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Comparison of the increase of both muscle strength and hypertrophy of *biceps brachii* muscle in strengthening exercise with low-intensity resistance training with and without the application of blood flow restriction and high-intensity resistance training

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ABSTRACT

Background: Strengthening exercise is an important component of rehabilitation programs. Recently, it is reported that strengthening exercise with low-intensity resistance training (20-30% of 1 Repetition Maximum) combined with the application of blood flow restriction potentially increases muscle strength and induces muscle hypertrophy as well.

Objective: This study aims to compare the increase in muscle strength and hypertrophy among the muscles trained with high-intensity resistance training (HIRT), low-intensity resistance training combined with the application of blood flow restriction using a sphygmomanometer cuff (LIRT+BFR) and low-intensity resistance training (LIRT) alone.

Method: The subjects (n=18) are randomly and equally divided into three groups, those are the groups getting the strengthening exercise for left *Biceps Brachii* muscle with HIRT (70% of 1 RM), LIRT (30% of 1 RM)+BFR and LIRT (30% of 1 RM). Before starting and after getting the resistance training for five weeks, each subject is measured for the left arm circumference.

Results: HIRT and LIRT+BFR produce an increase of the left arm circumference significantly greater than LIRT. However, there is no significant difference in the increase of left arm circumference between the HIRT and LIRT+BFR. There is a significant difference in the increase of the peak torque of left flexion elbow joint among the three groups, either at 60°/s or 120°/s or 180°/s angular velocity. At 60°/s angular velocity, LIRT+BFR produces the greatest increasing of the left elbow peak torque among the three groups. At both 120°/s and 180°/s angular velocity, there is no significant difference in the increase of the peak torque of flexion left elbow joint between HIRT and either LIRT+BFR or LIRT. However, at both 120°/s and 180°/s angular velocity, there is a significant difference in the increase of the peak torque of flexion left elbow joint between LIRT+BFR and LIRT.

Conclusion: the strengthening exercise for *Biceps Brachii* muscle with LIRT+BFR induces the *Biceps Brachii* muscle hypertrophy and increases the muscle strength more than strengthening exercise with LIRT alone. Compared to the HIRT, LIRT+BFR induces an equal muscle hypertrophy and increases more muscle strength for the trained *Biceps Brachii* muscle.

Keywords: *Low-intensity resistance training, blood flow restriction, hypertrophy, peak torque*

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INTRODUCTION

Strengthening exercise is an important component of rehabilitation programs.[1,2,3] American College of Sports Medicine (ACSM) recommends that to gain the increase in muscle strength and muscle mass, strengthening exercise with high-intensity resistance training (≥ 70% of 1 Repetition Maximum) must be performed.[4]

Recently, it is reported that strengthening exercise with low-intensity resistance training (20-30% of 1 Repetition Maximum) combined with the application of blood flow restriction potentially increases muscle strength and induces muscle hypertrophy as well.[5] It can be very useful of course as an alternative strengthening exercise method for those who are not able to tolerate the high-intensity resistance training. Almost all of the studies about low-intensity resistance training combined with the application of blood flow restriction used *KAATSU master* pneumatic cuff with 3 cm wide for upper extremities and 5 cm wide for lower extremities.[7] However, the cuff with that size is difficult to get in Indonesia.

Sphygmomanometer cuff for an adult (13 cm wide) is the kind of cuff that is easy to get in Indonesia. This study aims to compare the increase in muscle strength and hypertrophy among the muscles trained with high-intensity resistance training, low-intensity resistance training combined with the application of blood flow restriction using a sphygmomanometer cuff and low-intensity resistance training alone.

METHODS

Participants

The subjects of this study are 18 healthy, 26 – 45-year-old men, in Physical Medicine and Rehabilitation Department of Dr. Soetomo General Hospital, Surabaya who satisfy the inclusion criteria and not including in exclusion criteria. The inclusion criteria are normal body mass index (18,5 – 24,9 kg/m^2), systolic blood pressure 110-130 mmHg, diastolic blood pressure 70-80 mmHg and willing to voluntarily participate as a subject by signing informed consent and medical procedure agreement after getting a clear information. The exclusion criteria are doing or having done a strengthening exercise program routinely within at least the past eight months, ischemic heart disease, having a history or being found or having a risk of deep vein thrombosis and peripheral artery disease. This study was approved by the ethics committee for research in basic/clinical science in Dr. Soetomo General Hospital, Surabaya with the ethical clearance number *477/Panke.KKE/VI/2016*.

Figure 1 The pictures of the subjects during exercise

Figure 2 The measurement of the peak torque left elbow joint with Cybex isokinetic exercise machine

Exercise Protocol

The subjects are given a strengthening exercise program for five weeks for left *Biceps Brachii* muscle and randomly divided into three different intervention groups; those groups are the group with high-intensity resistance training, the group with low-intensity resistance training combined with the application of blood flow restriction and the group with low-intensity resistance training alone.

Before starting the exercise, each subject is determined his one repetitive maximum (1 RM). The determination of 1RM has performed automatically by using *EN-TreeM Measurement pulley machine.*

High-intensity resistance training (HIRT) of *Biceps Brachii* muscle is an isotonic strengthening exercise of left *Biceps Brachii* muscle using *EN-Tree pulley machine.* For biceps curl movement (a movement of the elbow joint from 0° extension to 135° flexion and then back to 0° extension) with 70% of 1RM load intensity. Three sets (12 repetitions in each set) with 2 minutes of the rest period between each sets, twice a week for at least one day off in between, for five weeks.

Low-intensity resistance training combined with the application of blood flow restriction (LIRT+BFR) of *Biceps Brachii* muscle is an isotonic strengthening exercise of left *Biceps Brachii* muscle using *EN-Tree pulley machine.*

For biceps curl movement (a movement of the elbow joint from 0° extension to 135° flexion and then back to 0° extension) with 30% of 1RM load intensity. Four sets (30 repetitions in the first set and 15 repetitions in each second until the fourth set) with 30 seconds of the rest period between each sets, twice a week with at least one day off in between, for five weeks.

During the exercise, adult sphygmomanometer cuff is applied to the proximal portion (2 fingers wide below the axilla) of the exercised limb and inflated to achieve 50 mmHg pressure. The pressure is maintained all the time during the exercise by locking up the sphygmomanometer screw, including during rest period between each set. Low-intensity resistance training (LIRT) of *Biceps Brachii* muscle is an isotonic strengthening exercise of left *Biceps Brachii* muscle using *EN-Tree pulley machine* for biceps curl movement (a movement of elbow joint from 0° extension to 135° flexion and then back to 0° extension) with 30% of 1RM load intensity. Four sets (30 repetitions in the first set and 15 repetitions in each second until the fourth set) with 30 seconds of the rest period between each sets, twice a week with at least one day off in between, for five weeks.

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Evaluation

Before starting the strengthening exercise program and after getting the strengthening exercise program for five weeks, each subject is measured for the left arm circumference, and the peak torque of flexion left elbow joint to find any increase in hypertrophy and muscle strength of the left *Biceps Brachii* muscle after the 5-week training. The measurement of the left arm circumference is performed using a measuring tape at area 12 cm above the fossa cubitus during the subject in standing position with the upper extremities are in the anatomical position, and the *Biceps Brachii* muscle is in a relax condition. The measurement of the peak torque of flexion left elbow joint is performed using a Cybex isokinetic exercise machine.

Table 1 **Characteristics of subjects**

Characteristics	High Intensity (n=6)	Low Intensity + Blood Flow Restriction	Low Intensity (n=6)	P value
Age (years)	33,3 ± 3,14	33 ± 3,1	31 ± 2,2	0,334
BMI (kg/m²)	22,57 ± 1,48	23,25 ± 0.80	21,9 (18,6 - 22,50)	0,090
Left ABI score	1,11 ± 0,58	1,13 ± 0,6	1,11 ± 0,62	0,801
Systolic blood pressure (mmHg)	120 (120 - 125)	120 (120 - 125)	120 (110 - 120)	0,284
Diastolic blood pressure (mmHg)	80 (70 - 80)	80 (75 - 80)	75 (70 - 80)	0,268

Note:
- The number is mean ± standard deviation (SD) for normally distributed data
- The number is median (minimum – maximum) for non-normally distributed data

Table 2 **The increase in the left arm circumference after the 5-week strengthening exercise program**

	Before exercise (cm)	After 5-week exercise (cm)	Increase (cm)	p value
High intensity	28,05 ± 1,1	29,63 ± 1,04	1,58 ± 0,34	< 0,0001*
Low intensity + blood flow restriction	27,17 ± 0,98	28,65 ± 1,21	1,48 ± 0,26	< 0,0001*
Low intensity	26,08 ± 1,56	26,40 ± 1,65	0,32 ± 0,65	0,026*

Note:
The number is mean ± standard deviation (SD)
* significant p value (p<0,05)

Table 3 **The increase of left arm circumference after the 5-week strengthening exercise program among the groups**

	High intensity (cm)	Low intensity + blood flow restriction	Low intensity (cm)	p value
Increasing Left arm circumference after exercise (cm)	1,58 ± 0,34 [a]	1,48 ± 0,26 [a]	0,32 ± 0,65 [b]	< 0,0001*

Note: different letter *superscript* shows significant difference (p<0.05)

Statistical Analysis

Statistical Analysis is performed with SPSS program for the statistic. *The one-sample Kolmogorov-Smirnov* test is used to determine the homogeneity of the data in each group. *Paired t – test* is used to compare both the diameter of the left arm and the peak torque of left elbow joint before starting the exercise program and after the 5-week exercise program in each group. *ANOVA test* is used to compare the difference of both the diameter of the left arm and the peak torque of left elbow joint after the 5-week exercise program among the three groups. The significance level is set at $p \leq 0.05$.

RESULTS

Descriptive Findings

The physical characteristics of subjects are shown in Table 1. There are no significant differences among the three groups about age, Body Mass Index, left Ankle Brachial Index, systolic blood pressure, and diastolic blood pressure.

The increase in the left arm circumference after the strengthening exercise program for five weeks can be seen in Table 2. We found significant increasing of the left arm circumference after the strengthening exercise program for five weeks in all intervention groups.

Table 3. shows that after the strengthening exercise program for five weeks, the groups with HIRT and LIRT+BFR produce the increase of left arm circumference significantly greater than that of the group with LIRT alone. However, there is no significant difference in the increase of left arm circumference between the group with HIRT and LIRT+BFR.

The difference in the circumference between left and right arm after the left arm has been given the strengthening exercise program for five weeks was present in Table 4. A significant difference between left and right arm after the left arm has been given the strengthening exercise program for five weeks was only found in the groups with HIRT and LIRT+BFR.

Table 5. shows the increase of the peak torque of left flexion elbow joint at 60°/s angular velocity after the strengthening exercise program for five weeks. The significant increase is only found in the groups with HIRT and LIRT+BFR.

The increase of the peak torque of flexion left elbow joint at 120°/s angular velocity after the strengthening exercise program for five weeks shown in Table 6. The significant increase is only found in the group with LIRT+BFR, while Table 7. shows the increase of the peak torque of flexion left elbow joint at 180°/s angular velocity after the

Table 4 The difference of circumference between left and right arm after 5-week strengthening exercise program

	Right arm (cm)	Left arm (cm)	Difference (cm)	p value
High intensity	28,38 ± 1,11	29,63 ± 1,04	1,25 ± 0,27	< 0,0001*
Low intensity + blood flow restriction	27,28 ± 0,95	28,65 ± 1,21	1,37 ± 0,29	< 0,0001*
Low intensity	26,37 ± 1,70	26,40 ± 1,65	0,03 ± 0,08	0,363

Note: The number is mean ± standard deviation (SD); * Significant p-value (p<0.05)

Table 5 The increase in the peak torque of flexion left elbow joint at 60º/s angular velocity after the 5-week strengthening exercise program

	Before exercise (FtLbs)	After 5-weeks exercise (FtLbs)	Increase (FtLbs)	p value
High intensity	20.17 ± 5.95	25.67 ± 7.06	5.5 ± 2.59	< 0.003
Low intensity + blood flow restriction	17.50 ± 6.25	25.83 ± 5.23	8.33 ± 2.07	< 0.0001*
Low intensity	16.67 ± 2.58	17.33 ± 2.58	0.67 ± 1.75	0.394

Table 6 The increase in the peak torque of flexion left elbow joint at 120º/s angular velocity after exercise program

	Before exercise (FtLbs)	After 5-week exercise (FtLbs)	Increase (FtLbs)	p value
High intensity	13,33 ± 6,56	17,67 ± 5,72	4,33 ± 4,55	0,067
Low intensity + blood flow restriction	9,67 ± 5,01	17,83 ± 2,99	8,17 ± 3,66	0,003*
Low intensity	10,33 ± 1,86	10,83 ± 2,56	0,50 ± 2,07	0,580

Note: * Significant p-value (p<0.05)

Table 7 The increase in the peak torque of flexion left elbow joint at 180º/s angular velocity after exercise program

	Before exercise (FtLbs)	After 5-week exercise (FtLbs)	Increase (FtLbs)	p value
High intensity	9,67 ± 6,28	13,00 ± 5,06	3,33 ± 3,72	0,080
Low intensity + blood flow restriction	7,83 ± 2,93	13,33 ± 2,16	5,50 ± 2,17	0,002*
Low intensity	7,83 ± 1,94	8,50 ± 1,05	0,67 ± 1,63	0,363

Note: The number is mean ± standard deviation (SD); * significant p-value (p<0.05)

Table 8 Comparison of the increase of peak torque of flexion left elbow joint after the 5-week exercise program among intervention groups

Angular velocity	High intensity (FtLbs)	Low intensity + blood flow restriction (FtLbs)	Low intensity (FtLbs)	p-value
60°/sec	5,50 ± 2,59 ^{a}	8,33 ± 2,07 ^{b}	0,67 ± 1,75 ^{c}	< 0,0001*
120°/sec	4,33 ± 4,55 ^{ab}	8,17 ± 3,66 ^{a}	0,50 ± 2,07 ^{b}	0,008*
180°/sec	3,33 ± 3,72 ^{ab}	5,50 ± 2,17 ^{a}	0,67 ± 1,63 ^{b}	0,022*

Note: different letter superscript shows significant difference (p<0.05)

strengthening exercise program for five weeks. The significant increase is only found in the group with LIRT+BFR.

Table 8 shows that after the strengthening exercise program for five weeks, there is a significant difference in the increase of the peak torque of left flexion elbow joint among the three groups, either at 60º/s or 120º/s or 180º/s angular velocity. At 60º/s angular velocity, LIRT+BFR produces the greatest increase in the peak torque of flexion left elbow joint among the three groups. At both 120º/s and 180º/s angular velocity, there is no significant difference in the increase of the peak torque of flexion left elbow joint between HIRT and either LIRT+BFR or LIRT. However, at both 120º/s and 180º/s angular velocity, there is a significant difference in the increase of the peak torque of flexion left elbow joint between LIRT+BFR and LIRT.

DISCUSSION

The study was carried out among 18 healthy men who aged 26 – 45 years old, in Physical Medicine and Rehabilitation Department of Dr. Soetomo General Hospital, Surabaya. Homogenization was done for the gender of subjects (only men) to minimize bias effect of individual factors. Men have muscle hypertrophy response twice faster than women. Women have myostatin *Lys 153 arg polymorphism,* which functions as inhibitor of muscle growth.[8]

The result of this study showed there were no significant differences among the three groups with regard to age, Body Mass Index, left Ankle Brachial Index, systolic blood pressure, and diastolic blood pressure. Age was inversely correlated with muscle strength due decreasing the number of muscle fibers type 2 (fast twitch fibers) in elderly.[9]

Body Mass Index can be used to determine the grade of obesity. Obesity is often related to a sedentary lifestyle which makes the muscle weak and prone to induced muscle damage.[10] Left Ankle Brachial Index (ABI) score can be used to exclude the peripheral artery disease in left extremities which were going to be trained in this study. Peripheral artery disease (PAD) reduces blood supply into the muscle; this will affect its condition during exercise. The systolic and diastolic blood pressure affects the severity of the vessels occlusion during the strengthening exercise with blood flow restriction.

All subjects were treated by strengthening exercise program for 5 weeks because the gain of muscle strength during the first few weeks (< 4 weeks) of training is caused by neural adaptation, which increases the motor unit recruitment. Muscle hypertrophy was an important factor to increase the muscle strength, which usually occurs after the fourth week of training.[11,12]

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In this study, we found increasing left arm circumference after 5 weeks strengthening exercise program in all groups (HIRT, LIRT+BFR, and LIRT). However, further evaluation of muscle circumference between the left arm (trained side) and right arm (untrained side) after 5 weeks reveals that the difference between the left arm (trained side) and the right arm (untrained side) was only found in HIRT and LIRT+BFR groups. This finding suggests the increasing left arm circumference after the 5-week strengthening exercise program in both HIRT and LIRT+BFR groups was due to hypertrophy effect.

In LIRT group, the increasing left arm circumference after 5-week strengthening exercise program was not followed by the significant difference between the left arm (trained side) and the right arm (untrained side) circumference. It suggests that the increase of the left arm circumference after the 5-week strengthening exercise program in LIRT group may be not caused by the hypertrophy effect, but it caused by increasing body weight since the increase of right arm circumference also occurs (untrained side).

In this study, increasing left arm circumference after 5-week resistance training with intensity 70% of 1 RM in HIRT group is matched with the *American College of Sport Medicine* (ACSM) recommendation "the use of intensity at least 70% of 1 RM during strengthening exercise to gain the increase in muscle strength and muscle mass".[4] The finding of the increase of left arm circumference after 5-week training in LIRT+BFR group in this study is also relevant to the result of the study by Yasuda *et al.* suggesting that low-intensity resistance exercise with load 20-30% of 1 RM combined with blood flow restriction may induce muscle hypertrophy.[5]

This study suggests after 5-week strengthening exercise program, the groups with HIRT and LIRT+BFR produce the increase of left arm circumference greater than the group with LIRT alone. However, there is no difference in the increase of left arm circumference between the group with HIRT and LIRT+BFR. This finding shows that LIRT+BFR may induce an equal muscle hypertrophy as HIRT does. In HIRT, the muscle hypertrophy is gained due to the mechanical stress induced by high load intensity during the training. The mechanical stress activates Protein Kinase B (PKB)/Akt and ERK (Extracellular Signal-Regulated Protein Kinase). Protein Kinase B (PKB)/Akt increases protein synthesis in muscle through the activation of mTOR (Mammalian Target of Rapamycin) pathway and the blockage of the muscle protein degradation by inactivating FOXO (Forkhead Box) transcription factor. Extracellular Signal-Regulated Protein Kinase (ERK) is responsible for blocking Tuberous Sclerosis Complex (TSC2). If TSC2 is not blocked, it can block mTOR pathway.[9]

In LIRT + BFR, muscle hypertrophy is mainly caused by the metabolic accumulation due to blood flow restriction during the training. The metabolic accumulation may cause the increase of lactate leading to decrease of pH intramuscular. The low pH stimulates sympathetic nerve activity through a chemoreceptive reflex mediated by intramuscular receptors and the afferent fibers group III and IV. Consequently, the same pathway has recently been shown to play a role in the regulation of hypophyseal secretion of growth hormone.[3] Growth hormone is known to increase the production of the muscle-specific insulin like growth factor-1 (IGF-1), which has been shown to have potent anabolic effects by activating satellite cells and stimulating pathways for protein synthesis, resulting in myofibril hypertrophy.[11]

Low-intensity resistance training combined with blood flow restriction may also increase phosphorylation of ribosomal S6 kinase1 (S6K1) by enhancing mTOR (Mammalian Target of Rapamycin) pathway to stimulate protein synthesis resulting in muscle hypertrophy.[3,12] Other mechanisms which play a role in muscle hypertrophy in LIRT + BFR group are the shifting of fluid from plasma to muscle leading to muscle swelling. Muscle swelling due to osmotic fluid shifting into the muscle cells triggers anabolic processes through both an increase in protein synthesis and a decrease in proteolysis.[5]

The measurement of the peak torque of left flexion elbow joint in this study is done at 60°/s, 120°/s and 180°/s angular velocity. The muscle contraction at 60°/s angular velocity is mainly found during daily activities. The muscle contraction at higher angular velocity (120°/s and 180°/s) is important especially for doing sports activities, such as discus throw, javelin, baseball, etc.

In this study, after the 5-week strengthening exercise program, the HIRT group shows an increase in the peak torque of flexion left elbow joint only at 60°/s angular velocity but not at 120°/s and 180°/s angular velocity. In group trained with HIRT, motor units are recruited from the smallest to the largest. Small motor units innervate slow twitch fibers involving in muscle endurance, and larger motor units innervate fast twitch fibers involving in muscle strength.[2]

At 60°/s angular velocity, the muscle still has enough time to do the motor units recruitment from the smallest to the largest. Thus, there are a lot of large motor units recruited. The number the large motor units are recruited, the greater force can be exerted so there is an increase in the peak torque of flexion left elbow joint only at 60°/s angular velocity. However, at 120°/s and 180°/s angular velocity, the muscle does not have enough time to do the motor units recruitment. Thus, there are only a few large motor units recruited. The less the large motor units are recruited, the less force can be exerted, so there is no increase in the peak torque of flexion left elbow joint at 120°/s and 180°/s angular velocity.

In LIRT + BFR group, there is found an increase in the peak torque of left flexion elbow joint at 60°/s, 120°/s and 180°/s angular velocity. These findings may be explained, during LIRT + BFR, the motor units type 1 that innervate slow twitch fibers and normally are recruited during muscle contraction with low load intensity will get fatigue early so that the motor units type 2 that innervate fast twitch fibers and normally are recruited during muscle contraction with higher load intensity will be recruited early.[3] Consequently, there will be the faster recruitment of motor units type 2 in group trained with LIRT + BFR. The faster recruitment of motor unit type 2 makes the muscle still have enough time to do a lot of large motor units recruitment not only at 60°/s angular velocity but also at 120°/s and 180°/s angular velocity. The number the large motor units are recruited, the greater force can be exerted so there is an increase in the peak torque of left flexion elbow joint at 60°/s, 120°/s and 180°/s angular velocity. The study of Moritani *et al*. also found the increase of muscle fibers type 2 (fast twitch muscle fibers) during hand grasping after an isometric strengthening exercise program for hand grasping using hand dynamometer with low intensity (20% of maximal voluntary contraction) applied with blood flow restriction.[12]

After the 5-week strengthening exercise program, the LIRT group shows no increase in the peak torque of left flexion elbow joint at 60°/s, 120°/s and 180°/s angular velocity. This can be explained because the LIRT is not enough to induce either neural adaptation or muscle hypertrophy.[4] Absence of neural adaptation after the LIRT causes minimal motor units recruited during muscle contraction, so there is no increasing of peak torque of left elbow joint flexion at all angle of the angular velocity.

The comparison of the increase in the peak torque of flexion left elbow joint at each 60°/s, 120°/s, and 180°/s angular velocity after the 5-week. Strengthening exercise program among the three intervention groups shows that at all of the angular velocity, the LIRT+BFR group has the greatest increase in the peak torque of left elbow flexion. These findings may be related to the faster recruitment of motor units type 2 in group trained with LIRT + BFR that makes the muscle have enough time to do a lot of large motor units recruitment that innervates fast twitch fibers involving in muscle strength.[2,3]

Further studies are needed to investigate the effectively of low-intensity resistance training combined with blood flow restriction used in this study for subjects from other populations. Also, it is also important to detect any side effects, such as muscle damage and vascular damage after the treatment of low-intensity resistance training combined with blood flow restriction.

CONCLUSION

This study shows that the strengthening exercise for *Biceps Brachii* muscle with the low-intensity resistance training combined with blood flow restriction induces more *Biceps Brachii* muscle hypertrophy and more increases in muscle strength than strengthening exercise with the low-intensity resistance training alone. Compared to the high-intensity resistance training, the low-intensity resistance training combined with blood flow restriction induces an equal muscle hypertrophy and increases more muscle strength for the trained *Biceps Brachii* muscle.

REFERENCES

1. Hoffman MD, Kraemer WJ and Judelson DA. Therapeutic Exercise. In: DeLisa's Physical Medicine and Rehabilitation Principle and Practice 5th edn. Philadelphia: Lippincott Williams & Wilkins. 2010; pp. 1619-1672.
2. Manimmanakorn A, Hamlin MJ, Ross JJ, Taylor R and Manimmanakorn N. Effects of Low – Load Resistance Training Combined with Blood Flow Restriction or Hypoxia on Muscle Function and Performance in Netball Athletes. Journal of Science and Medicine in Sport. 2013; 16: 337-342.
3. Yasuda T, Ogasawara R, Sakamaki M, Ozaki H, Sato Y and Abe T. Combined Effects of Low – Intensity Blood Flow Restriction Training and High – Intensity Resistance Training on Muscle Strength and Size. Eur J Appl Physiol. 2011; 111: 2525-2533.
4. Evetovich T and Ebersole K. Adaptations to Resistance Training. In: ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription 5th edn. Philadelphia: Lippincott Williams & Wilkins. 2006; pp. 325-335.
5. Yasuda T, Fukumura K, Iida H and Nakjima T. Effect of Low-Load Resistance Exercise with and without Blood Flow Restriction to Volitional Fatigue on Muscle Swelling. Eur J Appl Physiol. 2015; 15(5): 919-926.
6. Loenneke JP and Pujol TJ. The Use of Occlusion Training to Produce Muscle Hypertrophy. Strength and Conditioning Journal. 2009; 31(3): 77-84.
7. Fahs CA, Loenneke JP, Rossow LM, Thiebaud RS and Bemben MG. Methodological Considerations for Blod Flow Restricted Resistance Exercise. Journal of Trainology. 2012; 1: 14-22.

8. Ivey FM, Roth SM, Ferrel RE, Tracy BL, Lemmer JT, Hurlbut DE, Martel GF, Siegel EL, Fozard JL, Metter EJ, Fleg JL and Hurley BF. Effects of Age, Gender and Myostatin Genotype on the Hypertrophic Response to Heavy Resistance Strength Training. Journal of Gerontology Medical Sciences. 2000; 55A(11): 641-648.
9. Lemmer JT, Hurlbut DE, Martel GF, Tracy BL, Ivey FM, Metter EJ, Fozard JL, Fleg JL and Hurley BF. Age and Gender Responses to Strength Training and Detraining. Medicine & Science in Sport & Exercise. 2000; 32(8): 1502-1512.
10. Pratanu S. Buku Pedoman Kursus Elektrokardiografi. Surabaya: Airlangga University Press. 2008; pp. 61-68.
11. Manini TM and Clark BC. Blood Flow Restricted Exercise and Skeletal Muscle Health. Exercise and Sport Sciences Reviews. 2009; 37(2): 78-85.
12. Moritani T, Michael SW, Shibata M, Matsumoto T and Shinohara M. Oxygen Avaibility and Motor Unit Activity in Humans. Eur J Appl Physiol Occup Physiol. 1992; 64:552-556.