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Alterations of Muscular Strength and Left and Right Limb Balance in Weightlifters after an 8-week Balance Training Program

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Abstract. [Purpose] Balance is generally defined as the ability to maintain the body's center of gravity within its base of support and may be categorized by either static or dynamic balance. The purpose of the present study was to evaluate the effect of 8 weeks of balance training on strength, and the functional balance ability of elite weightlifters. [Subjects] Thirty-two elite weightlifters were recruited for the present study. They were divided into exercise groups (8 high school students, 8 middle school students) and control groups (8 high school students, 8 middle school students). [Methods] Body compositions were measured by the electrical impedance method, and a Helmas system was used to measure basic physical capacities. The muscular function test was conducted using a Cybex 770. [Results] There were no significant changes in body composition after the training. In contrast, significant changes were found in the number of push-ups, one-leg standing time with eyes closed, and upper body back extension. Interestingly, only the left arm external rotation value after the exercise training program showed a statistically significant difference from the baseline value. [Conclusion] The peak torque values of shoulder internal rotation and knee extension were significantly changed compared to the baseline values, which mean subjects showed balance of their muscular power. Therefore, the results of the present study suggest that an 8-week balance-training program would positively affect elite weightlifters' balance ability and flexibility. We think that well-balanced muscular functionality may enhance athletes' sport performance.
Key words: Balance training, Body composition, Stabilization

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INTRODUCTION

For elite weightlifters, the enhancement of strength and balance plays a critical role in their performance, since they must control extremely heavy weights above their head height for a couple of seconds, while their arms are fully extended. Any kind of muscle imbalance and inappropriate technique may hamper athletes' performance and lead to dangerous situations. However, a prolonged clean, jerk motion, which is thought to be the fundamental movement for weightlifting seems to aggravate muscular imbalances leading to higher injury incidence.

Balance is generally defined as the ability to maintain the body's center of gravity within its base of support and may be categorized by either static or dynamic balance[1, 2)]. Optimal posture control requires sensory information from the visual, vestibular, and proprioceptive nerves. The absence of any of these sensory inputs can influence body sway during static balance.

Balance training has been commonly utilized after injury to re-establish basic neural perception to enhance proprioceptive function and kinesthetic awareness[3)]. Thus, it should be included in injury prevention and rehabilitation processes. In addition, exercise performed on unstable surfaces rather than under stable conditions seems to more effectively increase muscle activation patterns in the trunk region[4, 5)] and limbs[6)], while decreasing perceived exertion[7)]. The overall effects of this approach, which is termed "core stability and strength enhancement", may possibly improve athletic performance and reduce the incidence of injury. As a result, it has a growing popularity not only among elite athletes but also the general population.

Training should be practical. For example, training under unstable and imbalanced conditions results in instability that can be experienced during a variety of daily and sport activities[8)]. However, it is reasonable to assume that using unstable surfaces during training should be based on improvement of the neuromuscular adaptation process, particularly at the early stages of a resistance training program[9)]. In addition, it is a favorable to admit that enhancing balance ability produces greater muscular functionality

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Table 1. Physical characteristics of the subjects

Variable		CO	Pre	Post
Height (cm)	HS	171.3±1.5	171.8±2.2	172.0±2.2
	MS	162.5±2.9	166.2±2.7	167.3±2.6
Weight (kg)	HS	87.4±5.2	86.2±5.5	87.2±5.8
	MS	65.7±4.9	73.0±5.5	73.1±5.2
BMI (kg/m^2)	HS	29.5±1.4	29.0±1.4	29.2±1.5
	MS	24.7±1.3	25.9±1.2	25.7±1.2
%fat	HS	23.9±1.6	18.6±1.9	23.0±3.1
	MS	21.6±6.0	28.4±2.3	27.7±1.7

mean±SE, HS; high school athlete, MS; middle school athlete
CO, control group; Pre, pre-training; Post, post-training
*, between group significant difference: p<0.05

Table 2. Procedure of the 8-week balance-training program

Procedure	Exercise (three sets of each)	Repetitions	Hold time (s)	Rest time (s)
1	Single leg raise with arm lateral raise	–	30	20
2	Oblique crunch on ball	12–15	–	20
3	Gluteus bridge on ball	–	30	30
4	Ball pull over	12–15	–	30
5	Cat on the ball	12–15	–	40
6	Prone leg raise on ball	–	30	40
7	Torso twist on ball	12–15	–	50
8	Assisted ball push-up	12–15	–	50
9	Dumbbell fly on ball	12–15	–	60
10	Assisted ball lunge	–	30	60

which may maximize athletic performance. However, only a few studies have been conducted examining the effects of simple balance training in this field. Additionally, it is hard to find a relatively short and time-efficient balance training program, particularly one suitable for middle and high school elite weightlifters.

Therefore, the purpose of the present study was to evaluate the effects of 8 weeks of balance training on muscular function equalization that could be utilized in an elite weightlifters' basic training program.

SUBJECTS AND METHODS

Thirty-two male elite weightlifters were recruited. The subjects were 16 middle school (MS) weightlifters (Control group n=8, Exercise group n=8, average age 14 years) with an averageweight lifting experience of 25.44 months, and 16 high school (HS) weightlifters (Control group n=8, Exercise group n=8, average age 17.00 years) with an average weightlifting experience of 55.44 months. This study meets the ethical standards of the International Journal of Sports Medicine[10] The physical characteristics of the subjects are summarized in Table 1.

Anthropometric measurements of all subjects included height (cm), and body weight (kg), and percent body fat (%), was measured by a body composition analyzer (Jawon Medical, Gyeongsan, Korea) at the Exercise Physiology Laboratory of Dong-A University. Basic physical performances were measured by a Helmas (O2 run, Seoul, Korea) system before and after the 8-week balance-training program and included sit-ups, push-ups, handgrip power, vertical jump, side step, body reaction time, one-leg standing time with closed eyes. Flexibility in the sagittal plane, sit and reach, and back hyperextension in the prone position were also measured.

All subjects were asked to come to the laboratory before 8:00 on the experimental day. The strength tests were performed using a Cybex Norm 770 (Cybex division of Lumax, NY, USA) isokinetic dynamometer. The maximal voluntary knee flexion and extension %body weight peak torque (%BWPT) were assessed for both legs at angular velocities of 60°/s and 120°/s. Additionally, upper arm internal and external rotation were measured at angular velocities of 30°/s and 90°/s. At the end, wrist extensor and flexor power were also measured at angular velocities of −10°/s and 30°/s. For each test, each subject performed a maximal contraction three times, with a recovery period of 3 minutes to avoid fatigue induced performance decrements. The highest value of three trials was accepted for the %BWPT. The reliability of the strength test was investigated prior to the formal measurement. Intraclass correlation coefficients for the test-retest reliability ranged from 0.89–0.99 for the knee, arm, and wrist tests.

The 8-week balance training-program was conducted after baseline measurements, as detailed in Table 2 and Fig. 1.

All data were analyzed using SPSS 14.0 for Windows.

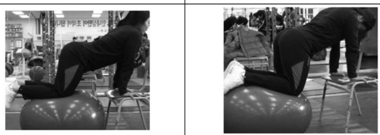
	Holding 2 kg dumbbell, each hand is maintained horizontal to the ground while raising one leg for 30 s.
	Oblique crunch twist, while maintaining an adequate balance keeping the plate between the knees.
	90° leg curl with a ball for 30 s while maintaining balance.
	Thirty second pullover of 5 kg dumbbell on the ball. Triceps extension of 5 kg dumbbell on the ball for 30 s.
	Maintaining balance on the ball for 30 s
	Lying on the floor initially with both legs on the ball, then raising one leg up approximately vertically to the floor in a well-controlled manner.
	Trunk rotation on the ball with a 3 kg dumbbell for 30 s.
	Push-ups with feet on the ball for 30 s.
	Dumbbell fly on the ball.
	Maintaining forward lunge pose with one leg on the ball for 30 s.

Fig. 1. Photographs of the aspects of the balance training program

Data are expressed as the mean ± standard error (SE). All data were tested for normal distribution using Shapiro-Wilk test. The measured values of the Control groups, and the Exercise groups before and after the 8-week balance training program were compared using one-way ANOVA. The Duncan protocol was used for the post hoc test. Statistical significance was accepted for values of $p<0.05$.

RESULTS

No appreciable changes in body composition were found on completion of the 8-week balance training program (Table 1).

In the MS groups, there was a significant difference in the number of push-ups between the Control (CO), and Exercise groups at pre-training (Pre) and post-training (Post) while no differences were found in the HS groups and time trials ($p<0.05$). Differences in grip strength were found between the MS group, statistical significance. In addition, in the HS groups, there were significant differences in one-leg standing time with closed eyes (CO: 14.10±3.19 vs. Pre: 22.12±3.40 vs. Post: 39.75±6.78, respectively, $p<0.05$). In the flexibility measurement, back hyperextension was significantly increased in the HS group by the training, how-

Table 3. Physical fitness measurements before (pre) and after (post) the 8-week balance-training program

Variable		CO	Pre	Post
TV	HS	4674.00±180.42	4242.50±223.33	4367.50±201.89
(mL)	MS	3460.00±271.30	3601.11±200.24	3842.78±229.43
Sit-up	HS	27.6±1.08	23.5±0.77	25.00±1.09
(number/30s)	MS	26.0±0.50	28.11±0.94	27.55±1.55
Push-up	HS	30.4±3.41	39.62±2.39	38.25±2.92
(number/30s)	MS	17.00±3.55	36.55±2.68#	36.89±2.26#
Grip strength	HS	51.26±2.47	54.79±2.55	54.81±2.31
(kg)	MS	39.82±4.41	38.81±3.08	40.35±2.75
Vertical jump	HS	52.30±2.42	53.50±2.88	51.87±2.83
(cm)	MS	41.60±2.46	48.55±2.31	49.33±2.47
Side-step	HS	36.1±1.39	30.37±2.56	35.12±1.18
(number/30s)	MS	35.00±1.25	34.22±1.47	31.89±1.23
Reaction time	HS	0.209±0.01	0.213±0.01	0.244±0.01
(s)	MS	0.233±0.02	0.251±0.01	0.217±0.01
One leg standing time	HS	14.10±3.19*	22.12±3.40*	39.75±6.78
with eyes closed (s)	MS	22.20±5.11	38.44±7.63	48.00±10.93
Sit and reach	HS	20.37±1.61	14.57±1.63	15.88±1.74
(cm)	MS	19.44±2.92	16.55±1.12	18.82±1.31
Back hyperextension	HS	60.36±1.16	58.81±2.76*	66.90±2.33
(cm)	MS	58.54±1.82	58.38±2.16	64.02±1.51

mean±SE, CO, control group; Pre, pre-training; Post, post-training
HS; high school athlete, MS; middle school athlete, TV; tidal volume
*, between group significant difference: $p<0.05$
#, significant pre and post difference: $p<0.05$

ever no improvements were found in the sit and reach test in any group (Table 3).

The effects of the 8-week training program on the wrist, arm rotation, knee isokinetic extension, and flexion tests are presented in Tables 4 and 5. After training, in the HS exercise group, there was a significant difference in post left-arm external rotation torque from the control group and the pre HS values. In the MS group, after 8 weeks of training, the left-arm, external rotation torque of %BWPT significantly increased ($p<0.05$).

Table 5 shows changes of internal and external rotation. After training, only the HS group showed a significantly positive change in arm internal rotation %BWPT (left–right value); no significantly positive changes were found in the MS group ($p<0.05$, respectively). Interestingly, a significantly negative change was found in arm external rotation of the HS group ($p<0.05$) (Table 5). Inter and intragroup knee extension, flexion of %BWPT remained unchanged, while knee flexion of %BWPT (left − right) of Post HS was significantly different from that of CO of Post HS ($p<0.05$) (Table 5). Knee extension %BWPT (left − right) of Post HS also showed a significant change from the Pre HS value.

DISCUSSION

Elite weightlifters should possess equal strength in both arms, because imbalance of muscular strength may hamper their performance, and it may further lead to serious injuries. In the present study, we found severe imbalances in bilateral muscle strengths of MS and HS students. This study showed that a newly designed 8-week balance-training program beneficially affected elite weightlifters in terms of balanced strength gain. These changes were more significant among the highly-unbalanced HS elite lifters than among the MS group.

The human body is kept in balance through complicated processes including visual, vestibular, and proprioceptive information[11]. Muscle strength is essential for posture and stability[15]. Muscle forces coupled with kinematic adjustments, especially around the knee and the ankle joints, are used to maintain stability and prevent falling[12]. Furthermore, there is some evidence that reduced lower extremity strength is associated with poor balance and a greater risk of unexpected falls[13, 14], though this is not always the case[15, 16].

Exercise training may improve balance ability[17, 18]. However, few studies have been conducted which have investigated the effects of simple balance training in this field. One study showed significant correlations between hockey skating exercise and static balance tests,[19] which is in agreement with the findings of present study of increased one-leg standing time with closed eyes. Another study reported an increase in vertical jump height following 5 weeks of balance training[20]. However, the present study did not show any significant leg power improvement. In the present study, relatively lower loads were utilized throughout whole exercise program, and the majority of exercises were based on using subjects' body weight and gym balls.

Table 4. Change of arm internal and external rotation and knee extension and flexion

Variable		Left		Right	
		HS	MS	HS	MS
ER (%BW)	CO	49.10±4.07	42.66±3.67	61.00±2.29	43.00±1.53
	Pre	48.37±4.21	37.25±10.43	59.12±6.45	44.00±9.37
	Post	74.62*±5.70	56.12#±3.90	73.50±5.01	59.12±6.04
IR (%BW)	CO	73.40±2.54	58.67±4.77	76.40±2.95	63.67±3.83
	Pre	76.25±4.93	58.00±5.52	74.62±5.11	59.50±6.36
	Post	86.12±4.35	62.35±4.82	80.50±5.74	66.00±5.82
KE (%BW)	CO	240.00±24.59	221.17±27.30	214.9±20.82	221.00±31.55
	Pre	291.12±23.19	305.12±12.70	316.38±18.83	269.50±13.16
	Post	294.00±17.17	216.88±18.97	290.88±15.97	217.38±18.97
KF (%BW)	CO	146.80±13.92	127.00±16.66	140.30±12.32	126.5±16.55
	Pre	167.00±9.35	165.88±11.97	167.75±7.28	166.25±6.68
	Post	173.00±2.95	140.75±10.72	173.75±4.38	146.75±6.96

Mean±SE; *: significantly different from Pre HS; #, significantly different form Pre MS
external rotation (ER); internal rotation (IR); knee extension (KE); knee flexion (KF)
CO, control group; Pre, pre-training; Post, post-training
HS; high school athlete, MS; middle school athlete

Table 5. Changes of internal and external rotation and keen extension and flexion %BW(the values expressed as left − right)

			CO	Pre	Post
ER (%BW)	L-R	HS	3.00±0.75	−1.63±0.84	−5.625*±1.33
		MS	5.00±1.15	1.50±0.68	3.625±1.16
IR (%BW)	L-R	HS	11.90±2.89	10.75±2.66	−1.12*,#±0.49
		MS	0.33±0.88	6.75±1.67	3.00±0.67
KE (%BW)	L-R	HS	−25.10±4.96	25.25±5.86	−3.13#±1.48
		MS	−0.16±0.77	−35.63±7.89	0.50±1.69
KF (%BW)	L-R	HS	−6.50±4.56	0.75±5.36	0.75*±2.12
		MS	−0.50±5.47	0.37±1.48	6.00±4.77

Mean±SE; *: significantly different form CO; #, significantly different from Pre
CO, control group; Pre, pre-training; Post, post-training
HS; high school athlete, MS; middle school athlete

Thus, we recommend dynamic balance training for further performance enhancement. On the other hand, some studies have found instability-induced decreases (60–70%) in force[21, 22], and other studies reported more modest decrements (6–10%) in force and power[11] or no decrement in force with a dynamic barbell chest press[23]. In addition, a small decrement in muscular force and power may not compromise the training effect. Perhaps the extent of instability is a mitigating factor in the depression of force[24]. Also, an unstable base such as a Swiss ball may permit strength training adaptation if the instability is moderate, allowing the generation of overload forces[22].

There is another reason why this study focused more on muscular balance rather than strength and/or power development. Greater instability seems to challenge the neuromuscular system to a greater extent than stable conditions, possibly enhancing strength gains, which are attributed to neural adaptations. Hence, instability resistance training programs may improve athletic performance, while reducing the incidence of injuries. However, the studies cited above did not focus on instability training.

Balance is generally defined as the ability to maintain the body's center of gravity within its base of support and can be categorized as either static or dynamic balance. Static balance is the ability to sustain the body in static equilibrium or within its base of support[1, 2]. Dynamic balance is believed to be more challenging because it requires the ability to maintain equilibrium during a transition from a dynamic to a static state[25]. The results of the present study demonstrate that upper body back hyperextension, a flexibility factor, significantly increased after the 8-week balance-training program. This supports the suggestion that balance training for stability maintenance linearly increases antagonist activity.

Muscle strength is important for posture, stability, and balance[26, 27]. Previous studies have shown that individuals with stronger knee and ankle muscles have superior balance ability[28, 29]. In addition, reduced strength has been linked with poor balance and a higher risk of falls[13, 14]. The present study showed the training program tend to balance the strength of the subjects without any strength compromise, especially the HS group. As mentioned in the introduction, weightlifters must possess strength since it is directly related to their athletic performance. However, at the end of explosive movement, only absolute muscular balance maintains the weight. Muscular balance without strength loss may be the best strategy for a training program. Weightlifting features a jerk action and left and right balance of strength is easy to change. The longer athletic career comes to the fore. Present study, high school athletic career, such as a higher middle school athletes is higher than the difference of the left and right balance. The balance exercise results show that imbalance in the strength of the right and left sides can be reduced.

Isokinetic testing is used by many clinicians to assess muscular function such as, power and peak torque. It is generally used to monitor the progress of rehabilitation from injuries to the rotator cuff muscles, knees and wrists[30]. In the present study, arm internal and external rotation of %BWPT significantly increased only in the HS group. This suggests that muscle strength increment affects the force ability core. Left-right muscular imbalance in the HS group was significantly reduced after 8 weeks of balance training. It is difficult to believe the results of this study would extrapolate to the general population. However, the difference between the balance of strength training for a long period of time expressed through movement was improved, also the public can expect the effect to be considered. Adult when it is advantageous to considered from young players to continue to exercise to keep the left and right balance.

Equalized strength gain is critical for the improvement of the athletic performance of elite weightlifters. However, weightlifters and their coaches tend to focus training only on general strength gain. The results of this study suggest that the 8-week balance training program adjusts and maintains unbalanced strength, which may enhance performance.

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