Follistatin –like protein 1 (FSTL1) secretion during exercise

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Follistatin –like protein 1 (FSTL1) secretion during exercise

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<Table of contents>

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

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The benefits of aerobic training on cardio-metabolic health seem to be partly mediated by the cumulative effects of repeated, acute bouts of exercise-induced changes in several hormones and molecules such as the so-called myokines and adipokines, which are released from muscles and adipose tissue, respectively, to the blood and exert endocrine or paracrine effects in other cells, tissues or organs. Follistatin-like-1 (FSTL1) is a novel adipo-myokine that has been demonstrated in recent years to be associated with metabolism and insulin sensitivity. Also in heart, FSTL1 has been regarded as cardio-protective molecule upregulated in heart injuries including myocardial infarction, pressured overload-induced hypertrophy and ischemia/reperfusion injury. FSTL1 is also considered as an angiogenic factor, suggesting that FSTL1 might be an important factor in cardiovascular system. Recently, it has been reported that FSTL-1 facilitates adipocyte apoptosis, and in obese individuals, circulating FSTL-1 levels were found to be lower than those in nonobese individuals. Therefore, the primary objective of this study was to find out the factors that could affect the release of FSTL1 during exercise and finally investigate the cardio-protective effect of aerobic exercise through the aspect of myokine FSTL1.

Key words: FSTL1, myokine, aerobic exercise, obese, blood pressure, cardio-protective effect

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I. INTRODUCTION

The prevalence of overweight and obesity has increased substantially in all societies across the globe during last 3 decades and all indications are that this trend is likely to continue unabated in the coming years. This is a major public health concern because obesity has far reaching negative effects on health. The risk of type 2 diabetes, cardiovascular disease, certain types of cancers, and even mortality are directly proportional to the degree of obesity. Thus, it goes without saying that there is a need to reverse this modern epidemic. Exercise is recommended for weight management by virtually every public health organization [1].

Regular physical exercise is an effective lifestyle intervention for the prevention and treatment of numerous non-communicable diseases, with "aerobic" exercise being probably the most commonly prescribed modality. Aerobic exercise has proven to reduce cardiovascular disease (CVD) risk factors such as high blood pressure, hyperlipidemia, or altered glucose homeostasis among others [2]. However, the magnitude of the health benefits seem to depend on exercise loads.

For instance, a greater improvement in CVD risk factors and cardiorespiratory fitness (CRF) might be observed with vigorous exercise (i.e., >6 metabolic equivalents [METs], or >60% of maximal oxygen uptake [VO2 max]) than with less intense training [3]. The prescription of aerobic training loads can therefore be modified to maximize health benefits. In this regard, there is a high inter-individual variability in the physiological responses and adaptations to exercise at a fixed relative intensity (i.e., expressed as a percentage of VO2 max or maximal heart rate) [4]. By contrast, prescribing exercise loads relative to individually determined specific physiological indicators (“thresholds”) whose relative intensity varies between individuals might homogenize the elicited stress and thus reduce individual variability in metabolic responses [4].

The benefits of aerobic training on cardio-metabolic health seem to be partly mediated by the cumulative effects of repeated, acute bouts of exercise-induced changes in several hormones and molecules such as the so-called myokines and adipokines, which are released from muscles and adipose tissue, respectively, to the blood and exert endocrine or paracrine effects in other cells, tissues or organs [5]. Several myokines have been proposed to mediate exercise induced health benefits besides the most studied and well known myokine.

Recently, bioactive molecules, called adipo-myokines [7], which are produced by metabolic organs, such as skeletal muscle and adipose tissues, have attracted attention and have been reported as closely associated with metabolic disorders [6]. Follistatin-like-1 (FSTL1) [7] is a novel adipo-myokine that has been demonstrated in recent years to be associated with metabolism and insulin sensitivity. Specifically, FSTL1, also known as TSC-36, is a glycoprotein [8] associated with the metabolism of glucose [9]. It has been reported that FSTL1 enhances the uptake of glucose by stimulating the translocation of the glucose transporter 4 (GLUT4) to the plasma membrane in skeletal muscles [9].

Follistatin-like protein-1 (FSTL-1), identified initially as a transforming growth factor-β1–inducible gene, is a secretory extracellular glycoprotein that belongs to the FST SPARC family, and its amino acid sequence contains a follistatin-like domain [10]. In previous studies, FSTL-1 was found to be associated with tissue inflammation in vivo and induced interleukin-6 (IL-6) secretion in vitro [11-14]. Also in heart, FSTL1 has been regarded as cardio-protective molecule upregulated in heart injuries including myocardial infarction, pressured overload-induced hypertrophy and ischemia/reperfusion injury [15]. FSTL1 is also considered as an angiogenic factor, suggesting that FSTL1 might be an important factor in cardiovascular system [15-19]. Recently, it has been reported that FSTL-1 facilitates adipocyte apoptosis, and in obese individuals, circulating FSTL-1 levels were found to be lower than those in nonobese individuals [20-24]. Therefore, the primary objective of this study was to find out the factors that could affect the release of FSTL1 during exercise and finally investigate the cardio-protective effect of aerobic exercise through the aspect of myokine FSTL1.

II. RESEARCH DESIGN AND METHODS

1. Subjects

Fifteen untrained subjects (8 obese[male] and 7 normal-weight[male]) aged 18-40 participated in the study. Subjects with a BMI 25-29.9kg/m^2 were classified as class 1 obese, and those with a BMI between 18.5-22.9kg/m^2 were classified as lean-body weight. To limit the effect of training on physiological response to acute exercise, those who reported more than 150 min of moderate and high physical activity levels per week as determined by a 7-day physical activity recall questionnaire were excluded from participation. Subjects were excluded from participation if they possessed any known inflammatory diseases/conditions, with a history of cardiovascular or metabolic disease, medical problems, or if they were taking medication known to affect health factors such as heart rate, blood pressure, or lipid profile. Subjects were also excluded from the study if they were users of tobacco products or if they consumed an average of ten or more alcoholic beverages per week. Subjects were instructed to undergo an 8 hour overnight fast and to abstain from alcohol, caffeine intake, and intense physical activity 24 hour prior to each laboratory visit. All participants were provided informed consent and completed a medical history questionnaire prior to participation, and the study was approved by the Institutional Review Board of Gangnam Severance Hospital.

2. Anthropometric measurements and Clinical parameters

A. Height, weight, waist circumference, blood pressure, heart rate

B. Bioimpedance analysis

Height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively, using a calibrated stadiometer and platform. Waist circumference and blood pressure were checked with their light clothes on. Waist circumference measurement was carried out at midpoint between the border of the iliac crest and the last rib, the same protocol proposed by the World Health Organization(WHO), European Society of Cardiology(ESC) and International Society for the Advancement of Kinanthropometry(ISAK). Body composition (body fat and skeletal muscle mass, body fat percent and body mass index) was determined by InBody test based on bioimpedance analysis (Inbody770, Seoul, South Korea).

3. Biochemical parameters

A. Fating plasma glucose, total cholesterol, HDL-cholesterol, LDL-cholesterol, triglyceride

B. FSTL1

Each participant attended our laboratory between 8:00 and 10:00 on the morning after an 8hour overnight fasting. A 10ml blood samples were drawn from the antecubital vein and immediately centrifuged at 3000RPM for 10 min at room temperature. Baseline parameters including CBC, BUN, Creatinine, AST, ALT, Total cholesterol, Triglyceride, HDL-cholesterol were examined from the blood samples collected prior to exercise, half of exercise and immediately post and 1 and 2hours into recovery using the EDTA collection tubes. LDL-cholesterol was calculated by Friedwald equation.

Plasma was collected and immediately stored at -80C for future analysis of Glucose, Free glycerol, Insulin, Glucagon, Epinephrine, Free fatty acid, Fstl1. Enzyme-linked immunosorbent assay (ELISA) was used for the analysis of the concentration of FSTL1 (Boster, number: EK0965), Glycerol (Abcam, number: ab65337), FFA (Abcam, number: ab65341), Epinerphrine (MyBioSource, number: MBS494515), Insulin (Abcam, number: ab200011), Glucagon (Cloud Clone, number: CEB266Hu), Glucose (mg/dL).

4. Exercise test

Each individual exercised on the treadmill until they burned 300Kcal (moderate exercise), and the time was calculated by the equation including the following criteria: 1) Heart rate reserve(%HRR) and Targeted heart rate(THR) according to the American College of Sports Medicine (ACSM 2) Subjects performed moderate intensity aerobic exercise, expending 300Kcal, 3) Total exercise time(T) calculated by ACSM metabolic equation, time needed for consuming 300Kcal during exercise;

I. HRR= (220-age) – (Resting HR)

II. THR= (HRR X *exercise intensity) + Resting HR *moderate: 0.55

III. $VO_2max = (0.2 \cdot S) + (0.9 \cdot S \cdot G) + 3.5$ (ACSM equation), S: speed; G: grade

IV. Kcal*min= (MET*Body mass in kg*3.5)/200

Pre-exercise (T0)	Half-time exercise (T1/2)	Immediate post exercise (T)	Recovery 30 min (T30)	Recovery 1 hour (T60)	Recovery 2 hour (T120)
Baseline test	FSTL1, Glycerol, Free fatty acid, Epinephrine, Insulin, Glucgaon, Glucose				

Figure 1. Exercise test and time-points for baseline and biochemical parameter test

5. Statistical analysis

Data analysis was performed using SPSS version 21.0. Nonparametric test was conducted to compare baseline levels of all variables between normal-weight and obese subjects. Two group (normal-weight and obese) repeated measures by six time-point (pre, half-exercise, immediately post-exercise, recovery on 30min, 1hour and 2hour) were analyzed by using Spearman's rank correlation analysis to evaluate the effect of aerobic exercise on FSTL1, glycerol and glucose. To assess intensity of FSTL1 response to exercise, area-under-the-curves(AUC) was calculated. AUC was also calculated for glycerol, free fatty acid, epinephrine, insulin, glucagon, glucose. Levels of statistical significance were set at $P < 0.05$.

III. RESULTS

1. Participant anthropometric characteristics and clinical parameters

During the study period, there were no subjects to be dropped out. A total of 15 subjects (7 participants in the lean group and 8 participants in the obese group) completed the study. The participants' clinical parameters and anthropometric characteristics are presented in Table 1. While lean group mean age was 23 years, mean BMI 22.5kg/m^2, mean systolic blood pressure 123mmHg and mean diastolic blood pressure 82mmHg, obese group mean age was 24 years, mean BMI 28.7kg/m^2, mean systolic blood pressure 132.5mmHg and mean diastolic blood pressure 85.5mmHg. Bioimpedance analysis showed statistically significant differences between the lean and obese group. Mean skeletal muscle mass of lean group was 31.9kg and obese group was 35.6kg with p value 0.064. Mean body fat mass of lean group was 12.1kg and obese group was 24.2kg with p value 0.001. Mean body fat percent of lean group was 17.2% and obese group was 27.6% with p value 0.003. Mean visceral fat area of lean group was 46.5cm^2 and obese group was 99.4cm^2 with p value 0.003.

2. Biochemical parameters

Subjects' fasting plasma glucose, total cholesterol, HDL-cholesterol and LDD-cholesterol along with triglyceride are outlined in Table 1. Analyzed by nonparametric independent t-test, mean fasting plasma glucose level of lean group was 84mg/dL and obese group was 91.5mg/dL. Mean total cholesterol of lean group was 184mg/dL and obese group was 173mg/dL. Mean HDL-cholesterol of lean group was 54mg/dL and obese group 54.5mg/dL. Mean LDL-cholesterol of lean group was 100mg/dL and obese group 89.5mg/dL. Mean triglyceride of lean group was 126mg/dL and obese group 142.5mg/dL.

Table 1. Participant descriptive characteristics and anthropometric measures

	Lean group (n=7)	Obese group (n=8)	p value[a]
Age (years)	23 (21-25)	24 (19.25-24)	0.815
Ht (cm)	174.6 (168.2-178.8)	174 (167.03-178.7)	0.643
Bwt (kg)	68.1 (34.5-72)	87.6 (81.9-91.1)	0.002
Waist (cm)	82 (77.5-83)	92.3 (90.4-100.6)	0.001
BMI (kg/m^2)	22.5 (21.8-24.1)	28.7 (28.1-30)	0.001
HR (bpm)	72 (65-78)	75.5 (73-86)	0.27
SBP (mmHg)	123 (120-142)	132.5 (126.5-139.3)	0.452
DBP (mmHg)	82 (71-85)	85.5 (80-92)	0.201
Skeletal muscle mass (kg)	31.9 (27.8-35)	35.6 (32.8-37.6)	0.064
Body fat mass (kg)	12.1 (10.4-14.5)	24.2 (21.1-31.3)	0.001
Body fat percent (%)	17.2 (16.4-20.9)	27.6 (25.3-33.5)	0.003
Visceral fat area (cm^2)	46.5 (38.6-62.4)	99.4 (84.7-125.4)	0.003
FPG (mg/dL)	84 (80-98)	91.5 (85-101)	0.384
TC (mg/dL)	184 (162-194)	173 (151.3-197)	0.643
HDL-C (mg/dL)	54 (47-60)	54.5 (48.3-65.3)	0.685
LDL-C (mg/dL)	100 (89.2-122.4)	89.5 (68.6-106.6)	0.418
TG (mg/dL)	126 (98-150)	142.5 (119.5-165)	0.164

Data are presented as median (25%-75%). [a]Analyzed by nonparametric independent t-tests, Mann-Whitney U test. Ht: height; Bwt: body weight; BMI: body mass index; HR: heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure; FPG: fasting plasma glucose; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

3. FSTL1 concentration during exercise

Plasma concentration of FSTL1 was assessed on baseline and following the aerobic exercise in both lean and obese group (Table 2 and Figure1). The peak median level of FSTL1 on termination of exercise was 662.3ng/mL in lean group and 678.3ng/mL in obese group. FSTL1 level increased gradually after exercise and it decreased gradually on recovery both in lean and obese group. Median FSTL1 plasma concentration of lean group was higher than the obese group on each time point, but without statistical significance.

The product of FSTL1 plasma concentration and time during exercise is expressed as area under the concentration time curve (AUC). FSTL1 concentration AUC during exercise (EX AUC) of lean group was 20147.4 and obese group 18533.3. FSTL1 concentration AUC only after the termination of exercise, on the recovery time (Post exercise) of lean group was 74937.15 and obese group was 67097.03. FSTL1 concentration AUC during entire exercise study, AUC sum of during exercise and after the exercise during recovery, of lean group was 95084.55 and obese group was

85630.33. FSTL1 concentration AUC of lean group was higher than obese group on each time point, but also without statistical significance.

Table 2. Assessment of plasma FSTL1 concentrations at baseline and response to exercise in lean group and obese group

	FSTL1 (ng/mL)	
	lean group	obese group
Pre-exercise	595 (438.7-644.5)	507.3 (433-645.3)
Half-time exercise	652.2 (500-707.5)	635.1 (583.1-830.2)
Post-exercise	678.3 (525.9-732.1)	662.3 (589.4-897.5)
Recovery 30min	574.9 (491.7-679.4)	622.1 (603.5-749.3)
Recovery 1h	575.4 (414.5-601)	602.2 (589.9-682.2)
Recovery 2h	588.7 (463.5-658.4)	580.8 (535.3-624.5)

Plasma concentrations at baseline and following aerobic exericse.
Data are presented as median (25%-75%).

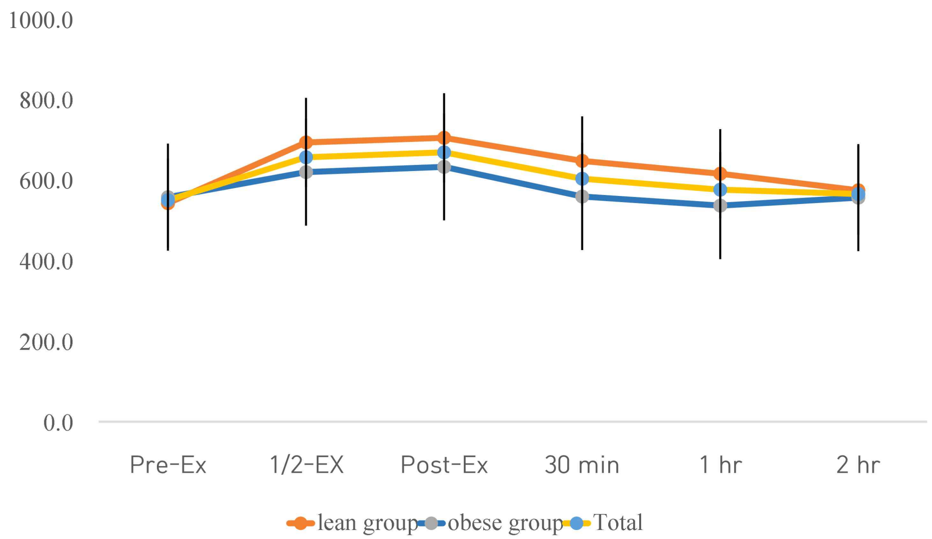
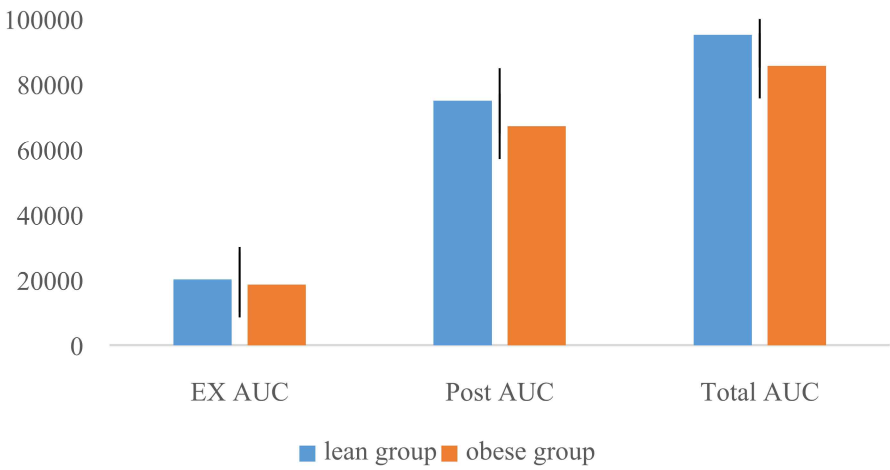


Figure 1. Average plasma concentrations of FSTL1 at baseline and following aerobic exercise in lean group and obese group and total group. Plus error bars in lean group and minus error bars in obese group are added. Pre-Ex: pre-exercise; 1/2-Ex: half-time exercise; Post-Ex: post-exercise; 30min: recovery 30min; 1hr: recovery 1hr; 2hr: recovery 2hr.



	EX AUC	Post AUC	Total AUC
lean group	20147.4	74937.15	95084.55
obese group	18533.3	67097.03	85630.33

Figure 2. FSTL1 plasma concentration AUC during exercise and post exercise and total time in lean group and obese group. Ex AUC: FSTL1 concentration AUC during exercise; Post AUC: FSTL1 concentration AUC post exercise, only after the termination of exercise; Total AUC: FSTL1 concentration AUC as the sum of during exercise and after the exercise(= Ex AUC+Post AUC).

4. Dynamics correlation

To see the correlation between the subjects' biochemical or anthropometric characteristics and dynamic biomarkers, Spearmans' rank correlation test was done (Table 3,4). Myokine FSTL1 serum level on each stage of exercise, such as right before the exercise(;pre-exercise), on the half time of exercise(;half-time exercise), right after the exercise(;post-exercise), on 30minutes, 1hour and 2hour recovery after exercise, was detected to discover the correlation with the anthropometric measures, cardiovascular components and biochemical parameters. Correlation analyses showed significant associations between half-time exercise FSTL1 with Bwt and DBP (r=-0.582, r= -0.55 and p= 0.023, p= 0.034, respectively) in all subjects (Table 3). Also there was a significant correlation between the post-exercise FSTL1 and Bwt, DBP (r= -0.524, r= -0.666 and p= 0.045, p= 0.007, respectively). FSTL1 at 30minute recovery time after exercise showed significant association with Bwt, body fat mass, visceral fat area and systolic, diastolic blood pressure (r= -0.718, r= -0.621, r=-0.711, r=-0.588, r= -0.683 and p=0.003, p=0.013, p=0.003, p=0.021, p=0.005, respectively). FSTL1 at 1hour recovery time after exercise showed significant association with Bwt and visceral fat area (r= -0.621, r= -0.514 and p=0.013, p=0.05, respectively). Furthermore, correlation anaylsis of FSTL1 concentration AUC during exercise (:Ex AUC), after exercise (:Post AUC) and on the whole time (:Ex AUC+Post AUC) with anthropometric measures, cardiovascular components and biochemical parameters were conducted. Post AUC FSTL1 showed significant correlation with Bwt, sysolic blood pressure and diastolic blood pressure (r=-0.546, r= -0.611, r=-0.606 and p=0.035, p=0.015, p=0.017, respectively). And also total AUC FSTL1 showed significant correlation with Bwt, visceral fat area and diastolic blood pressure (r= -0.625, r=-0.575, r=-0.59 and p=0.013, p=0.025, p=0.021, respectively).

Table 3. Correlation between plasma FSTL1 concentrations at baseline and following aerobic exercise and measures of Anthropometry, Cardiovascular components, Biochemical parameters

	Pre-Ex		1/2-Ex		Post-Ex	
	r	p	r	p	r	p
Anthropometric measures						
Bwt	-0.168	0.55	-0.582	0.023*	-0.524	0.045*
Waist	0.193	0.49	-0.261	0.347	-0.192	0.494
BMI	0.039	0.889	-0.254	0.362	-0.238	0.394
skeletal muscle mass (kg)	-0.275	0.321	-0.456	0.088	-0.369	0.177
Body fat mass (kg)	0.039	0.889	-0.4	0.14	-0.386	0.155
Body fat percent (%)	0.036	0.899	-0.361	0.187	-0.35	0.201
Visceral fat area (cm^2)	-0.039	0.889	-0.486	0.066	-0.475	0.073
Cardiovascular components						
HR	-0.267	0.336	-0.26	0.35	-0.254	0.362
SBP	-0.391	0.149	-0.502	0.056	-0.498	0.059
DBP	-0.419	0.12	-0.55	0.034*	-0.666	0.007*
Biochemical parameters						
FPG	0.063	0.824	-0.208	0.457	0.015	0.957
TC	0.139	0.621	0.221	0.428	0.391	0.149
HDL-C	-0.009	0.975	-0.139	0.62	-0.208	0.458
LDL-C	0.05	0.86	0.214	0.443	0.424	0.116
TG	0.422	0.117	0.351	0.2	0.29	0.294

Analyzed by spearman's rank correlation test. Significantly associated with variables, $p<0.05$. Pre-EX: pre-exercise; 1/2-Ex: half-time exercise; Post-Ex: post-exercise; 30 min: recovery 30min; 1 hr: recovery 1hr; 2 hr: recovery 2hr; Ht: height; Bwt: body weight; BMI: body mass index; HR: heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure; FPG: fasting plasma glucose; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

	30 min		1 hr		2 hr	
	r	p	r	p	r	p
Anthropometric measures						
Bwt	-0.718	0.003*	-0.621	0.013*	-0.411	0.128
Waist	-0.499	0.058	-0.367	0.179	-0.018	0.95
BMI	-0.479	0.071	-0.332	0.226	-0.154	0.585
skeletal muscle mass (kg)	-0.486	0.066	-0.502	0.056	-0.393	0.147
Body fat mass (kg)	-0.621	0.013*	-0.454	0.089	-0.161	0.567
Body fat percent (%)	-0.504	0.056	-0.436	0.104	-0.118	0.676
Visceral fat area (cm^2)	-0.711	0.003*	-0.514	0.05*	-0.257	0.355
Cardiovascular components						
HR	-0.376	0.167	-0.281	0.31	-0.394	0.146
SBP	-0.588	0.021*	-0.368	0.177	-0.513	0.051
DBP	-0.683	0.005*	-0.375	0.169	-0.507	0.054
Biochemical parameters						
FPG	-0.018	0.949	-0.414	0.125	0.016	0.955
TC	0.407	0.132	0.107	0.704	0.357	0.191
HDL-C	-0.311	0.259	-0.03	0.914	0.018	0.95
LDL-C	0.454	0.089	0.046	0.869	0.257	0.355
TG	0.265	0.34	0.417	0.122	0.458	0.086

Analyzed by spearman's rank correlation test. Significantly associated with variables, $p<0.05$. Pre-EX: pre-exercise; 1/2-Ex: half-time exercise; Post-Ex: post-exercise; 30 min: recovery 30min; 1 hr: recovery 1hr; 2 hr: recovery 2hr; Ht: height; Bwt: body weight; BMI: body mass index; HR: heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure; FPG: fasting plasma glucose; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

Table 4. Correlation between plasma FSTL1 concentration AUC during exercise, post exercise and total time and age, measures of Anthropometry, Cardiovascular components, Biochemical parameters

	Ex AUC		Post AUC		Total AUC	
	r	p	r	p	r	p
Anthropometric measures						
Bwt	-0.554	0.32	-0.546	0.035*	-0.625	0.013*
Waist	-0.415	0.124	-0.211	0.45	-0.361	0.186
BMI	-0.261	0.348	-0.275	0.321	-0.314	0.254
skeletal muscle mass (k	-0.384	0.157	-0.479	0.071	-0.436	0.104
Body fat mass (kg)	-0.446	0.095	-0.357	0.191	-0.482	0.069
Body fat percent (%)	-0.407	0.132	-0.307	0.265	-0.429	0.111
Visceral fat area (cm^2)	-0.529	0.043	-0.433	0.098	-0.575	0.025*
Cardiovascular components						
HR	-0.016	0.955	-0.367	0.178	-0.22	0.43
SBP	-0.329	0.231	-0.611	0.015*	-0.508	0.053
DBP	-0.373	0.171	-0.606	0.017*	-0.59	0.021*
Biochemical parameters						
FPG	-0.251	0.367	-0.013	0.965	-0.145	0.606
TC	0.143	0.612	0.321	0.243	0.336	0.221
HDL-C	-0.266	0.337	-0.147	0.602	-0.202	0.47
LDL-C	0.175	0.533	0.293	0.289	0.346	0.206
TG	0.247	0.375	0.426	0.114	0.326	0.236

Analyzed by spearman's rank correlation test. Significantly associated with variables, $p<0.05$. Ex AUC: FSTL1 concentraion AUC during exercise; Post AUC: FSTL1 concentration AUC post exercise, only after the termination of exercise; Total AUC: FSTL1 concentration AUC as the sum of during exercise and after the exercise(= Ex AUC+Post AUC).

5. Independent effect of anthropometric parameters on FSTL1

Based on prior studies and our results, that plasma concentration of FSTL1 in obese person are lower than the lean person, we conducted multiple linear regression analysis to investigate the factor that independently affects the release of FSTL1. On the multiple linear regression analysis, anthropometric measures which are suspected to affect the plasma concentration of FSTL1 and which actually showed statistically significant correlation with FSTL1 were set as independent variables. All of the anthropometric measures were not an independent predictor of plasma FSTL1 concentration. Bwt showed statistical tendency as an independent predictor for half-time exercise plasma concentration of FSTL1 with p value 0.051 and beta coefficient= -6.406.

Table 5. Independent effect of anthropometric parameters on FSTL1

		Independent variables					
		Bwt(kg)		Waist(cm)		BMI(kg/m^2)	
		B	p	*B*	p	*B*	p
Dependent variables	Pre-Ex	-6.163	0.148	0.977	0.172	0.591	0.651
	1/2-Ex	-6.406	0.051	0.739	0.153	1.117	0.254
	Post-Ex	-4.965	0.113	0.919	0.089	1.677	0.107
	30min	-0.641	0.831	0.666	0.217	0.095	0.924
	1hr	-2.197	0.553	0.499	0.432	0.484	0.69
	2hr	-3.289	0.365	0.763	0.227	-0.237	0.839
	Ex AUC	-6.333	0.071	-0.108	0.836	1.558	0.158
	Post AUC	-2.609	0.417	0.715	0.206	0.388	0.71
	Total AUC	-3.805	0.229	0.502	0.339	0.746	0.459

Analyzed by multiple linear regression test. Statisticaly significant, $p<0.05$. Dependent variable: FSTL1 on each time point.*B* : beta coefficient, regression coefficient; Bwt: body weight; BMI: body mass index.

		Independent variables							
		Skeletal muscle mass(kg)		Body fat mass(kg)		Body fat percent(%)		Visceral fat area(cm^2)	
		B	p	*B*	p	*B*	p	*B*	p
Dependent variables	Pre-Ex	2.075	0.289	4.395	0.239	-2.574	0.555	1.652	0.687
	1/2-Ex	1.424	0.309	5.639	0.055	-4.684	0.16	2.184	0.464
	Post-Ex	0.194	0.886	5.437	0.064	-6.531	0.066	2.509	0.407
	30min	-0.369	0.797	4.247	0.147	-1.804	0.587	-3.053	0.342
	1hr	0.095	0.956	3.078	0.365	-1.673	0.678	-0.799	0.83
	2hr	1.564	0.367	6.756	0.259	0.57	0.883	-2.465	0.506
	Ex AUC	1.824	0.24	4.562	0.133	-2.733	0.43	1.555	0.63
	Post AUC	0.382	0.799	4.158	0.171	-1.942	0.577	-1.457	0.656
	Total AUC	0.821	0.57	4.442	0.131	-2.251	0.5	-0.631	0.839

Analyzed by multiple linear regression test. Statisticaly significant, $p<0.05$. Dependent variable: FSTL1 on each time point.*B* : beta coefficient, regression coefficient; Bwt: body weight; BMI: body mass index.

6. Independent effect of anthropometric parameters and FSTL1 on blood pressure

In multiple linear regression analysis, with anthropometric measures and FSTL1 concentration as independent variables and blood pressure (; both systolic and diastolic) as dependent variable, baseline and half-time exercise cocentration FSTL1 were independent predictor of diasolic blood pressure (*B*= -0.554, *B*= -0.737 and p=0.034, p=0.048). FSTL1 on 2hour recovery time after exercise was an independent predictor of diastolic blood pressure (*B*= -0.675, p= 0.014) along with waist and visceral fat area (*B*= -0.825, *B*= -5.232 and p= 0.049, p= 0.033, respectively). Plasma concetration AUC of FSTL1 on recovery time after exercise (;Post AUC FSTL1) and whole time during exercise (;Total AUC FSTL1= Ex AUC + Post AUC FSTL1) did not independently predict the blood pressure. However they both showed statistical tendency for independent predictor (*B*= -0.633, *B*=-0.666 and p= 0.064, p= 0.062, respectively) (Table 6).

Table 6. Independent effect of anthropometric parameters and FSTL1 on blood pressure

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
Pre-Ex FSTL1	-0.4	-0.554	0.438	0.034*
Bwt(kg)	0.027	-0.18	0.996	0.942
Waist(cm)	-0.351	-0.798	0.723	0.091
BMI(kg/m^2)	-0.073	-0.861	0.966	0.253
Skeletal muscle mass(kg	1.018	1.39	0.699	0.235
Body fat mass(kg)	-3.266	-0.59	0.525	0.781
Body fat percent(%)	4.278	5.292	0.461	0.059
Visceral fat area(cm^2)	-0.396	-2.654	0.94	0.259

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; Pre-Ex FSTL1: pre-exercise FSTL1; Bwt: body weight; BMI: body mass index; SBP: systolic blood pressure; DBP: diasolic blood pressure.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
1/2-Ex FSTL1	-0.792	-0.737	0.256	0.048*
Bwt(kg)	-2.581	-1.488	0.686	0.622
Waist(cm)	-0.156	-0.795	0.868	0.11
BMI(kg/m^2)	0.576	-0.365	0.74	0.657
Skeletal muscle mass(kg	1.316	1.29	0.595	0.287
Body fat mass(kg)	-0.558	1.131	0.921	0.673
Body fat percent(%)	1.598	3.266	0.792	0.276
Visceral fat area(cm^2)	0.673	-1.96	0.895	0.428

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; 1/2-Ex FSTL1: half-time xercise FSTL1; Bwt: body weight; BMI: body mass index; SBP: systolic blood pressure; DBP: diasolic blood pressure.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
Post-Ex FSTL1	-0.172	-0.624	0.814	0.11
Bwt(kg)	1.64	0.138	0.799	0.964
Waist(cm)	-0.584	-0.767	0.606	0.185
BMI(kg/m^2)	-0.021	-0.142	0.992	0.889
Skeletal muscle mass(kg	0.221	0.361	0.93	0.765
Body fat mass(kg)	-4.091	0.366	0.517	0.901
Body fat percent(%)	4.186	2.645	0.582	0.469
Visceral fat area(cm^2)	-0.626	-2.004	0.914	0.476

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; Post-Ex FSTL1: post-exercise FSTL1; Bwt: body weight; BMI: body mass index; SBP: systolic blood pressure; DBP: diasolic blood pressure.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
30min FSTL1	-0.298	-0.667	0.665	0.061
Bwt(kg)	2.302	2.807	0.663	0.254
Waist(cm)	-0.544	-0.895	0.59	0.079
BMI(kg/m^2)	-0.281	-1.125	0.871	0.176
Skeletal muscle mass(kg	0.078	-0.005	0.975	0.996
Body fat mass(kg)	-3.759	-0.193	0.505	0.937
Body fat percent(%)	4.771	5.515	0.429	0.068
Visceral fat area(cm^2)	-1.966	-5.605	0.736	0.063

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; 30min FSTL1: recovery 30min FSTL1; Bwt: body weight; BMI: body mass index; SBP: systolic blood pressure; DBP: diasolic blood pressure.

	B		p	
	SBP	DBP	SBP	DBP
Independent variables				
1hr FSTL1	-0.041	-0.309	0.942	0.344
Bwt(kg)	2.402	2.556	0.663	0.409
Waist(cm)	-0.721	-1.185	0.457	0.055
BMI(kg/m^2)	-0.289	-1.039	0.871	0.311
Skeletal muscle mass(kg	0.192	0.27	0.94	0.847
Body fat mass(kg)	-4.897	-2.074	0.355	0.47
Body fat percent(%)	5.239	6.201	0.39	0.094
Visceral fat area(cm^2)	-1.09	-3.816	0.942	0.239

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; 1hr FSTL1: recovery 1hr FSTL1; Bwt: body weight; BMI: body mass index; SBP: systolic blood pressure; DBP: diasolic blood pressure.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
2hr FSTL1	-0.544	-0.675	0.337	0.014*
Bwt(kg)	0.702	1.015	0.893	0.609
Waist(cm)	-0.327	-0.825	0.726	0.049*
BMI(kg/m^2)	-0.438	-1.348	0.788	0.061
Skeletal muscle mass(kg	1.039	1.296	0.678	0.199
Body fat mass(kg)	-2.98	-0.491	0.546	0.789
Body fat percent(%)	5.618	7.102	0.317	0.011*
Visceral fat area(cm^2)	-2.399	-5.232	0.65	0.033*

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; 2hr FSTL1: recovery 2hr FSTL1; Bwt: body weight; BMI: body mass index; SBP: systolic blood pressure; DBP: diasolic blood pressure.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
Ex AUC FSTL1	-0.393	-0.468	0.554	0.212
Bwt(kg)	0.006	0.269	0.999	0.939
Waist(cm)	-0.785	-1.39	0.387	0.021*
BMI(kg/m^2)	0.303	-0.459	0.879	0.668
Skeletal muscle mass(kg	0.904	1.094	0.742	0.464
Body fat mass(kg)	-3.234	-0.889	0.563	0.764
Body fat percent(%)	4.235	5.439	0.484	0.124
Visceral fat area(cm^2)	-0.446	-2.841	0.935	0.347

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; Ex AUC FSTL1: FSTL1 concentration AUC during exercise; Bwt: body weight; BMI: body mass index; SBP: systolic blood pressure; DBP: diasolic blood pressure.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
Post AUC FSTL1	-0.306	-0.633	0.642	0.064
Bwt(kg)	1.695	1.584	0.758	0.525
Waist(cm)	-0.523	-0.887	0.605	0.083
BMI(kg/m^2)	-0.19	-0.943	0.913	0.252
Skeletal muscle mass(kg	0.305	0.482	0.903	0.668
Body fat mass(kg)	-3.753	-0.394	0.498	0.871
Body fat percent(%)	4.714	5.49	0.433	0.071
Visceral fat area(cm^2)	-1.502	-4.491	0.785	0.104

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; Post AUC FSTL1: FSTL1 concentration AUC post exercise; Bwt: body weight; BMI: body mass index; SBP: systolic blood pressure; DBP: diasolic blood pressure.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
Total AUC FSTL1	-0.374	-0.666	0.586	0.062
Bwt(kg)	1.07	0.7	0.853	0.787
Waist(cm)	-0.554	-1.005	0.562	0.048*
BMI(kg/m^2)	-0.03	-0.691	0.987	0.402
Skeletal muscle mass(kg	0.495	0.787	0.845	0.497
Body fat mass(kg)	-3.364	-0.067	0.551	0.979
Body fat percent(%)	4.466	5.219	0.458	0.084
Visceral fat area(cm^2)	-1.293	-3.99	0.811	0..135

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; Total AUC FSTL1: Ex AUC + Post AUC FSTL1; Bwt: body weight; BMI: body mass index; SBP: systolic blood pressure; DBP: diasolic blood pressure.

7. Independent effect of lipid profile and FSTL1 on blood pressure

In multiple linear regression analysis, with lipd profile and FSTL1 concentration as independent variables and blood pressure (; both systolic and diastolic) as dependent variable, FSTL1 on half-time exercise and immediately after the termination of exercise independently predicted the diastolic blood pressure (*B*= -0.601, *B*=-0.667 and p=0.023, p=0.019, respectively). Also FSTL1 on 30 minute recovery time after exercise was as independent predictor of diastolic blood pressure (B= -0.751, p=

0.031). Plasma concentration AUC of FSTL1 on recovery time after the exercise (Post AUC FSTL1) and on entire time during and after exercise (Total AUC FSTL1= Ex AUC + Post AUC FSTL1) both were discovered as independent predictor of diasolic blood pressure (*B*=-0.615, *B*=-0.615 and p= 0.044, p=0.039, rescpectively) (Table 7).

Table 7. Independent effect of lipid profile and FSTL1 on blood pressure

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
Pre-Ex FSTL1	-0.355	-0.542	0.348	0.103
TC	-3.665	-3.342	0.609	0.577
HDL-C	1.803	1.677	0.569	0.527
LDL-C	3.549	3.024	0.61	0.603
TG	0.922	1.007	0.619	0.517

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; Pre-Ex FSTL1: pre-exercise FSTL1; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
1/2-Ex FSTL1	-0.576	-0.601	0.052	0.023*
TC	-5.05	-6.554	0.344	0.163
HDL-C	2.324	2.986	0.328	0.154
LDL-C	4.983	6.22	0.337	0.172
TG	1.273	1.778	0.37	0.157

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; 1/2-Ex FSTL1: half-time exercise FSTL1; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
Post-Ex FSTL1	-0.475	-0.667	0.162	0.019*
TC	-5.595	-6.501	0.345	0.16
HDL-C	2.557	2.93	0.333	0.155
LDL-C	5.574	6.3	0.333	0.16
TG	1.425	1.816	0.366	0.143

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; Post-Ex FSTL1: post-exercise FSTL1; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

	B		p	
	SBP	DBP	SBP	DBP
Independent variables				
30min FSTL1	-0.694	-0.751	0.077	0.031*
TC	-7.661	-9.293	0.171	0.062
HDL-C	3.376	4.084	0.173	0.064
LDL-C	7.773	9.161	0.156	0.06
TG	2.114	2.67	0.164	0.05*

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; 30min FSTL1: recovery 30min FSTL1; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

	B		p	
	SBP	DBP	SBP	DBP
Independent variables				
1hr FSTL1	-0.408	-0.501	0.206	0.08
TC	-8.097	-9.879	0.186	0.07
HDL-C	3.751	4.543	0.169	0.062
LDL-C	7.916	9.439	0.185	0.075
TG	2.122	2.731	0.2	0.066

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; 1hr FSTL1: recovery 1hr FSTL1; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
2hr FSTL1	-0.532	-0.561	0.157	0.1
TC	-5.028	-6.506	0.399	0.23
HDL-C	2.387	3.041	0.368	0.207
LDL-C	5.032	6.25	0.385	0.234
TG	1.442	1.951	0.359	0.175

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; 2hr FSTL1: recovery 2hr FSTL1; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
Ex AUC FSTL1	-0.513	-0.522	0.106	0.07
TC	-8.633	-10.261	0.141	0.06
HDL-C	3.891	4.609	0.134	0.056
LDL-C	8.515	9.871	0.138	0.063
TG	2.219	2.754	0.16	0.062

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; Ex AUC FSTL1: FSTL1 concentration AUC during exercise; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
Post AUC FSTL1	-0.525	-0.615	0.13	0.044*
TC	-6.85	-8.374	0.237	0.097
HDL-C	3.146	3.814	0.222	0.089
LDL-C	6.817	8.104	0.227	0.099
TG	1.862	2.407	0.232	0.079

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; Post AUC FSTL1: FSTL1 concentration AUC post exercise; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

	B		*p*	
	SBP	DBP	SBP	DBP
Independent variables				
Total AUC FSTL1	-0.547	-0.615	0.105	0.039*
TC	-7.366	-8.976	0.197	0.075
HDL-C	3.357	4.063	0.186	0.07
LDL-C	7.326	8.688	0.189	0.077
TG	1.983	2.538	0.199	0.064

Analyzed by multiple linear regression test. Statistically significant, $p<0.05$. B: beta coefficient, regression coefficient; Total AUC FSTL1: Ex AUC + Post AUC FSTL1; TC: total cholesterol; HDL-C: HDL-cholesterol; LDL-C: LDL-cholesterol; TG: triglyceride.

IV. DISCUSSION

The aim of this study was to find out the factors that could affect the release of FSTL1 during exercise and finally elucidate the cardio-protective effect of aerobic exercise through the aspect of myokine FSTL1 while exercising in two groups: grade 1 obese and normal-weight individuals. Currently, there are other studies [4,6,7,13] that describe FSTL1 as an adipomyokine functionally implicated in a range of process including apoptosis, inflammation, or adipogenesis and say that FSTL1 plays a significant role in the obesity development. Another recent study by Martin Horak et al [20], reported that super obesity are potentially associated with a decline in FSTL1 levels due to the continuous loss of adipogenesis and increased number of maturated adipocytes, increased cell senescence, enhanced demand for lowering FSTL1 antiapoptotic activity. Also, previous studies have reported cardio-protective and angiogenic effects of FSTL1. FSTL1 molecule was upregulated in heart injuries including myocardia l infarction, pressured overload-induced hypertrophy and ischemia/reperfusion injury [15-19].

In line from these previous study and our study, we suspected that obese persons with larger body fat mass, body fat percent or visceral fat area may have lower and slower increase in FSTL1 during exercise. Our results showed FSTL1 gradually increasing during exercise and gradually decreasing after the termination of exercise. And as expected, obese group participants' median and mean level of plasma FSTL1 concentrations on each point through exercise were lower than the lean group, but without statistical significance. We can presume the lack of statistical significance to a small number of participants.

Based on prior studies and our results, that plasma concentration of FSTL1 in obese person are lower than the lean person [20-23], we first conducted nonparametric correlation analysis to see the associations between FSTL1 and anthropometric, cardiovascular and biochemical measures. Our nonparametric correlation analysis showed significant correlations among body weight, body fat mass, visceral fat area and systolic, diastolic blood pressure and FSTL1. However those anthrometric measures were not an independent predictor of FSTL1. We think the lack of statistical significance of body weight, waist, BMI, body fat mass or visecral fat area as an independent predictor to FSTL1 comes from our unique study population consisting of lean and obese males, in which obese participants are metabolically healthy and both group subjects within the narrow range of age beween 20 and 29. However, multiple linear regression analysis showed FSTL1 as an independent predictor for diastolic blood pressure. This analysis was based on the fact that FSTL1 works as a cardio-protective protein and from our study results which showed statistically significant association between FSTL1 and blod pressure. We conducted multiple linear regression analysis to investigate whether FSTL1 acts as a meaningful independent predictor of blood pressure during exercise. And also, the result that only the diastolic but not the systolic blood pressure defined as an independent predictor of FSTL1 might come from the main limitation of smaller number of participants.

From the results of our study and previous ones [20-24], slower increase and lower serum concentration of FSTL1 during and after exercise could be potentially related to cardio-metabolic health benefits of FSTL1 on exercise. Also it could be related to higher and relatively uncontrolled blood pressure during and on recovery of exercise. Collectively, we suspect that obese persons who have larger body weight, body fat mass and visceral fat area, may have slower increase and as a result lower amount of FSTL1 on exercise and from their cardio-protective effect, this could be related to higher and unstable blood pressure on exercise.

This study has several limitations that must be noted, notably the small study size. There were only 15 subjects, lean group 7 and obese group 8 each, which might have caused the p-values. Secondly, the present study was conducted on subjects between 20 and 29. The mean age of lean group was 23 years and obese group was 24 years.

Thirdly, even though obese group were BMI adjusted grade 1 obese group, the participants were metabolically healthy considering their age. This study would have observed more meaningful findings between FSTL1 and anthropometric measures including body weight, waist, BMI and body fat mas, body fat percent and visceral fat area also with blood pressure both systolic and diastolic if the number of study group were larger and the age or characteristics were broader with diverse age group (e.g., female, older and metabolically unhealthy people). Beyond these results, we do not know exactly why there are differences in increase amount of FSTL1 during exercise between the lean group and obese group. More thorough research is thus necessary to determine why and how the exercise regulates myokine such as FSTL1 and why there are apposite results in obese and lean group. However, further researches are needed to elucidate the mechanism on how FSTL1 effects systolic and diastolic blood pressure. Although there are previous studies that assessed the cardio-protective effects of FSTL1 [15-19], the strength of this study is that, to our knowledge, this is the first study to assess the dynamic level of FSTL1 during exercise and after the exercise, and we were able to propose the relationship of FSTL1 during exercise with blood pressure and body weight.

In conclusion, in this first dynamic study of FSTL1 during aerobic exercise on both male group (; lean and obese group), FSTL1 shows significant correlation with body weight, body fat mass, visceral fat area and blood pressure. And furthermore, the FSTL1 concentration AUC after the exercise on recovery state and also the entire exercise time(; during exercise + recovery time FSTL1) were an independent predictor of diastolic blood pressure. From these results, we introduce FSTL1, a novel myokine that is associated with cardio-protective effect. Up-to-date, exact association and physiological explanation are not yet conducted; therefore, more precise research is needed to better understand this novel myokine.

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ABSTRACT (IN KOREAN)

운동 중 FSTL1 의 분비

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심혈관계 건강과의 연관성을 인정받고 있는 호르몬인 FSTL1 의 운동 중 분비에 영향을 미치는 요인을 유산소 운동을 통한 실험으로 확인하고, 유산소운동이 심혈관계 건강증진에 기여함을 마이오카인인 FSTL1 의 관점에서 해석하고자 함.

지속적인 중강도의 유산소 운동 수행에 무리가 없는 건강한 만 19-40세의 남성 중 BMI 18.5-22.9kg/m2의 lean group 7명과 BMI 25-29.9kg/m2의 obese group 8명으로, 총 15명을 대상으로 모은 개인에게 설정된 중강도 유산소 운동(300Kcal 소모)을 Tread mill test 로 시행함. 모든 대상자들은 운동시작 전 인체계측 및 8시간 금식 유지한 상태에서 TC, Tg, HDL-C,LDL-C을 포함한 생화학적 특징 조사를 시행하였고, 운동 시작한 후, 운동중간, 운동직후, 운동완료

회복기 30분, 1시간, 2시간 지점에서 각각 공복혈당과 FSTL1 을 채혈을 통해 측정함.

운동 전구간에서 FSTL1 의 평균값은 obese group 에 비해 lean group 에서 높게 측정되었지만, 통계학적인 유의미성은 없었음. 1) 상관성분석: 운동중간지점 FSTL1과 Bwt, DBP 은 통계적으로 유의미한 상관성을 보임(r=-0.582,r=-0.55/p=0.023,p=0.034). 운동직후의 FSTL1 과 Bwt, DBP도 유의미한 상관성을 보임(r=-0.524,r=-0.666/ p=0.045,p=0.007). 회복기 30분의 FSTL1 과 Bwt, body fat mass, visceral fat area, SBP, DBP는 유의미한 상관성을 보임 (r=-0.718,r=-0.621,r=-0.711,r=-0.588,r=-0.683/ p= 0.003,p=0.013,p=0.003,p=0.021,p=0.005). 회복기1시간의 FSTL1과 Bwt, visceral fat are 는 유의미한 상관성을 보임 (r=-0.621,r=-0.514/p=0.013,p=0.05). 운동회복기의 Post AUC FSTL1 은 Bwt,SBP,DBP 와 유의미한 상관성을 보임.(r=-0.546,r=-0.611,r=-0.606/ p=0.035,p=0.015,p=0.017). Total AUC FSTL1 은 Bwt,visceral fat area, DBP 와 유의미한 상관성을 보임 (r= -0.625,r=-0.575,r=-0.59/ p=0.013, p=0.025,p=0.021). 2) 다중회귀분석: Anthropometric measure 와 FSTL1을 독립변수로 한 분석에서는, 운동전,운동중간지점,회복기2시간FSTL1,은 독립적으로 DBP 에 영향을 줌(p=0.034, p=0.048, p=0.014/ B=-0.554,B=-0.737,B=-0.675). Lipid profile 과 FSTL1을 독립변수로 한 분석에서는,운동중간지점,운동직후,회복기30분FSTL1이 DBP에

독립적 영향을 줌(p=0.023,p=0.049,p=0.031/ B=-0.601,B=-0.667,B=-0.751). 회복기와 운동전구간 FSTL1 AUC 는 각각 DBP에 독립적으로 영향을 줌(p=0.044,p=0.039/ B=-0.615,B=-0.615).

Anthropometric measures 와 blood pressure 그리고 FSTL1 은 서로 유의미한 상관성을 보임. Anthropometric measures의 FSTL1 에 대한 독립적 영향력은 확인하지 못함. 운동중과 후의 FSTL1 은 DBP에 독립적 영향을 주는 요인으로 해석되며, 이는 유산소운동의 심혈관계 건강 증진에의 효과를 해석하는데 마이오키인은 FSTL1 을 통해 해석을 할 수 있을 것으로 기대됨.

핵심단어: FSTL1, 마이오카인, 유산소운동, 비만, 혈압, 심혈관계