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Effect of Training Program with Restricted Venous Blood Flow "KAATSU" Training" on Skeletal Muscle (Mass and Size), Strength, Prostaglandins (PGE2) and 400 M Sprinting Records.

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Abstract

Many studies have shown that intensity resistance training with restricted muscular venous blood flow (KAATSU) causes muscle hypertrophy and strength gain. There are very rare studies were performed on swimmers. Exercise leads to increased circulating prostaglandins, affecting cardio-vascular system, increasing blood flow to all muscles to provide oxygen needed for physical activities. Prostaglandin-E2 (PGE2) is the main prostaglandin for raised blood flow, exerts muscles building and provides oxygen needed for activities. Aim of this study is to investigate the effects of training combined with band restricted blood flow on skeletal muscle (mass and size), strength, Prostaglandins (PGE2) and 400 M sprint records. Material and methods Thirteen healthy athletes performed band blood restriction training with external weight at each hand and each leg, and other ten control healthy athletes performed training with external weight alone. Training was conducted once, 3 days/wk, for 10 wk at (65% - 85%) from the maximum intensity of pulse using polar watch. Plasma PG-E2 and physical parameters were recorded before and after effort before and after program, and compared to each others. Also, Muscle volume and sprinting times were assessed. Results revealed significant differences between control group and experimental group in post exercise plasma PG-E2, and muscle volume. There were significant variations in the sprinting times by (3.48%) after program for the KAATSU group but no difference in (BS). It is concluded that band restricted blood flow causes muscle hyperplasia and hypertrophy .

Key words*: Restricted venous blood flow training (kaatsu resistance training) - Prostaglandins (PGE2) - Strength-circumference- skeletal muscle mass (SMM) - (400) m sprinting.*

Introduction:

Low- high intensity resistance exercise training combined with blood flow restriction (REFR) increases muscle size and strength as much as conventional resistance exercise with high loads. However, the cellular mechanism (s) underlying the hypertrophy and strength gains induced by REFR are unknown.

Previous studies of contracting muscle with low loading and partial vascular occlusion demonstrated hypertrophy and strength adaptations similar to and exceeding those observed with traditional moderate to high resistance (Shinohara et al., 1998; Takarada et al., 2000 and Takarada et al., 2002 Abe et al., 2004),

The Occlusion training is a novel method for muscle training, originally developed by (Sato et al, 2005). He designated it as KAATSU training. Under the conditions of restricted muscle blood flow, even short-term, low-intensity exercise can induce muscle strength, and hypertrophy (Takarada et al, 2000b; Takarada et al., 2002; Takarada & Ishii, 2002; Yasuda et al., 2004; Abe et al., 2005a, b), breathing stability (AiliangXie et al., 2009). Aerobic exercise training induces skeletal muscle hypertrophy and age-dependent adaptations in myofiber function in young and older men (Matthew**,** et al., 2012). In addition, The Occlusion training increases the amount of circulating growth hormone (GH) (Takarada et al., 2000a; Takano et al., 2005a,b; Sato et al., 2005), which may enhance lipolysis and bone formation, resulting in a reduction of obesity and bone diseases as well as improving strength and inducing hypertrophy of muscle (Beekley et al., 2005). Aside from its effect on muscle size and strength, Kaatsu training also causes metabolic adaptation in skeletal muscle that is similar to the metabolic response of muscle to ischemia (Burgomaster et al., 2003), Increase muscles protein synthesis (Fujita, et al., 2007).

Although the many researchers studied KAATSU training**,** there is no research involved the effect of Prostaglandins in KAATSU. It is proved that levels of prostaglandin E2 (PGE2) and thromboxane B2 (TXB2) are increased in skeletal muscle and plasma under the effect of physical exercise (Todd et al., 2013).

Prostaglandin (PG-E2) is the regulator of constriction and/or dilation in vessels of smooth muscles, regulate inflammatory mediation observed with physical activities (29). It is also involved in several other organs such as the gastrointestinal tract, and increase blood flow which represented clearly at Prostaglandins (PGE2) in men as an indicator for blood flow **(**Ayman fekry 2006**).** Prostaglandin-induced inhibition of natural killer (NK) cell function **(** Brunda et al., 1980) (Tvede, 1993**),** leukotriene promotes constriction of bronchi associated with asthma, so it works in high efforts exercises (28**).** Finally it increases muscle protein synthesis in muscles (Campos et al., 2002).

Aim of this study is to investigate the effects of (3 days) training activity units combined with band restricted blood flow on skeletal muscle (mass & size), strength, Prostaglandins (PGE2) and 400 M sprint records. Results will be compared to that observed in control athletes for evaluating Prostaglandin PGE2 effects in KAATSU training program.

Material and Methods

Subjects:

Twenty three volunteers 400m sprint athletes were divided into two groups (experimental group and control group). Experimental group age (24.4±2.4 years), height (172.3 ± 3.9 cm), weight (68.8 ± 2.3 kg) and years of training (6.8±1.6 years) exercised for ten weeks on 400 M sprint training program with bands on the proximal part of both upper arms and the proximal part of both thighs with external weight (500gm) at each arm and (1000gm) at each leg. The control group age (24.1±1.9 years), height (173.7 ± 3.2 cm), weight (67.9 ± 1.9 kg) and years of training (6.4±1.8 years) performed the same program without bands with the same external weight. Both groups were tested by 400m sprint rec. test at rest and after effort before and after program.

Blood restriction design:

A blood pressure reading was taken from the arm after (15) min of semi-recumbent resting. Fifteen minutes before testing. The proximal ends of upper and lower limbs of both sides were moderately compressed to restrict the venous blood flow by means of elastic belts attached to the sleeves and the pants. The occlusive pressure was previously calibrated with respect to the stretch distance of the elastic belt and the circumferences of the upper or lower limbs. The elastic belt was affixed to the dominant arm, centered in the space between the superior aspect of the biceps brachia and the inferior aspect of the anterior deltoid muscles. The belt was inflated to a pressure of 120 mmHg below the acute systolic pressure determined 15 min prior. The same design was applied for the quadriceps femurs and biceps femurs muscles of the legs.

(Semi-recumbent = نصف نائم) (Quadriceps = العضلة الرباعية)

Training program

All players performed a (65% - 85%) from the maximum Intensity of pulse using polar watch, by sprinting distance between (50-600 M) - different repeat, with (5) rest intervals for (35min.).The (KAATSU) group was performing the training program with restricted venous blood flow for major muscle groups in the upper and lower limbs. The control group performed the same program without restricted venous blood. This process was repeated from (120) mmHg until a final occlusion pressure of (160) mmHg is reached. Both groups continued the traditional training unit to the end of the program. Both groups performed the same exercises the training program designed as (3 days/week) for (10) weeks for both groups (attach 1).

Measurements:

Anthropometric measurements (age, weight, height, training age, blood pressure and heart rate) were taken before the program. Physiological and talent measurements were assayed before and after the program, compared to each other and correlated.

Statistical analysis:

All data are reported as means ± standard deviation (SD). SPSS 17 was used to execute all statistical analyses. Paired sample T. test was used to compare means of KAATSU group to control group. All resulted data was correlated to training program with and without blood restriction. The level of significance was set at $p \leq 0.05$.

RESULTS:

Results are expressed as means and standard deviations (SD) for anthropometric variables postulated in table (1). There were no significant differences between the two groups.

(Table 1)
Comparison between the anthropometric parameters using paired sample t test between controls vs. experimental group

Parameter	Means exp vs.con		SD exp vs.con		t	p	significance
Age	24.4	24.1	1.3	0.831	0.356	0.729	NS
Weight	68.4	67.9	0.768	2.241	-0.212	0.837	NS
T age	6.8	6.4	0.698	1.874	0.163	0.874	NS
Height	172.3	173.7	0.364	0.878	-0.653	0.529	NS
SYS.P	108.3	109.27	1.145	2.231	-0.563	0.652	NS
DI.P	70.22	72.19	2.005	1.007	0.845	0.335	NS
HR	63.12	62.87	1.264	2.082	-0.437	0.593	NS

T age = Training age

Plasma PGE2 levels were compared in table 2. Results revealed significant higher levels after effort regardless of training due to increased blood flow during exercise for higher tissues demand for oxygen. Also, increased plasma PGE2 levels were significant in experimental group after effort compared to control group indicating training effect with higher capacity to exercise effort.

(Table 2)
Comparison between plasma PGE2 levels using paired sample t test in the two investigated groups

Parameter	t	p	significance
Rest vs. Effort before and after training program			
EXP before	-9.119	0.000	S
EXP after	-11.212	0.000	S
CON before	-10.311	0.000	S
CON after	-14.477	0.000	S
Experimental vs. control groups			
Rest before	-0.156	0.880	NS
Effort before	-0.975	0.353	NS
Rest after	1.964	0.078	NS
Effort after	10.588	0.000	S

EXP=Experimental group CON=Control group (P significant at ≤ 0.05)

All physical parameters got significant improvement due to training program as illustrated in table 3, indicating general muscle gain in both mass and power or strength.

(Table 3)
Comparison between physical parameters using paired sample t test in the two investigated groups

Experimental group (Before vs. after program)	t	p		significance
SMM (Skeletal muscles mass)	-9.842	0.000		S
RHG (Right hand grip)	-6.900	0.000		S
LHG (Left hand grip)	-6.035	0.000		S
BS (Back strength)	-3.373	0.006		S
LG (Leg girth)	-6.076	0.000		S
AC (Arm circumference)	-10.775	0.000		S
TC (Thigh circumference)	-9.220	0.000		S
LA (Leg ability)	-7.390	0.000		S
Control group (Before vs. after program)	t	p		significance
SMM	-0.847	0.417		NS
RHG	-2.113	0.061		NS
LHG	-0.990	0.346		NS
BS	-0.762	0.464		NS
LG	-2.466	0.033		S
AC	-2.958	0.014		S
TC	-3.537	0.005		S
LA	-2.695	0.023		S
Control vs. Experimental (Before program)	t	p		significance
SMM	-1.838	0.096		NS
RHG	-0.216	0.833		NS
LHG	-0.445	0.666		NS
BS	0.065	0.949		NS
LG	0.793	0.446		NS
AC	1.353	0.206		NS
TC	-1.560	0.150		NS
LA	-0.404	0.695		NS
Control vs. Experimental (After program)	t	p		significance
SMM	6.290	0.000		S
RHG	3.995	0.003		S
LHG	2.230	0.050		S
BS	0.482	0.640		NS
LG	4.573	0.001		S
AC	4.397	0.001		S
TC	3.262	0.009		S
LA	4.529	0.001		S

The numerical records for athletes in 400 M sprint was shorter in time either for experimental after training program compared to that obtained before program or in experimental compared to control after the program (table 4).

(Table 4)
Comparison between 400m sprint rec. using paired sample t test in the two investigated groups

400M Sprint rec.	means		t	p	significance	% of improvement
EXP Record before - EXP Record after	56.76	53.18	4.663	0.001	S	6.3%
CON Record before - CON Record after	55.96	55.02	1.074	0.308	NS	1.67%
EXP Record before - CON Record before	56.76	55.96	0.879	0.400	NS	1.4%
EXP Record after - CON Record after	53.10	55.02	-3.391	0.007	S	3.48%

Discussion:

There is no doubt that resistance training with restricted blood flow would amplify high-energy phosphate depletion and lactate production compared with training at the same load with normal flow. In this study we compared the effect of occlusion in 400 M sprint training on some physiological biomarkers and sprint performance including Skeletal muscle mass (SMM), Hand grip (HG), Back strength (BS), legs strength (LS), Ability (A), Arm Circumference (AC) and Thigh Circumference (TC) and 400 M sprint record levels in seconds compared to Prostaglandin (PGE2).

As designed, it is found same responses between control and experimental groups' trials, indicating the same metabolic stress produced by both trials. The study investigated the effect of KAATSU resistance training on (PGE2) as an indicator for blood flow to discover if restricting muscles may endanger humans or affects negatively blood vessels. 400 M sprint records were shorter in experimental group compared to control group after program which represent an effect of the band restriction that may increase the effort for sprinters and that was clearly presented at the significance between the two groups in the sprint time after the program which was for the experimental group.

The mechanism by which acute changes in high-energy phosphates or other linked metabolites might trigger the hypertrophic signaling cascade is unknown. However, there is evidence that metabolic sensors such as AMP-dependent protein kinase can play important regulatory roles in skeletal muscle (Dreyer, 2006). Training Strength (1RM) is considered the most influenced by cross-training and neural effects in general on body muscles, which is shown by the paramount increases already after (10) training sessions on muscles (L. Holm, et al., 2009).

Of course, there are other possible explanations for the hypertrophic response to exercise with flow restriction besides a hypothesized metabolic sensor. Exercises without vascular occlusion did not cause substantial albeit significant changes in muscles size, whereas exercises with vascular occlusion can be considered as the cause for the muscular hypertrophy observed (Reeves, et al., 2006). Thus it may be that the enhanced hypertrophic response to exercise with flow restriction simply results from enhanced mechanical load on the muscle fibers in large motor units. The inflammatory mediator PGE2 increased immediately after exercise. (Abigail et al., 2007) agreed with results of the present study where confirm that Prostaglandin considered as an indicator of increased blood flow and breathing stability in young athletes.

While this is the first study to demonstrate that Kaatsu resistance training induce improving in (400m) sprinting rec. other studies (1) (2) (10) (12) (14) (26) have consistently shown that Kaatsu resistance training induce increasing of human performance and physical fitness elements. The anaerobic capacity was seen to be more increased in the experimental group. Also, athletes were originally trained together with the same program design and their records were varied with just few seconds which affect the statistical results with a great variation in the sprint events (Abe, 2005). It can be explained as Hypoxia enhances vascular endothelial growth factor (VEGF) and fibroblast growth factor (FGF) secretion. These two factors are highly effective in vessels and myofibrils synthesis, leading to increased vasculature and muscle hypertrophy (Barry et al., 2004).

Conclusion:

Band restricted blood flow causes muscle hypertrophy with increased muscle strength. Increased muscle hypertrophy may be due to enhanced protein kinases stimulations, increased PGE2 secretions. Muscle strength may be developed due to increased high phosphate utilization through the hypoxic phase and enhanced mechanical load on the muscle fibers in large motor units.

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