development.

Shima et al. (2002) investigated training and detraining effects after 6 weeks of training and 6 weeks of detraining in 15 healthy and physically active males. A decrease of 6,2 ± 3,7% in isometric strength after detraining was observed. Tsolakis et al. (2004) reported a decrease in strength of 9,5% (elbow flexion) after two months of detraining. However, strength gain after the 2 months training period was 64%. This rather large increase was due to the high training load and intensity, and was probably the main reason for the smaller detraining effect after two months.

2. Detraining effects on dynamic strength.

Häkkinen et al. (1981) observed a detraining effect after 8 weeks on the 1 repetition maximum (RM) squat of 11,6 ± 3,9% in experienced strength athletes (training period of 16 weeks). A muscle size decrease was responsible for the loss in strength, according to the authors. In the study of Colliander et al. (1992), a 4% significant detraining effect has been observed (after 12 weeks) in the 3RM half squat in subjects who followed an eccentric-concentric programme. However, no considerable detraining effect was found in the concentric training group. Again, the principle of reversibility explains the tempo in which the strength decrease occurs. The longer the development period, the slower the detraining will happen (Thorstensson, 1977; Houston et al., 1983; Häkkinen et al., 1983a,b; Häkkinen et al., 1985; Dudley et al., 1991; Staron et al., 1991). In 2000 Lemmer et al. found similar results after 12 weeks of detraining (and with a 9 week training period). However, after a period of 31 weeks, a dynamic strength decrease of 8 ± 2% and 14 ± 2% was observed in young and older subjects respectively. Atrophy and a less efficient recruitment of motor units explained the larger decrease in the older subjects. Some studies did not report considerable detraining effects after a relative short period of detraining (i.e. 6 weeks). Kraemer et al. (2002) found no significant decrease in 1RM squat in recreational strength athletes.

3. Detraining effects on eccentric strength.

Housh et al. (1996) noticed that a dynamic training programme (8 weeks), followed by 8 weeks of detraining, did not result in a decrease in the 1RM eccentric strength. The subjects maintained their strength gain. Compared to a more perceptible decrease in concentric strength, detraining in eccentric measures seems to need more time to happen or maybe otherwise, seems harder to quantify. However, detraining effects on eccentric strength are rarely subject of training studies.

4. Detraining effects on maximal jump performance (explosive strength).

Most of the training studies did not find significant changes in explosive strength (jumps) after 6-12 weeks of detraining (Häkkinen et al., 1981; Häkkinen et al., 1983b; Colliander et al., 1992; Kraemer et al., 2002). Maximal isometric strength and power account only for 38% in the kinematic variance of a vertical jump (Kraemer et al., 1989). Consequently, other factors (coordination and technique) are the main predictors in jump performance. Although jump performance is related to strength development and power, a decrease in (explosive) strength does not necessarily reflect in a decrease in jump performance on the short term.

Tables 1 and 2 summarize the most important results from the literature.

Table 1: Overview on the different training and detraining studies with indication of the protocols used.

Study	Training/detraining period	Training protocol	Frequency	Load/intensity
Shaver, 1975	6 wk training, 8 wk detraining	Dynamic biceps training (elbow flexion curls)	3 x / week	1 set 10 reps at ½ 10 RM 1 set 10 reps at ¾ 10 RM 1 set 10 reps at 10 RM
Häkkinen et al., 1981	16 wk training, 8 wk detraining	Eccentric / concentric	3 x / week	Dynamic leg ext 80 – 120 % 1RM
Häkkinen et al., 1983a	16 wk training, 8 wk detraining	Eccentric / concentric	3 x / week	Dynamic leg ext 80 – 120 % 1RM
Häkkinen et al., 1983b	16 wk training, 8 wk detraining	Eccentric / concentric	3 x / week	Dynamic leg ext 80 – 120 % 1RM
Houston et al., 1983	10 wk training, 12 wk detraining	Dynamic training quadriceps	Unknown	leg press, leg extension, with 10 reps ↑ load
Häkkinen et al., 1985	24 wk training, 12 wk detraining	Dynamic squats	3 x / week	Dynamic 70 – 100 % 1RM
Colliander et al., 1992	12 wk training, 12 wk detraining	Concentric group and mixed conc / ecc group	3 x / week	4 à 5 sets max bilat quadriceps. Group conc: 12 conc; group conc/ecc: 6 mixed movements
Housh et al., 1996	8 wk training, 8 wk detraining	Eccentric training	3 x / week	3 – 5 sets, 6 reps at 80% 1RM
Lemmer et al., 2000	9 wk training, 31 wk detraining	Dynamic knee-extension	3 x / week	Leg extension 1RM
Winters et al., 2000	12 m training, 6 m detraining	Dynamic jumps + strength exercise legs	3 x / week	9 sets, 10 – 12 jumps 9 sets, 10 – 12 reps leg exercise
Shima et al., 2002	6 wk training, 6 wk detraining	Dynamic calf (calf-raise & foot-press)	4 x / week	3 sets, 10 – 12 reps at 70 – 75 % 1RM
Tsolakis et al., 2004	2 m training, 2 m detraining	Isokinetic + isotonic	3 x / week	6 exercises, 3 x 10RM
Kraemer et al., 2002	6 wk detraining	Detraining: 6 weeks inactivity		

Table 2: Overview on the significant training and detraining effects from previous studies.

Studies	Results
Shaver, 1975	Training: isometric strength: ↑ 12,6%
	Detraining: 1 wk: ↓ 0,8%, 4 wk: ↓ 2%, 6 wk: ↓ 3,1%, 8 wk: ↓ 3,2%
Häkkinen et al., 1981	Training: ↑ 25,5 ± 7,4 % full squat, ↑ 21,0% ± 10,9% isom leg ext, vert jump: ↑ 9,6 ± 12,3%
	Detraining: ↓ 11,6 ± 3,9% full squat, ↓ 12,0 ± 6,0% isom leg ext
Häkkinen et al., 1983a	Training: ↑ 21,0 ± 2,9% max isometric strength
	Detraining: ↓ 12,0 ± 1,6% max isometric strength
Häkkinen et al., 1983b	Training: max isom strength: ↑ 21,0 ± 10,9%, squat jump: ↑ 9,7% cmj: ↑ 7%
	Detraining: max isom strength: ↓ 12,0 ± 6%, vertical jump: no sign difference
Houston et al., 1983	Training: ↑ 60% at 45°per sec, 39% at 270° per sec
	Detraining: ↓ 21% at 90° tot 16% at 270° per sec
Häkkinen et al., 1985	Training: ↑ 26,8% max isometric strength
	Detraining: ↓ 11,4% max isometric strength
Colliander et al., 1992	Training: 3RM half-squat: ↑ 13% conc en ↑ 24 % ecc-conc, vert jump: ↑ 4% conc, ↑ 9% ecc-conc
	Detraining: exc: ↓ 4%, conc: not specified, vertical jump: no sign difference
Housh et al., 1996	Training: ↑ 29% eccentric strength
	Detraining: no detraining effect: still 100% of 1RM
Lemmer et al., 2000	Training: younger group: ↑ 34 ± 3% 1RM and older group: ↑ 28 ± 3% 1RM
	Detraining: younger group: ↓ 8 ± 2% 1RM, older group: ↓ 14 ± 2% 1RM
Winters et al., 2000	Training: ↑ knee extension: 17% en ↑ 27% hip abduction, 28% general leg strength
	Detraining: ↓ 8% knee extension and hip abduction, 18% general leg strength
Shima et al., 2002	Training: trained leg MVC ↑ 18,9 ± 6,6 %
	Detraining: trained leg MVC ↓ 6,2% ± 3,7%
Tsolakis et al., 2004	Training: ↑ 17,5% isometric strength
	Detraining: ↓ 9,5% isometric strength
Kraemer et al., 2002	Detraining: Peak power elbow extension: ↓ 17,5%, peal power elbow flexion: ↓ 11,9%, Peak power knee extension: ↓ 9,2 %, vertical jump: no sign difference

5. Conclusion and research questions.

Study of the literature showed that the conventional training programmes are effective in developing strength. Detraining varies between 2% and 15% depending on the duration of the detraining periods. Most of the studies used a detraining period between 6 and 12 weeks.

The present study investigates the training and detraining after a whole body vibration (WBV) programme in young sports active adults (physical education students). Most of the students don’t have experience with specific strength training. Therefore a significant increase in maximal strength after 10 weeks of WBV training is expected. Moreover, we expect also a decrease in maximal strength after a detraining period of 6 weeks.

Two research questions will be further investigated:

- Does WBV positively effects maximal and explosive strength in upper and lower body?
- Is there a difference in training and detraining magnitudes between the conventional training studies and the present WBV study?

Methods

1. Subjects.

The study sample originally consisted of 46 first Bachelor students of Physical Education and Movement Sciences (Ghent University). Students were informed about this study during an introductory week prior to the first semester. Subjects were asked not to participate in any extra-curricular sports activities, nor in any extra-curricular resistance or fitness training (curriculum: circa 10u/week). Students willing to participate gave their written informed consent, and received further information orally or by e-mail.

These persons were divided into 3 groups. The **training group** finally consisted of 11 subjects. They participated in the entire intervention of 10 weeks of vibration plate training, followed by 6 weeks of maintenance training on the vibration plate. The second groups was the **detraining group**, finally consisting of 16 persons. They only participated in the first 10 week training period, and afterwards completely stopped training on the vibration plate. The **control group** included the remaining 10 subjects, not doing any kind of training during the period of 16 weeks. Division of subjects in study groups was randomized. Nine students dropped out of the study, because of diverse reasons.

Table 3 shows means and standard deviations of the three groups. Mean body weight was lower in the training group (approximately 4 kg lower), however this difference was not statistically significant.

Table 3: Anthropometric measures (means ± standard deviations) of the three groups.

	Detraining group (N=16)	Training group (N=11)	Control group (N=10)
Age (years)	18 ± 0,5	18,1 ± 0,3	18 ± 0,0
Height (cm)	174,2 ± 9,0	172,4 ± 9,6	172,0 ± 5,0
Weight (kg)	67,1 ± 8,7	62,9 ± 9,8	67,8 ± 10,1

2. Training protocol.

This is a experimental trial including 3 different conditions. The training group participated in both training period 1 (10 weeks) and training period 2 (6 weeks). The detraining group only participated in the first training period (10 weeks), and immediately stopped vibration plate training afterwards. The control group did not take part in any kind of training during the period of 16 weeks. The first training period included 3 training sessions per week. The second training period, performed by the training group only, included 1 training session per week. Each training session included a 4 minute warm-up of the lower body using a cycle ergometer at 50W, and a 4 minute warm-up of the arms at 25W. This warm-up was followed by the dynamic vibration plate training. This dynamic training always consisted of 4 sets of squats, followed by 4 sets of push ups. During the squat movement, legs were flexed until a knee angle of approximately 100° was made, the concentric phase of the movement stopped just before the knees were extended. During the push up movement, knees were on the ground, and hands were positioned on the vibration plate at shoulder width. Subjects flexed their arms until an elbow angle of approximately 90° was reached, and arms were not totally extended at the end of the movement cycle. Table 4 shows the vibration plate training protocol of the first and second training period.

Table 4: Training protocol

Training period 1: 3 sessions per week					
Week	***Set***	***Amplitude***	***Duration***	***Frequency***	***Rest***
1	4	4 mm	30 s	30 Hz	30 s
2	4	4 mm	30 s	35 Hz	30 s
3	4	4 mm	30 s	35 Hz	30 s
4	4	4 mm	30 s	35 Hz	30 s
5	4	4 mm	45 s	35 Hz	30 s
6	4	4 mm	45 s	40 Hz	30 s
7	4	4 mm	45 s	40 Hz	30 s
8	4	4 mm	45 s	40 Hz	30 s
9	4	4 mm	60 s	50 Hz	30 s
10	4	4 mm	60 s	50 Hz	30 s

Training period 2 (only training group): 1 session per week Detraining period (only detraining group): no training					
Week	***Set***	***Amplitude***	***Duration***	***Frequency***	***Rest***
1	4	4 mm	60 s	50 Hz	30 s
2	4	4 mm	60 s	50 Hz	30 s
3	4	4 mm	60 s	50 Hz	30 s
4	4	4 mm	60 s	50 Hz	30 s
5	4	4 mm	60 s	50 Hz	30 s
6	4	4 mm	60 s	50 Hz	30 s

3. Methods.

3.1. Vibration platform

The Body Coach® (Figure 1) was used for vibration training. The options to vary in intensity for this device are: amplitude (2 and 4 mm), frequency (30, 35, 40 and 50 Hz) and duration (30, 45 and 60 s).

Figure 1: The Body Coach®

3.2. Anthropometric characteristics

Weight was evaluated using the Seca weight scale. Height was measured by means of the Martin anthropometer, at the beginning of the study. Four circumference measurements were taken, more specifically biceps circumference in the extended arm at rest, biceps circumference flexed, medial thigh circumference and proximal thigh circumference. All anthropometric measurements were performed according to the official guidelines of Lohman et al. (1988).

3.3. Maximal strength

All maximal strength tests were executed in fitness centre Curves, Rooigemlaan, Ghent. Maximal strength was evaluated by means of 6 RM (repetition maximum). In all exercises, subjects performed the concentric and the eccentric movement phase in a controlled manner. All repetitions were executed non-stop, without any rest. Minimal load changes were 2.5 kg in all device. Table 5 shows all different exercises, including dominant muscle groups used in each exercise.

Table 5: Devices for maximal strength testing and dominant muscle groups used in each exercise

Exercise/device	Muscle groups used
Leg press	M. Quadriceps, Mm. Glutei
Leg extension	M. Quadriceps
Hamstring curl	M. Semimembranosus, M. Semitendinosus, M. Biceps Femoris
Chest press	M. Pectoralis Major, M. Pectoralis Minor, M. Deltoideus pars anterior, M. Triceps Brachii
Triceps press	M. Triceps Brachii
Biceps curl	M. Biceps Brachii

3.4. Explosive strength

All tests for explosive strength were executed in the Department of Movement and Sports Sciences, Ghent University. Two tests for upper body explosive strength and two tests for lower body explosive strength were performed.

3.4.1. Vertical Jump

In order to measure explosive strength of the legs, the vertical jump (Sargent jump) was chosen (Harman et al., 1991). Using this protocol, difference between standing height (both arm stretched and upwards) and jumping height (touching the board with hand at the highest point) was calculated, with an accuracy of 1 cm. The subjects performed three maximal jumps from stance (both feet, without a running start). Arm movements were allowed to support the jumps. The best performance was used for further analysis.

3.4.2. Counter Movement Jump

Besides the Sargent Jump, also the Counter Movement Jump (Optojump, Microgate) was used as a measure of explosive strength. Hands were positioned at the waist or hip and arm movements were not allowed to support the jump. Each subject performed three jumps. The best performance was used for further analysis.

3.4.3. Upper body explosive strength (basketball throw and chest pass)

Two different throws with a medicine ball (2 kg) were used to measure explosive strength of the upper body. Both medicine ball throws are performed while seated on a chair, with the back against the back rest of the chair. Additional movements of the trunk or legs were not allowed. The feet stayed positioned on the floor, with the knees flexed (90°). The first medicine ball throw was performed like an overhead basketball throw with both hands. The second throw was the chest throw in which the ball has to be pushed as far as possible from the chest. After three "warming up" trials, the highest score from three maximal throws was used for further analysis. Test-retest reliability for those two tests was investigated. Intra class correlation coefficients were for both tests 0.93 ($p<0.01$), indicating high reliability.

3.5. Flexibility

Two tests were used to measure flexibility. De Sit and reach tests measured the flexibility of the Hamstrings and lower back (Council of Europe, 1988).

The shoulder flexibility was measured by using a measuring rule (Burgerhout et al., 1995). Subjects were asked to bring the rule with the hands at the two ends, and with stretched arms, over the head and towards the back side with the following procedure: “start by holding a measuring rule (a stick) in front of the body with both hands apart and palms facing downwards. Lift the stick over the head to behind the back, maintaining the hand grip on the stick. Repeat test, moving hands closer together each time until the movement cannot be completed”. The closest distance between the two hands was the final score.

3.6. Data analysis

Data were analysed using SPSS 12.0. and were checked for extreme values and normal distribution. Descriptive statistics (means and standard deviations) were calculated. Analysis of variance (ANOVA) was used to check for initial differences for the different measures. In order to study the training and detraining effects, a repeated measures ANOVA was used. Post hoc tests were performed in order to analyse differences between the groups and the measurement points (pre vs. post training, post training vs. post detraining, pre vs. post detraining), again with repeated measures ANOVA. Minimal significance level was set at $p<0,05$.

Results

1. Drop out.

The exercise programme (Training period) existed of 30 sessions in total during the first 10 weeks. The detraining period existed of only one session per week during six weeks. Mean number of participated sessions was 28. During detraining all sessions were followed. The reasons for drop out were lack of time (4 subjects), changing in study curriculum (1 subject), sports related injuries (2 subjects), and 2 subjects did not participate in the final post-test measurement session. No drop out was caused by the whole body vibration programme. The subjects experienced the exercise programme on the vibration plate as pleasant.

2. Side effects.

During the vibration programme some subjects experienced some side effects: a red (red spots) tingling skin on arms and legs. These side effects appeared especially after the first week when the vibration frequency was increased to 35 Hz. The itch and the red skin disappeared mostly 10 minutes after the training session. No other side effects were concluded.

3. Pre test differences.

The ANOVA analysis showed no significant differences between the control group, the training group and the detraining group at start of the study.

4. Training and detraining effects.

Results from the repeated measures ANOVA are shown in Table 6. Table 7 shows the results from the post hoc tests (pre vs. post training, post training vs. post detraining, pre vs. post detraining).

Table 6: Results from repeated measures ANOVA: means ± standard deviations and effects for time, programme and time*programme interaction.

Variable	Unit	Time									Effect		
		Pre			After 10 weeks (post training)			After 16 weeks (post detraining)					
		Control N=10	Training N=11	Detraining N=16	Control N=10	Training N=11	Detraining N=16	Control N=10	Training N=11	Detraining N=16	Time	Intervention	T x I
6 RM-tests													
Leg Press	kg	188,0 ± 39,7	157,3 ± 35,5	171,5 ± 37,4	183,0 ± 38,0	170,0 ± 27,6	186,9 ± 38,2	190,0 ± 39,2	181,8 ± 35,4	183,8 ± 35,0	**	n.s.	*
Leg Extension	kg	70,5 ± 17,9	59,1 ± 16,3	62,1 ± 16,6	73,5 ± 15,1	68,2 ± 19,4	73,6 ± 17,0	78,0 ± 14,6	72,7 ± 19,3	74,6 ± 18,2	**	n.s.	n.s.
Hamstrings Curl	kg	33,3 ± 5,0	31,5 ± 9,1	37,5 ± 8,4	37,8 ± 8,3	35,5 ± 10,4	44,6 ± 10,5	41,1 ± 7,4	36,0 ± 10,5	42,1 ± 9,4	**	n.s.	n.s.
Biceps Curl	kg	22,5 ± 7,5	22,3 ± 8,8	24,7 ± 5,9	25,0 ± 7,1	25,9 ± 8,3	30,0 ± 7,8	26,5 ± 8,2	27,7 ± 7,9	28,0 ± 6,5	**	n.s.	n.s.
Triceps Press	kg	56,5 ± 13,6	49,1 ± 14,8	56,3 ± 11,9	56,5 ± 11,1	56,4 ± 14,7	64,4 ± 12,5	58,5 ± 12,5	58,2 ± 14,2	65,0 ± 14,6	**	n.s.	*
Chest Press	kg	47,5 ± 14,8	42,7 ± 19,0	45,6 ± 13,6	49,0 ± 13,5	49,1 ± 15,8	56,3 ± 12,2	53,5 ± 12,7	50,9 ± 16,9	55,0 ± 15,2	**	n.s.	*
Explosive strength													
Vertical jump	cm	38,5 ± 8,0	34,5 ± 8,3	35,0 ± 8,9	38,0 ± 6,8	38,8 ± 6,1	43,5 ± 9,4	38,0 ± 5,4	38,4 ± 7,5	41,7 ± 10,2	**	n.s.	**
Optojump	cm	28,3 ± 4,0	28,4 ± 5,0	32,1 ± 6,6	28,5 ± 3,9	29,2 ± 4,7	33,7 ± 6,8	29,8 ± 3,8	30,2 ± 5,9	33,4 ± 6,8	n.s.	n.s.	n.s.
Overhead throw	cm	568,5 ± 66,0	549,7 ± 154,2	567,5 ± 88,0	595,0 ± 59,1	599,5 ± 133,8	615,6 ± 88,9	590,5 ± 57,7	600,9 ± 144,3	611,3 ± 87,2	**	n.s.	n.s.
Chest throw	cm	572,7 ± 96,5	532,6 ± 131,9	574,7 ± 121,5	596,5 ± 74,2	580,9 ± 111,4	623,1 ± 117,9	601,0 ± 82,1	585,5 ± 115,9	629,4 ± 113,0	**	n.s.	n.s.
Flexibility													
Sit and Reach	cm	27,3 ±10,9	28,9 ± 7,4	28,8 ± 9,6	29,4 ± 10,4	30,6 ± 7,6	32,1 ± 7,3	30,0 ± 8,7	32,2 ± 7,2	32,6 ± 7,1	**	n.s.	n.s.
Shoulder	cm	87,1 ± 17,2	73,7 ± 27,7	81,3 ± 20,3	87,3 ± 15,8	73,5 ± 29,1	81,8 ± 16,5	85,1 ± 11,5	73,8 ± 28,5	83,3 ± 16,9	n.s.	n.s.	n.s.
Muscle circumferences													
Biceps extended	cm	27,1 ± 2,5	25,6 ± 1,8	26,2 ± 2,2	27,7 ± 2,7	26,3 ± 1,8	27,2 ± 2,2	27,5 ± 2,7	26,2 ± 1,6	27,1 ± 2,3	**	n.s.	n.s.
Biceps flexed	cm	30,7 ± 2,7	29,0 ± 2,4	30,1 ± 3,1	31,1 ± 3,3	29,8 ± 2,4	31,0 ± 2,7	31,2 ± 3,1	29,9 ± 2,1	30,8 ± 2,8	**	n.s.	n.s.
Mid-thigh	cm	53,7 ± 4,6	52,0 ± 3,3	53,1 ± 3,9	53,2 ± 4,5	51,0 ± 3,0	53,5 ± 3,3	53,5 ± 4,0	51,9 ± 2,5	53,4 ± 3,3	n.s.	n.s.	n.s.
Proximal thigh	cm	57,9 ± 5,1	56,8 ± 2,7	58,3 ± 5,4	57,8 ± 5,5	55,8 ± 3,4	57,8 ± 4,9	57,4 ± 5,0	55,1 ± 2,5	57,2 ± 4,2	**	n.s.	n.s.

Training group (10 weeks training 3 x / week + 6 weeks training 1 x / week); Detraining group (10 weeks training 3 x / week + 6 weeks detraining)

*: P< 0,05; **: P< 0,01; n.s.: not significant

Table 7: Results from post hoc tests

		Pre vs. Post Training			Post Training vs. Post Detraining			Pre vs. Post Detraining		
Variable	**Unit**	**Time**	**Intervention**	**T x I**	**Time**	**Intervention**	**T x I**	**Time**	**Intervention**	**T x I**
6 RM-test										
Leg Press	kg	n.s.	n.s.	*	0,075	0,093	n.s.	**	n.s.	*
Leg Extension	kg	**	n.s.	**	**	n.s.	n.s.	**	n.s.	n.s.
Hamstrings Curl	kg	**	n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.
Biceps Curl	kg	**	n.s.	0,056	n.s.	*	n.s.	**	n.s.	n.s.
Triceps Press	kg	**	n.s.	**	n.s.	n.s.	n.s.	**	n.s.	0,076
Chest Press	kg	**	n.s.	**	n.s.	n.s.	n.s.	**	n.s.	0,061
Explosive strength										
Vertical jump	cm	**	n.s.	**	n.s.	n.s.	n.s.	**	n.s.	**
Optojump	cm	0,077	n.s.	0,078	n.s.	n.s.	n.s.	*	n.s.	n.s.
Overhead throw	cm	**	n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.
Chest throw	cm	**	n.s.	*	n.s.	n.s.	n.s.	**	n.s.	n.s.
Flexibility										
Sit and Reach	cm	n.s.	n.s.	n.s.	*	n.s.	n.s.	**	n.s.	n.s.
Shoulder	cm	**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Muscle circumferences										
Biceps extended	cm	**	n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.
Biceps flexion	cm	**	n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.
Mid-thigh	cm	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Proximal thigh	cm	n.s.	n.s.	n.s.	*	n.s.	n.s.	**	n.s.	n.s.

In the figures below, the interaction (time*programme) effects are shown. Interaction effect was significant in Vertical Jump performance (p<0,01) with strength increase varying between 12-24% for Training and Detraining groups (first 10 weeks). However, the Detraining group lost about 5% in performance after the detraining period (Figure 2).

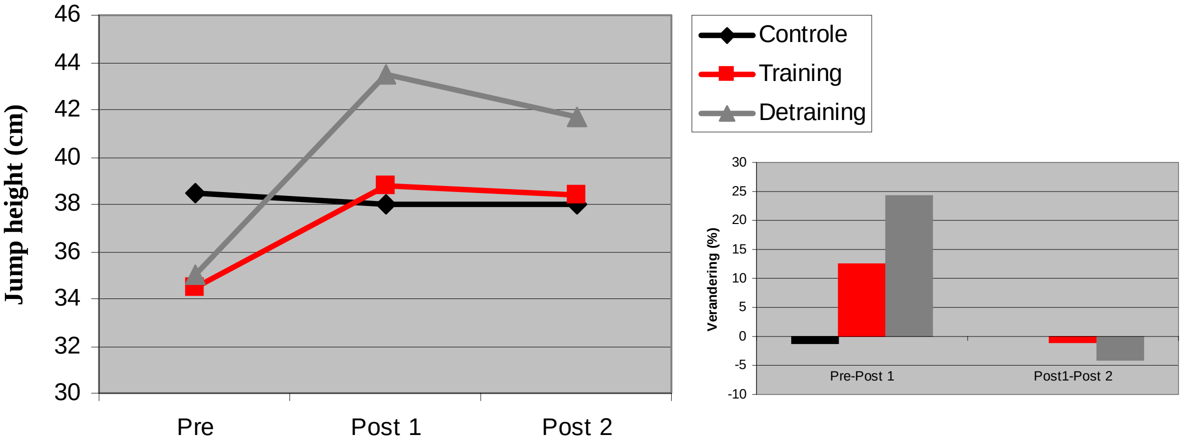

Figure 2: Vertical Jump performances for the three groups over time, with changes in terms of percentages (post 1: post training; post 2: post detraining).

Performances on Leg Press, Triceps Press and Chest Press showed also significant interaction effects (p<0,05). The Leg Press results are similar to those from the Vertical Jump (Figure 3). The increase in Leg Press performance was 8-9% for the first 10 weeks. Even in the detraining period, the Training group (1 session per week) showed an increase in strength (6%), while the Detraining group stagnates. The same pattern is observed for the Chest Press (Figure 4).

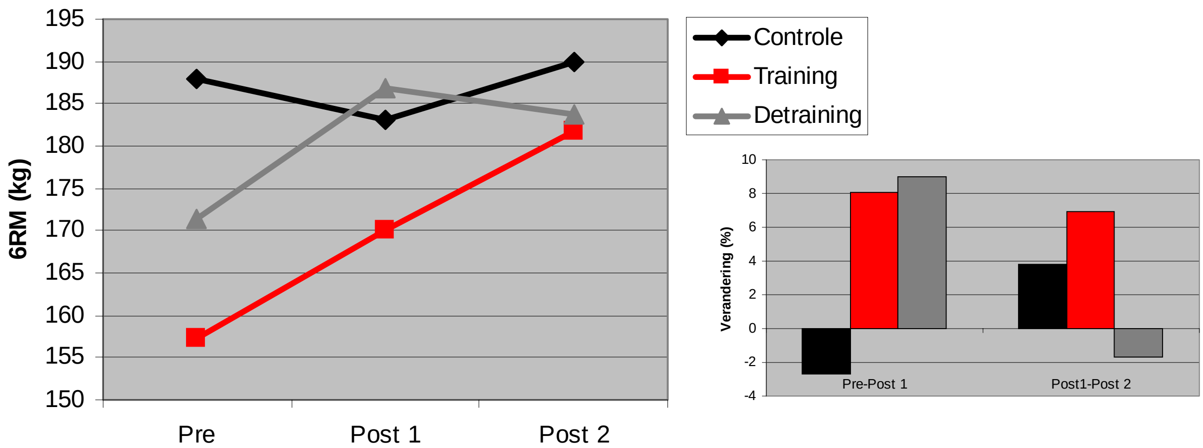

Figure 3: Leg Press performances for the three groups over time, with changes in terms of percentages (post 1: post training; post 2: post detraining).

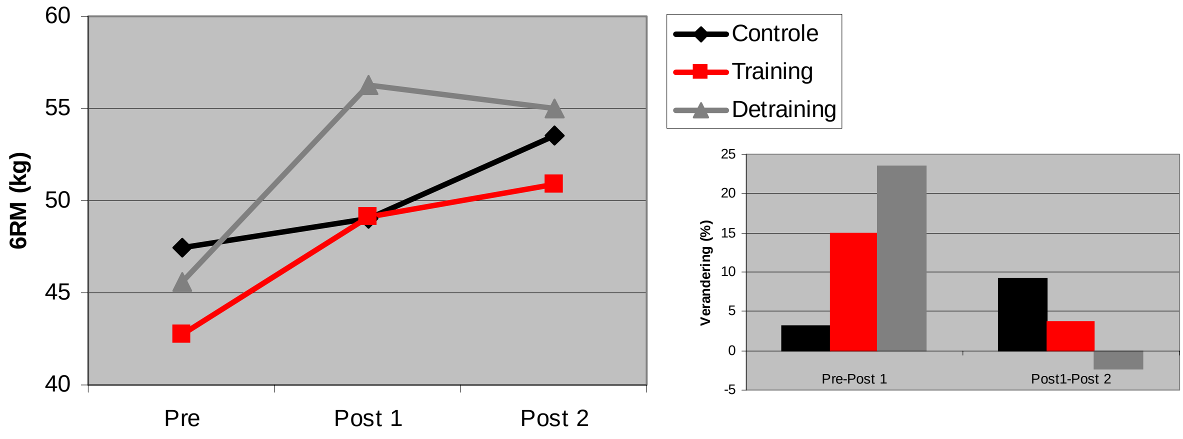

Figure 4: Chest Press performances for the three groups over time, with changes in terms of percentages (post 1: post training; post 2: post detraining).

Both Training and Detraining groups increased significantly their strength after 10 weeks, and are showing permanent strength increases, however small, even in the detraining period. Progression of the Detraining group is smaller than the progression of the Training group (Figure 5).

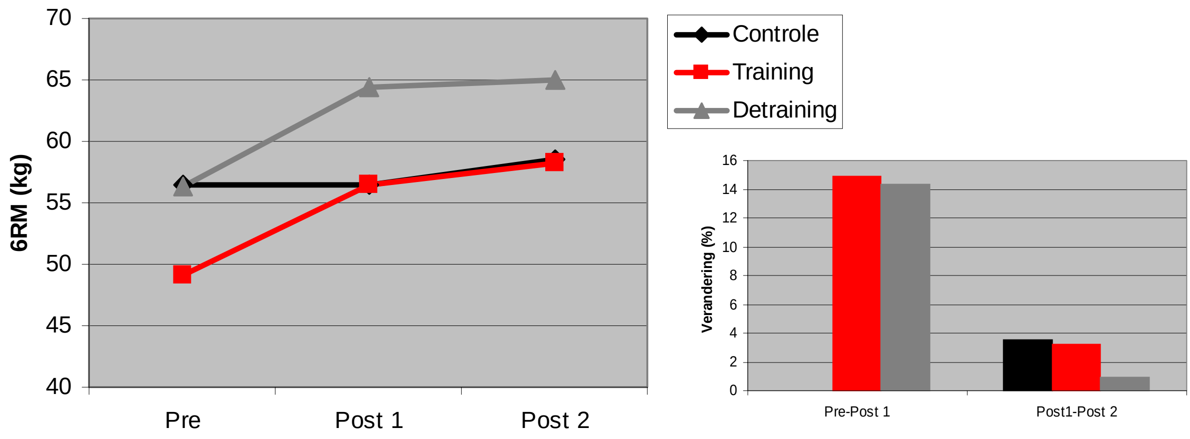

Figure 5: Triceps Press performances for the three groups over time, with changes in terms of percentages (post 1: post training; post 2: post detraining).

Similar results are found for Hamstrings Curl (Figure 6) and Biceps Curl (Figure 7), although the interaction effects were not significant. However, we notice that the Detraining group shows a decrease in strength in both tests while the Training group showed twice an increase.

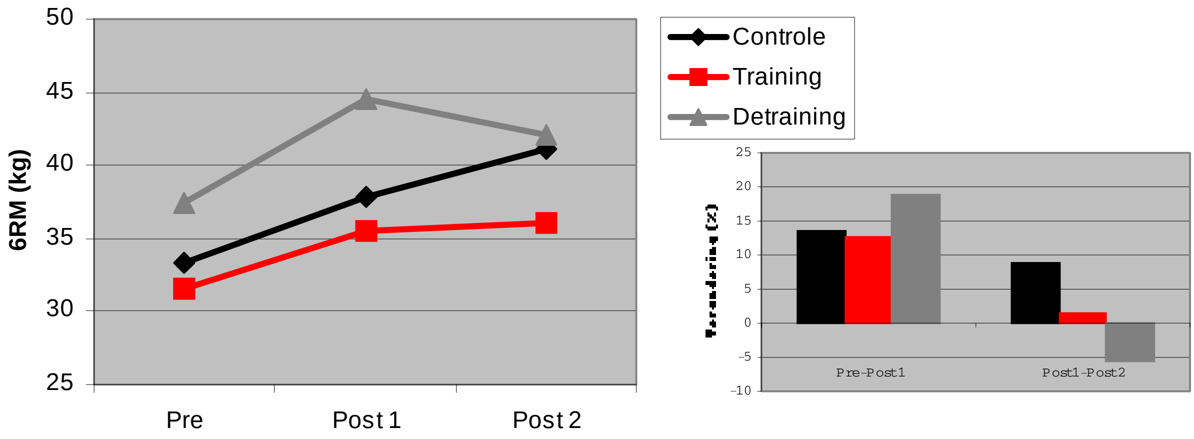

Figure 6: Hamstring Curl performances for the three groups over time, with changes in terms of percentages (post 1: post training; post 2: post detraining).

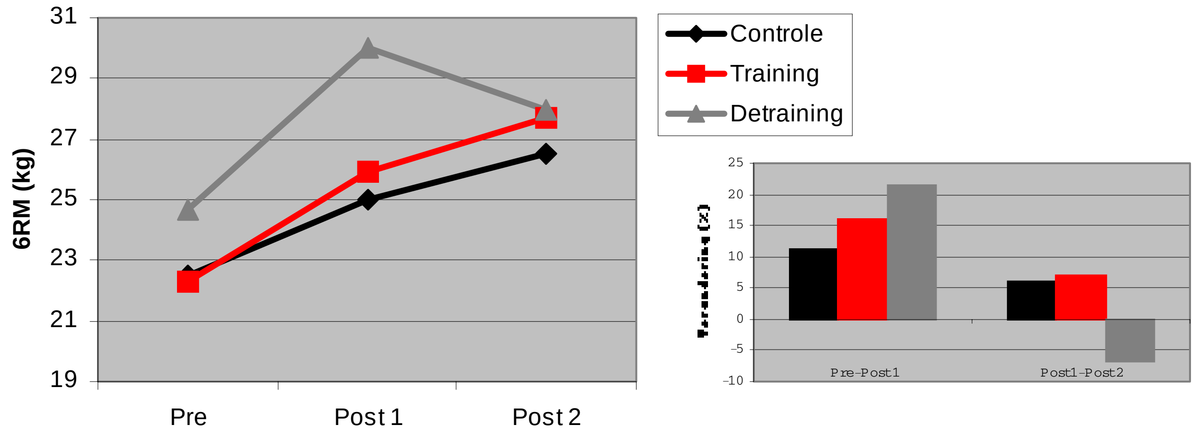

Figure 7: Biceps Curl performances for the three groups over time, with changes in terms of percentages (post 1: post training; post 2: post detraining).

Changes in terms of percentages are presented in table 8. As expected, the Detraining group showed considerable decrease in strength after de detraining period (post Training vs. post Detraining), varying between –6.7% +1.4%. The Training group for the same period in most cases an increase, varying between –1.0% en +6.9%. The Detraining group showed detraining effects after the 16 weeks on 7 out 10 strength measures.

Table 8: Overview on the training and detraining changes (in %) for the three groups over time.

Changes expressed in %									
	Pre vs. Post Training			Post Training vs. Post Detraining			Pre vs. Post Detraining (Total period)		
Variable	**C**	**T**	**DT**	**C**	**T**	**DT**	**C**	**T**	**DT**
6 RM-tests									
Leg Press	-2,7	8,1	9,0	3,8	6,9	-1,7	1,1	15,5	7,2
Leg Extension	4,3	15,4	18,5	6,1	6,6	1,4	10,6	23,0	20,1
Hamstrings Curl	13,5	12,7	18,9	8,7	1,4	-5,6	23,4	14,3	12,3
Biceps Curl	11,1	16,1	21,5	6,0	6,9	-6,7	17,8	24,2	13,4
Triceps Press	0	14,9	14,4	3,5	3,7	0,9	3,5	18,5	15,5
Chest Press	3,2	15,0	23,5	9,2	3,7	-2,3	12,6	19,2	20,6
Explosive strength									
Vertical jump	-1,3	12,5	24,3	0	-1,0	-4,1	1,3	11,3	19,1
Optojump	0,7	2,8	5,0	4,6	3,4	-0,9	5,3	6,3	4,0
Overhead throw	4,7	9,1	8,5	-0,8	0,2	-0,7	3,9	9,3	7,7
Chest throw	4,2	9,1	8,4	0,8	0,8	1,0	4,9	9,9	9,5
Flexibility									
Sit and Reach	7,7	5,9	11,5	2,0	5,2	1,6	9,9	11,4	13,2
Shoulder	0,3	-0,3	0,6	-2,5	0,4	1,8	-2,3	0,1	2,5
Muscle circumferences									
Biceps extended	2,2	2,7	3,8	-0,7	-0,4	-0,4	1,5	2,3	3,4
Biceps flexed	1,3	2,8	3,0	0,3	0,3	-0,6	1,6	3,1	2,3
Mid-thigh	-0,9	1,9	0,8	0,6	1,8	-0,2	-0,4	-0,2	0,6
Proximal thigh	-0,2	-1,8	-0,9	-0,7	-1,3	-1,0	-0,9	-3,0	-1,9

C: Control group; T: Training group; DT: Detraining group

Discussion

The present study investigates the training and detraining after a WBV programme in young sports active adults (physical education students). The results indicate that, concerning the anthropometric measures, no differences are found after 10 and 16 weeks. However, this is no indication to conclude that the lean body mass remained stable over the period because data about body composition are not available.

After 10 weeks of training, maximal leg strength increased significantly (8,1- 15,4% in the Training group, 9,0-18,9% in the Detraining group). These results are in agreement with previous studies. Delecluse et al. (2003) found an increase in isometric and dynamic leg strength of respectively 16,6 ± 10,8 % and 9,0 ± 3,2% in untrained subjects after 12 weeks of exercise.

Upper body maximal strength increased by about 15,0% in the Training group and between 14,4% and 23,5% in the Detraining group. Chest Press and Triceps Press performances increased by respectively 15,0% and 14,9% in the Training group, and by 23,5% and 14,4% in the Detraining group. The larger increase for the Chest Press is possibly explained by the larger specific transfer between the exercise (push ups) and the used strength tests. Referring to the SAID principle (specific adaptation to imposed demands), highest transfer can be expected between exercises with strong biomechanical similarities (Glowacki et al, 2004).

Concerning the **lower body explosive strength**, performance in Vertical Jump increased by 12,5% (Training group) and by 24,3% (Detraining group). Increase in Optojump performance was 2,8% (Training group) and 5,0% (Detraining group). The training effect was more considerable and pronounced in the Vertical Jump, compared to the Optojump. Coordination and technique play an important role in the Vertical Jump performance, which is less the case for the Optojump (counter movement jump). Probably a learning effect influenced positively the coordination and consequently the performance in Vertical Jump.

Flexibility did not change during and after the WBV programme. Taking into account the intensity of the programme, and the fact that physical education students follow a mandatory curriculum of 12-13 hours of sports practice (gymnastics, soccer, karate, track and field, …as possible confounding factors) no chronic changes were expected.

The 6 week of detraining did not result in further increase in strength. Lemmer et al. (2000) found similar results for their maximal dynamic strength tests. Maximal dynamic strength stayed unchanged after a detraining period of 12 weeks, in young and older subjects. Neither Kraemer et al. (2002) noticed significant changes in maximal squat performance after 6 weeks of detraining, nor Housh et al. (1996) detected a strength decrease after 8 weeks of training and 8 weeks of detraining (1 RM eccentric strength). The present results for the explosive strength measures are similar to the results found by Häkkinen et al., (1981), Häkkinen et al. (1983b), Colliander et al. (1992) and Kraemer et al. (2002). Maximal isometric strength and power account only for 38% in the kinematic variance of a vertical jump (Kraemer et al., 1989). Consequently, other factors (coordination and technique) are the main predictors in jump performance. Although jump performance is related to strength development and power, a decrease in (explosive) strength does not necessarily reflect in a decrease in jump performance on the short term. Moreover, the specific sample characteristics (PE students) are possibly responsible for some extra gain in strength. Although the subjects had no experience or were not involved in extra strength training programmes, their extra curricular sports activities were difficult to monitor, and therefore could have a possible confounding effect.

However, to what extent the whole body vibration, or the dynamic exercises on the vibration platform are responsible for the strength increase, is hard to quantify in the present study. Delecluse et al. (2003) noticed however a significant strength increase in the WBV group (9,0 ± 3,2%) as well as in the conventional strength training group (7,0 ± 6,2%), in contrast with a placebo group (exercising on a non-vibration platform) and a control group. Therefore, we can conclude that the present increase in strength can be attributed to both the WBV and the dynamic exercises on the platform.

What is/are the reason(s) for not finding considerable detraining effects after a detraining period of 6 weeks? Several explanations are possible. First, detraining or "inactivity" is rather a relative concept in PE students. Curricular activities but also extra curricular activities probably have enough load and intensity in order to prevent considerable detraining effects. Second, the amplitude of detraining is strongly related to the length of the training period. In PE students, a 6 weeks detraining period is probably not long enough to observe considerable detraining. Moreover, PE students are active enough to stabilise the training effects.

Nevertheless, detraining showed clearly that in 7 out of 10 strength measures performance declined in the detraining group (decrease between 0.7 and 6.7%), and this confirming detraining results from conventional training and detraining studies. Athletes can experience a strength decrease of 3-4% during their first week of inactivity (Appell, 1990). The used protocol would perhaps caused much larger detraining effects in a less sports active population. Finally, the number of subjects per condition (group) could have had an impact on the results. With increasing number of subjects and consequently an increased statistical power, the study could have led to a stronger detection of training and detraining effects.

General conclusion

The present Whole Body Vibration exercise programme has a positive effect on upper body and lower body maximal and explosive strength. After 10 weeks of vibration training, the training and detraining groups performed better on several strength tests. Cessation of the training programme resulted in a stagnation or in a decrease in strength after 6 weeks in young and sportive subjects. The Training group continued a maintenance programme (1 session per week). In order to avoid acute detraining effects, it can be concluded that the present minimal training modalities should be followed. However, evidence from conventional strength training studies indicated already that a minimal training frequency (1 session per week) is inadequate to ensure the strength stabilisation caused by neural (less efficient recruitment of motor units, …), hormonal (change in testosterone levels and protein synthesis, …) and muscular (fibre size, …) adaptation on the long term. Therefore, a stabilisation or maintenance programme (once a week) seems to be sufficient to keep the gained strength by using the whole body vibration method. On the long term, probably 1 session per week is not enough.

References

1. Appell H.J. (1990). Muscular atrophy following immobilization: a review. *Sports Medicine*, 10, 42-58.
2. Colliander E. B., Tesch P. A. (1992). Effects of detraining following short term resistance training on eccentric and concentric muscle strength. *Acta Physiol Scand*, 144, 23 – 29.
3. Council of Europe (1988). EUROFIT: European test of physical fitness. Rome: Council of Europe (Committee for the development of sport), 72p.
4. Delecluse C., Roelants M., Verschueren S. (2003). Strength increase after whole-body vibration compared with resistance training. *Medicine & Science in Sports & Exercise*, 35(6), 1033 – 1041.
5. De Smet J., Kenis K. (2004). *Effectiviteit van statische en dynamische vibratietraining op de krachtontwikkeling*. Gent: Universiteit Gent (Licentiaatscriptie Lichamelijke Opvoeding), 54p.
6. Glowacki S. P., Martin S. E., Maurer A., Baek W., Green J. S., Crouse S.F. (2004). Effects of resistance, endurance, and concurrent exercise on training outcomes in men. *Medicine & Science in Sports & Exercise*, 36(12), 2219 – 27.
7. Häkkinen K., Komi P. V., Tesch P. A. (1981). Effect of combined concentric and eccentric strength training and detraining on force- time, muscle fiber and metabolic characteristics of leg extensor muscles. *Scandinavian Journal of Sports Science*, 3(2), 50 – 58.
8. Häkkinen K., Komi P. V. (1983a). Electromyographic changes during strength training and detraining. *Medicine & Science in Sports & Exercise*, 15(6), 455 – 460.
9. Häkkinen K., Komi P. V. (1983b). Alterations of mechanical Characteristics of human skeletal muscle during strength training. *European Journal of Applied Physiology*, 50, 161 – 172.
10. Häkkinen K., Alén M., Komi P. V. (1985). Changes in isometric force- and relaxation-time, electromyographic and muscle fibre characteristics of human skeletal muscle during strength training and detraining. *Acta Physiol Scand*, 125, 573 – 585.
11. Harman E. A., Rosenstein M. T., Frykman P. N., Rosenstein R. M., Kraemer N. J. (1991). Estimantion of human power output from vertical jump. *Journal of Applied Sports Science Research*, 5, 116 – 120.

12. Henneman E., Olson C. (1965). Relations between structure and function in the design of skeletal muscles. *Journal of Neurophysiology*, 28, 581 – 598.
13. Housh T. J., Housh D. J., Weir L. L., Weir J. P. (1996). Effects of eccentric- only resistance training and detraining. *International Journal of Sports Medicine,* 17(2), 145 – 148.
14. Houston M. E., Froese E. A., Valeriote St. P., Green H. J., Ranney D. A. (1983). Muscle performance, morphology and metabolic capacity during strength training and detraining: a one leg model. *European Journal of Applied Physiology*, 51, 25 – 35.
15. Kraemer W. J., Koziris L. P., Ratamess N. A., Häkkinen K., Triplett-McBride N. T., Fry A. C., Gordon S. E., Volek J. S., French D. N., Rubin M. R., Gómez A. L., Sharman M. J., Lynch J. M., Izquierdo M., Newton R. U., Fleck S. J. (2002). Detraining produces minimal changes in physical performance and hormonal variables in recreationally strength-trained men. *Journal of Strength and Conditioning Research*, 16(3), 373 – 382.
16. Lemmer J. T., Hurlbut D. E., Martel G. F., Tracy B. L., Ivey F. M., Metter E. J., Fozard J. L., Fleg J. L., Hurley B. F. (2000). Age and gender responses to strength training and detraining. *Medicine & Science in Sports & Exercise*, 1505 – 1512.
17. Lohman T., Roche A., Martorell. (1988). *Antropometric Standardization Reference Manual,* Champaign, Human Kinetics.
18. Shaver L. G. (1975). Cross transfer effects of conditioning and deconditioning on muscular strength. *Ergonomics*, 18(1), 9 – 16.
19. Shima N., Ishida K., Katayama K., Morotone Y., Sato Y., Miyamura M. (2002). Cross education of muscular strength during unilateral resistance training and detraining. *European Journal of Applied Physiology,* 86, 287 – 294.
20. Thorstensson A. (1977). Observations on strength training and detraining. *Acta Physiol Scand*, 100, 491 – 493.
21. Tsolakis C. K., Vagenas G. K., Dessypris A. G. (2004). Strength adaptations and hormonal responses to resistance training and detraining in preadolescent males. *Journal of Strength and Conditioning Research*, 18(3), 625 – 629.
22. Waldman R., Stuli G. A. (1969). Effects of various periods of inactivity on retention of newly acquired levels of muscular endurance. *Research Quarterly*, 40, 396 – 401.
23. Winters K. M., Snow C.M. (2000). Detraining reverses positive effects of exercise on the musculoskeletal system in premenopausal woman. *Journal of Bone and Mineral Research*, 15(12), 2495 – 2503.