Comparison of hematologic response between trained and sedentary volunteers after high-intensity resistance exercises

Comparación de la respuesta hematológica entre voluntarios entrenados y sedentarios tras ejercicios de resistencia de alta intensidad

Authors

Leo Jose Rubin Neto [1]
André de Oliveira Teixeira [2]
Mayumi Silveira Sugano [1]
Isabele Braga Fernandes [1]
Leonardo Gelain [1]
Gustavo Penna Kramer Lima [1]
Antonio Marcos Vargas da Silva [1]
Luis Ulisses Signori [1]

[1] Federal University of Santa Maria (Brazil)
[2] Federal University of Rio Grande (Brazil).

Corresponding author:
Luis Ulisses Signori
l.signori@hotmail.com

Received: 12-11-25
Accepted: 02-03-26

How to cite in APA

Rubin Neto, L. J., Teixeira, A. de O., Silveira Sugano, M., Braga Fernandes, I., Gelain, L., Kramer Lima, G. P., Vargas da Silva, A. M., & Ulisses Signori, L. (2026). Comparison of hematologic response between trained and sedentary volunteers after high-intensity resistance exercises. *Retos, 78*, 1280-1290. https://doi.org/10.47197/retos.v79.118103

Abstract

Introduction: Hematological changes associated with high-intensity physical exercise remain controversial.
Objective: To compare hematological responses between practitioners and sedentary volunteers following a high-intensity resistance exercise (RE) session.
Methodology: Twenty-four healthy men participated in the study (pre–post with non-randomized parallel groups), including 14 sedentary (SG) individuals and 10 bodybuilding practitioners (+3x per week) for more than six months (PG). The 10RM test (leg extension, squat, and leg press) was used to determine the training load. The exercise session consisted of four sets of 10RM for each exercise, with 1-minute rest intervals between sets and 2 minutes between exercises. Blood samples were collected before and immediately (0min) after the RE session for erythrogram and leukogram analyses (absolute values and relative values [%]).
Results: RE increased the absolute values of the variables analyzed in both groups. Neutrophil counts were 13% (95%CI: 5 to 20%) higher in the PG before exercise, but similar post-exercise. After RE, monocyte counts were 2.4% (95%CI: 1.1 to 3.9%) higher in the PG. Lymphocyte levels in the PG were lower both before (DM: -13; IC95%: -6 to -20%) and after (DM: -8; IC95%: -1 to -14%) RE.
Conclusions: Practitioners exhibit greater neutrophil and monocyte reactivity following an RE session, but demonstrate residual lymphopenia associated with regular training.

Keywords

Erythrocyte count; immune response; leukocyte count; physical exercise; resistance training; exercise.

Resumen

Introducción: Los cambios hematológicos asociados al ejercicio físico de alta intensidad siguen siendo controvertidos.
Objetivo: Comparar las respuestas hematológicas entre practicantes y sedentarios tras una sesión de ejercicio de resistencia (ER) de alta intensidad.
Metodología: Veinticuatro hombres sanos participaron en el estudio (pre–post con grupos paralelos no aleatorizados), incluyendo 14 individuos sedentarios (SG) y 10 practicantes de culturismo (+3x por semana), durante más de seis meses (PG). Se utilizó la prueba de 10RM (extensión de piernas, sentadilla y prensa de piernas) para determinar la carga de entrenamiento. La sesión de ejercicio consistió en cuatro series de 10RM para cada ejercicio, con intervalos de descanso de 1 minuto entre series y 2 minutos entre ejercicios. Se recogieron muestras de sangre antes e inmediatamente (0min) después de la sesión de ER para analizar eritrogramas y leucogramas (valores absolutos y relativos [%]).
Resultados: El ER incrementó los valores absolutos de las variables analizadas en ambos grupos. El recuento de neutrófilos fue 13% (IC95%: 5 a 20%) mayor en el PG antes del ER, pero fue similar después del ejercicio. Tras el ejercicio, el recuento de monocitos fue 2,4% mayor en el PG (IC95 %: 1,1 a 3,9%). Los niveles de linfocitos en el PG fueron menores tanto antes del ejercicio (MD: -13; IC95%: -6,7 a -19,5%) como después (MD: -7,5; IC95%: -1,1 a -13,8%).
Conclusiones: Los practicantes presentan una mayor reactividad de neutrófilos y monocitos tras una sesión de ejercicio físico, pero presentan linfopenia residual asociada al entrenamiento regular.

Palabras clave

Ejercicio físico; recuento de eritrocitos; recuento de leucocitos; respuesta inmune; entrenamiento de fuerza; ejercicio físico.

Introduction

Regular physical activity can reduce morbidity and mortality, improve quality of life, and reduce the economic burden on individuals and society (Qiu et al., 2023; Steinacker et al., 2023; World Health Organization, 2020). To provide additional health benefits, muscle-strengthening activities at moderate or higher intensity involving all major muscle groups should be performed two or more days a week (World Health Organization, 2020). Performing regular resistance training (muscle contraction against external resistance) increases skeletal muscle mass, strength, and physical function (Mcleod et al., 2024), and is essential to improve the quality of life and physical fitness across different ages and populations (Bonilla et al., 2022). Resistance training prescription involves multiple programming variables, such as load, sets, frequency, rest intervals, muscle action type, and velocity, which may interfere with the results (Mcleod et al., 2024).

The benefits of a resistance training program (Steinacker et al., 2023; World Health Organization, 2020) are preceded by a paradox, as the acute intensity of these exercise sessions induces an inflammatory response clinically characterized by delayed-onset muscle soreness (Brito et al., 2022; Lima et al., 2023, 2024; Missau et al., 2018; Teixeira et al., 2014), and reduced functionality (Arbiza et al., 2024; Lima et al., 2023, 2024). This inflammatory response can be observed through hematological changes, including leukocytosis (Teixeira et al., 2014). Leukocytosis is mainly due to increases in neutrophils, but also in monocytes and lymphocytes (Brito et al., 2022; Missau et al., 2018; Teixeira et al., 2014). The alterations that occur immediately after resistance exercises (RE) are due to the increases in absolute (cells/μL) and relative (percentage) values of these cells, with absolute values being more sensitive to hemoconcentration (Brito et al., 2022; Missau et al., 2018; Teixeira et al., 2014) and relative values to the inflammatory response. These changes in concentration (Teixeira et al., 2014; Bjerre-Bastos et al., 2022), modulation, migration, and apoptosis of these cells are still being studied, as well as the factors that lead to these responses to different physical training variables (Luo et al., 2024; Tarnowski et al., 2021; Voskoboynik et al., 2024)

The leukocyte response can be divided into the innate immune response (neutrophils, monocytes, and macrophages) and the acquired immune response (lymphocytes) (Mickey et al., 2024; Netea et al., 2017). Innate immune cells react instantly to a stimulus, but are short-lived and lack specificity (Mickey et al., 2024; Netea et al., 2017). On the other hand, lymphocytes are responsible for adaptive immune responses, can specifically recognize pathogenic microorganisms, and build memory capable of protection against reinfection (Netea et al., 2017; Peake et al., 2017). Patients with primary breast cancer who underwent a combined aerobic and RE program for 6 weeks showed improvements in their hematological profile (red blood cells, hemoglobin, hematocrit, leukocytes, neutrophils, lymphocytes, monocytes, and platelets) after the program (Jesus et al., 2025).

Sessions (Brito et al., 2022; Missau et al., 2018; Teixeira et al., 2014; Weng et al., 2025) and/or programs of intense exercises can alter the adaptive and acquired immune responses, interfering with the body's ability to recover from physical stress and protect itself against external pathogens (Peake et al., 2017; Shi et al., 2025). However, an acute comparison of this hematological response between healthy volunteers and RE practitioners has not yet been performed. Understanding this immune response is crucial for developing strategies to promote recovery after exercise and for developing training programs (Bjerre-Bastos et al., 2022). We hypothesize that there are differences in hematological responses among these populations, as intense physical exercise may enhance memory of the immune response in RE practitioners (Peake et al., 2017). The present study aimed to compare hematological responses (leukocytes and erythrocytes) of practitioners and sedentary volunteers in a high-intensity RE session.

Method

The study was conducted at the Institute of Biological Sciences of the Federal University of Rio Grande (FURG), and the research project was approved by the Health Research Ethics Committee (protocol nº. 23116.002536/2010-48). The study followed the guidelines of Resolution No. 466/2012 of the Brazilian National Health Council and was conducted in accordance with the Declaration of Helsinki. Data was collected between November 2019 and December 2022. All participants provided written informed consent prior to participation.

Participants

The inclusion criteria comprised male participants aged between 20 and 35 years, literate, with a body mass index (BMI) below 30 kg/m^2, non-smokers, with no prior diagnosis of chronic diseases (rheumatologic, cardiovascular, metabolic, neurological, oncological, immunological, or hematological), not under medication use, and not participating in any dietary or ergogenic intervention programs.

On data collection days, all participants arrived after a 12-hour fasting period. Individuals presenting any alterations in vital signs such as body temperature (>37°C), heart rate (>90 bpm), systolic blood pressure (>125 mmHg), diastolic blood pressure (>85 mmHg), and/or reporting pain and/or symptoms of musculoskeletal injury were excluded. During baseline laboratory assessment, volunteers showing evidence of inflammatory response (C-reactive protein >3 mg/dL), hyperglycemia (>100 mg/dL), leukopenia (total leukocytes <4,000 ×10^3/μL), leukocytosis (>10,000 ×10^3/μL), or reporting recent use of medication, caffeine-containing beverages, or alcohol before training were also excluded. Based on these criteria, four volunteers were excluded: two for performing resistance exercises within 72 hours before testing, one due to elevated inflammatory markers (CRP >3 mg/dL), and one due to leukocytosis (total leukocytes >10,000 ×10^3/μL).

Participants classified as practitioners (Practitioners Group - PG) were those engaged in resistance training (bodybuilding) at least three times per week, for sessions lasting longer than 50 minutes, for more than six consecutive months. Volunteers who, in the prior 6 months, performed physical activity or exercise once a week or less were considered sedentary (Sedentary Group - SG). Subjects who, in this period, were involved in more than one regular exercise (aerobic or resistance) session per week, but for less than 20 min, were also considered sedentary (Mendham et al., 2011).

Participants were instructed to maintain their usual daily routines and dietary habits throughout the study period. Data collection was conducted between 3 and 5 days after the muscle strength assessment was complete.

Procedure

Muscle strength assessment

The 10-repetition maximum (10RM) test was used to perform the controlled overload evaluation protocol. The selected exercises included leg extension (LE), squat (SQ), and leg press (LP), all performed on Physicus® Plus equipment (Brazil). A 5-minute recovery period was adopted between exercises during testing sessions. Maximum load values in the 10RM test were determined over three to five attempts until the participant reached concentric failure in the dynamic movement. For each subsequent attempt, the load progressively increased by 5 kg, with a 3-minute rest interval between sets. The maximal load established was from the final successful repetition. Additionally, all participants performed the tests at the same time of day to minimize circadian variability. To reduce the margin of error during 10RM testing, standardized procedures and verbal encouragement were applied in accordance with established protocols (Arbiza et al., 2024; Brito et al., 2022; Missau et al., 2018; Teixeira et al., 2014).

Resistance training protocol

Initially, each session began with a warm-up, which involved performing each proposed exercise (1 series of 15 repetitions with 40% of the maximum load obtained in the 10RM test) (Arbiza et al., 2024; Brito et al., 2022; Missau et al., 2018; Teixeira et al., 2014). The sequence of RE (extensor bench, squat, and leg press) was randomized by drawing a closed brown envelope, and the exercise sessions were composed of 4 series of 10RM, with 1-minute intervals between sets and 2-minute intervals between exercises. During the evaluations and exercises, verbal stimuli were used.

Data collection

On the day of testing, participants first underwent evaluation of vital signs and screening for musculoskeletal symptoms. Subsequently, baseline blood samples were collected. Afterward, participants completed a standardized warm-up, followed by the resistance training session. Immediately after completing the resistance exercise session (0 min), a second blood sample was collected. During the period between blood collections (baseline and immediately post-exercise), participants were not allowed to drink any fluids. Additionally, all subjects were instructed to avoid performing the Valsalva maneuver during the exercise protocol.

Biochemical measurements

Total cholesterol, triglycerides, high-density lipoprotein cholesterol (HDL-C), glucose, uric acid, and urea were measured using commercial LAB TEST kits (Lagoa Santa, MG, Brazil) and analyzed with a LAB MAX 240® analyzer (Tokyo, Japan). Low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald formula. Fibrinogen was analyzed using a START model coagulometer (DIAGNÓSTICA STAGO, Asnières, France) with LAB TEST commercial kits (Lagoa Santa, MG, Brazil). Plasma total proteins were determined by the colorimetric Biuret method (Doles, GO, Brazil). Lactate levels were assessed using reagent strips (Roche Diagnostics GmbH, Mannheim, Germany). Serum glutamic oxaloacetic transaminase (GOT/AST) and glutamic pyruvic transaminase (GPT/ALT) were measured according to the IFCC method using a HITACHI 917® analyzer (Roche Diagnostics, Florida, USA). These variables were measured to verify the inclusion criteria and the intensity of physical effort.

Erythrogram and leukogram analyses were automatically processed using ABX kits (Horiba Diagnóstica, Curitiba, Brazil) and confirmed by light microscopy. To ensure analytical accuracy, hematological variables were measured twice, and the results were expressed as the mean of both determinations. If a discrepancy greater than 10% was observed between the two measurements, the procedure was repeated.

Changes in Plasma Volume

Percentage changes in plasma volume (%ΔPV) were calculated using Van Beaumont's equation (1972) - %ΔPV = [100/(100-Hematocrit Before)]x[(100(Hematocrit Before – Hematocrit After))/Hematocrit After] - where %ΔPV = percent change in plasma volume, Hematocrit Before = hematocrit value Before RE, and Hematocrit After = hematocrit value immediately after RE. The values of hematological and inflammatory markers were adjusted for plasma volume changes using the following formula: Corrected value = Uncorrected value x [(100 + %ΔPV)/100]. The %ΔVP was applied as a correction factor for each variable (hematological and inflammatory) individually, and the results are shown as values after RE corrected for the percentage change in plasma volume (RE-%PV). These equations were applied in a previous study to estimate variations in plasmatic volume after RE (Teixeira et al., 2014).

Data analysis

The data are presented as mean and standard deviation. The Shapiro-Wilk normality test was used. Variables with two measurements were compared using the unpaired t-test or the Mann-Whitney test when appropriate. Variables with more than two measurements were compared using a two-way repeated measures ANOVA (Groups, Time, and Interaction), followed by the Bonferroni post hoc test. The variables with significant differences between (Groups) and within-groups (Time) are presented by the mean difference (MD), and the 95% confidence interval (95%CI). Additionally, effect size differences between recoveries were calculated using Hedge's g, and expressed as follows: trivial <0.2, small 0.2–0.49, moderate 0.5–0.79, and large >0.8. The significance level established was 5% (p<0.05).

Results

The sample consisted of 14 sedentary volunteers (SG) and 10 bodybuilding practitioner volunteers (PG). Their physical and biochemical characteristics are presented in Table 1. Age, body mass index (BMI), plasma glucose, lipid profile, urea, uric acid, AST, ALT, and blood pressure (systolic and diastolic) were similar between groups. All biochemical parameters were within the expected ranges for the sample.

The exercise session increased approximately seven times the plasma lactate levels in SG (Before: 1.2 ± 0.4 vs. After: 9.1 ± 0.6 x103 µmol/L; MD: 7.7, 95%CI: 7.3 to 8.3%; Time: p<0.001 g=15.803 large effects) and PG (Before: 1.3 ± 0.5 vs. After: 9.2 ± 0.7 x103 µmol/L; MD: 7.9, 95%CI: 7.4 to 8.5%; Time: p<0.001 g=12.768 large effects). No differences were observed between the groups (Group: p=0.799), and in the interaction (Interaction: p=0.671).

Table 1. Participant Characteristics of the Study.

Variable	Sedentary Group (n:14)	Practitioners Group (n:10)	*p-Value*
Age (years)	25.7 ± 4.7	27.3 ± 4.3	0.431
BMI (kg/m²)	25.6 ± 0.9	25.7 ± 0.9	0.285
SBP (mmHg)	118 ± 1	115 ± 2	0.178
DBP (mmHg)	78 ± 1	77 ± 1	0.578
Cholesterol (mg/dL)	141 ± 9	146 ± 8	0.472
Triglycerides (mg/dL)	88 ± 15	107 ± 18	0.173
HDL-c (mg/dL)	36 ± 2	35 ± 2	0.333
LDL-c (mg/dL)	86 ± 7	91 ± 8	0.512
Glucose (mg/dL)	85 ± 3	90 ± 2	0.317
Urea (mg/dL)	30.3 ± 3	29.9 ± 2	0.861
Uric Acid (mg/dL)	4.7 ± 0.2	4.9 ± 0.1	0.456
AST (U/L)	26.6 ± 1	28.2 ± 2	0.119
ALT (U/L)	31.9 ± 2	31.3 ± 3	0.857

Legend: n: number of participants. BMI: Body Mass Index; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; HDL-c: High-Density Lipoprotein Cholesterol; LDL-c: Low-Density Lipoprotein Cholesterol; AST: Aspartate Aminotransferase; ALT: Alanine Aminotransferase.

The results of erythrograms and leukograms before and after the resistance exercise sessions are shown in Table 2. The resistance exercise session increased absolute values of hematocrit, erythrocytes, hemoglobin, and platelets in both groups. However, no differences were observed between groups or in the time × group interaction for these variables.

Absolute leukogram values are also presented in Table 2. The exercise session increased the total leukocytes, neutrophils, monocytes, and lymphocytes in both groups, but did not affect eosinophils. Total leukocytes, neutrophils, and eosinophils did not differ between groups. Nevertheless, the PG showed higher absolute monocyte counts post-exercise (MD: 288, 95%CI: 145 to 430; p=0.005, g=1.405 large effects) and lower lymphocyte counts pre-exercise (MD: -1022, 95%CI: -458 to -1586; p=0.005, g=-2.464 large effects). The interaction (time × group) presented that the PG had a more pronounced increase than the SG in the total leukocytes (MD: 1428, 95%IC: 359 to 2497; p=0.011), monocytes (MD: 251, 95%IC: 88 to 415; p=0.007), and lymphocytes (MD: 614, 95%IC: 159 to 1068; p=0.010), whereas neutrophils and eosinophils remained unchanged.

Table 2. Erythrogram and leukogram data before and after resistance exercise sessions.

Variables	Session	Before	After	MD (95%CI) Before vs After	Time	Groups	Interaction
Hematocrit (mL/%)	SG	47.6 ± 2.9	49.9 ± 3*	2.6 (1.0 to 4.2)	<0.001	0.806	0.726
	PG	47.2 ± 1.5	49.8 ± 1.5*	2.3 (0.9 to 3.6)			
Erythrocytes (x10⁵/µL)	SG	5.2 ± 0.3	5.5 ± 0.4*	0.4 (0.2 to 0.5)	<0.001	0.071	0.319
	PG	5.4 ± 0.2	5.8 ± 0.6*	0.3 (0.2 to 0.4)			
Hemoglobin (g/dL)	SG	15.5 ± 0.9	16.2 ± 1.1*	0.8 (0.4 to 1.3)	<0.001	0.910	0.589
	PG	15.3 ± 0.7	16.2 ± 0.5*	0.7 (0.4 to 1.1)			
Platelets (x10³/µL)	SG	245 ± 33	291 ± 57*	53 (37 to 68)	<0.001	0.978	0.576
	PG	241 ± 23	294 ± 33*	46 (31 to 62)			
Total Leukocytes (x10³/µL)	SG	6834 ± 723	8541 ± 1440*	1707 (906 to 2507)	<0.001	0.431	0.011
	PG	6541 ± 1387	9675 ± 2005*	3135 (2187 to 4082)			
Neutrophils (x10³/µL)	SG	3829 ± 675	4911 ± 989*	1080 (499 to 1661)	<0.001	0.062	0.162
	PG	4529 ± 1386	6163 ± 2013*	1634 (947 to 2321)			
Eosinophils (x10³/µL)	SG	116 ± 63	117 ± 51	2 (-56 to 59)	0.440	0.705	0.421
	PG	98 ± 75	118 ± 48	18 (-76 to 39)			
Monocytes (x10³/µL)	SG	288 ± 76	454 ± 192*	166 (66 to 266)	<0.001	0.005	0.007
	PG	325 ± 63	742 ± 206*†	417 (299 to 536)			
Lymphocytes (x10³/µL)	SG	2600 ± 430	3059 ± 764*	460 (121 to 800)	<0.001	0.003	0.010
	PG	1578 ± 346†	2651 ± 445*	1073 (671 to 1475)			

Legend: MD: Mean Difference; 95%CI: 95% confidence interval; SG: Sedentary Group (n = 14). PG: Practitioners Group (n = 10), **p*<0.05 vs. pre-exercise (Time); †*p*<0.05 between-group comparison.

Changes in plasma volume were similar between the groups (SG: -8.6 ± 8.2 and PG: -9.8 ± 2.5; DM: -1.3, 95%CI: -6.9 to 4.4; p=0.206).

The results of the absolute value erythrograms and leukograms before and after the correction for changes in plasma volume (RE-%△PV) are shown in Table 3.

Table 3. Erythrogram and leukogram data before and corrected for changes in plasma volume (RE- %△PV) after resistance exercise sessions.

Variables	Session	Before	After corrected by RE-%△PV	MD (95%CI) Before vs After	Time	Groups	Interaction
Erythrocytes (x10⁵/µL)	SG	5.2 ± 0.3	5.0 ± 0.4	0.2 (-0.01 to 0.44)	0.007	0.081	0.883
	PG	5.4 ± 0.2	5.2 ± 0.6	0.2 (-0.06 to 0.46)			
Platelets (x10³/µL)	SG	245 ± 33	266 ± 54*	21 (5 to 38)	<0.001	0.863	0.854
	PG	241 ± 23	265 ± 26*	23 (6 to 40)			
Total Leukocytes (x10³/µL)	SG	6834 ± 723	7802 ± 1459*	967 (201 to 1732)	<0.001	0.571	0.024
	PG	6541 ± 1387	8705 ± 1747*	2165 (1259 to 3070)			
Neutrophils (x10³/µL)	SG	3829 ± 675	4496 ± 981*	667 (126 to 1208)	<0.001	0.076	0.332
	PG	4529 ± 1386	5551 ± 1802*	1013 (372 to 1652)			
Eosinophils (x10³/µL)	SG	116 ± 63	106 ± 51	-10 (-27 to 47)	0.942	0.672	0.442
	PG	98 ± 75	107 ± 48	9 (-35 to 52)			
Monocytes (x10³/µL)	SG	288 ± 76	414 ± 181*	126 (35 to 216)	<0.001	0.004	<0.001
	PG	325 ± 63	666 ± 180*†	342 (235 to 448)			
Lymphocytes (x10³/µL)	SG	2600 ± 430	2.785 ± 701	184 (-128 to 496)	<0.001	0.002	0.005
	PG	1578 ± 346†	2381 ± 567*	802 (433 to 1172)			

Legend: MD: Mean Difference; 95%CI: 95% confidence interval; %△PV: percentage of the changes in plasma volume, SG: Sedentary Group (n = 14). PG: Practitioners Group (n = 10), **p*<0.05 vs. pre-exercise (Time); †*p*<0.05 between-group comparison.

Erythrocytes did not change after RE (-%△PV), as the model result (Time, p=0.007) was not confirmed by the Bonferroni post hoc test (SG: p=0.053; PG: p=0.165) or by the DM and their respective 95%CI (Data in Table 3). These cells did not show differences between the groups. In the Time, platelets increased in both groups (SG: p=0.012, g=0.455 minor effects; PG: p=0.006, g=0.936 large effects) after RE (-%△PV), but there were no differences between the groups.

The absolute values of total leukocytes (Time SG: p=0.012, g=0.816 large effects; PG: p<0.001, g=1.314 large effects), and of neutrophils (SG: p=0.014, g=0.608 moderate effects; PG: p=0.002, g=0.769 moderate effects) increased after the RE (-%△PV), but without differences between the groups. The eosinophils did not change throughout the experiment.

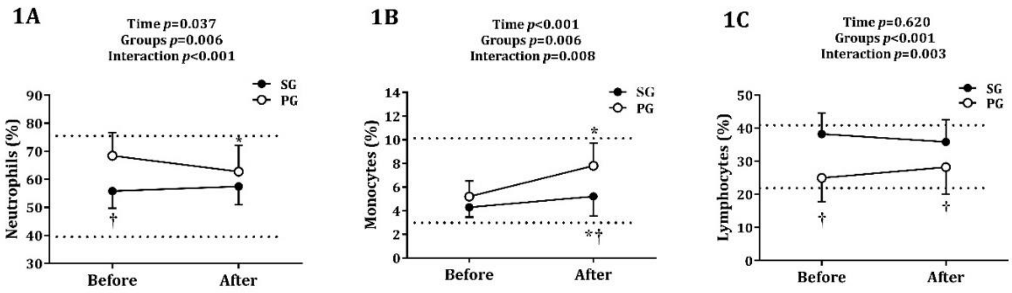
The value of absolute monocyte counts increased in both groups (SG: p=0.002, g=0.881 large effects; PG: p<0.001, g=2.422 large effects) after the RE (-%△PV). However, the PG group showed higher absolute monocyte values after the RE than the SG (DM: 252, 95%CI: 90 to 415 x103/µL, p<0.001, g=1.347 large effects). This increase is reinforced by the results of the interaction effect (time × group; MD: -192, 95%IC: -69 to -315, p<0.001).

The corrected absolute values of lymphocytes after ER (-%△PV) increased only in PG (DM: 802, 95%CI: 420 to 1184 x103/µL, p<0.001, g=1.637 large effects). However, before the RE, these cells were smaller in the PG (DM: -1022, 95%CI: -503 to -1541 x103/µL, p<0.001, g=-2.480 large effects). This is supported by the interaction effect (time × group; MD: -493, 95%IC: -284 to -701, p=0.005), which demonstrates that, while the PG increased Lymphocytes, the SG maintained relatively stable values.

Relative neutrophil, monocyte, and lymphocyte data (%) are presented in Figure 1. In the time (before vs. after, p=0.037), the PG decreased by -6% (95%CI: -2 to -9%; p=0.001 g=0.596 moderate effects) after exercise, whereas no change occurred in the SG (MD: 2, 95%CI: -1.2 to 5%; p=0.999) (Figure 1A). Between the groups, before exercise, the PG showed 13% higher values (95%CI: 5 to 20%; p<0.001 g=1.709 large effects) than the SG, but this difference was not observed post-exercise (MD: 5, 95%CI: -2 to 12%; p=0.187). This is supported by the interaction effect (time × group; MD: -7, 95%IC: -3 to -11, p<0.001), which demonstrates that, while the PG reduced neutrophil percentages, the SG maintained relatively stable values.

In the time (before vs. after, p<0.001), the monocyte percentages increase in SG (MD: 1.1, 95%CI: 0.3 to 1.9%; p<0.001 g=0.785 moderate effects) and PG group (MD: 2.6%, 95%CI: 1.6 to 3.6%; p<0.001 g=1.529 large effects) (Figure 1B). Pre-exercise monocyte percentages were similar between groups (MD: 0.9, 95%CI: -0.5 to 2.3%; p=0.272), but post-exercise, the groups showed differences (MD: 2.4%, 95%CI: 1 to 3.9%; p=0.001 g=1.353 large effects). The interaction (time × group; MD: 1.5, 95%IC: 0.4 to 2.6, p=0.005) showed an increase more pronounced in the PG than in the SG.

Figure 1. Analysis of the percentages of neutrophils (1A), monocytes (1B), and lymphocytes (1C) before and after resistance exercise.



Legend: SG: Sedentary Group (n = 14). PG: Practitioners Group (n = 10), Dashed lines indicate reference values according to the National Institutes of Health (Brihi & Pathak, 2024). * *p*<0.05 *vs* pre-exercise (Time); † *p*<0.05 between-group comparison.

The lymphocyte percentages did not alter over time in the group studies (p=0.620). However, the PG exhibited lower lymphocyte percentages both before (MD: -13, 95%CI: -6 to -20%; p<0.001 g=-1.192 large effects) and after (MD: -8, 95%CI: -1 to -14%; p<0.019 g=-0.999 large effects) the resistance exercise session (Figure 1C). The interaction (time × group; MD: 5.6, 95%IC: 2.1 to 9.2, p=0.003) indicated that lymphocyte percentages decreased in the SG but increased in the PG.

Discussion

The acute RE session increased hematocrit, erythrocytes, hemoglobin, and platelets similarly in both groups. The absolute values of total leukocytes, neutrophils, monocytes, and lymphocytes also increased immediately after the RE session. After adjusting for changes in plasma volume (RE-%△PV), the absolute values for platelets, total leukocytes, neutrophils, and monocytes remained elevated. Lymphocytes remained elevated only in the PG. The relative values (%) of leukocytes showed that the PG had larger neutrophil percentages before the exercises; however, in the PG, these percentages were similar to those of the SG after the RE session. The PG presents an increase in the percentage of monocytes only after the RE session, but a minor percentage of lymphocytes before and after the exercise session. It is noteworthy that the hematological changes observed in the present study fall within the expected parameters for healthy men (Brihi & Pathak, 2024; de Sá et al., 2023). The intensity of the RE session was assessed by blood lactate levels and classified as high intensity according to previous studies (Brito et al., 2022; Missau et al., 2018; Scott et al., 2023; Teixeira et al., 2014).

The increases in both groups in hematocrits, erythrocytes, hemoglobins, and platelets have already been demonstrated after exercises aerobic (Bjerre-Bastos et al., 2022), in a combined exercise program (aerobic and resistance) (Jesus et al., 2025), and in the RE acute session carried out at high intensity (Brito et al., 2022; Teixeira et al., 2014). This phenomenon also occurs with the absolute values of total leukocytes (absolute values) and your fraction after the RE session (Brito et al., 2022; Missau et al., 2018; Teixeira et al., 2014). These increases in absolute values that occur immediately after the RE session are partly due to the inflammatory response (Brito et al., 2022; Missau et al., 2018; Teixeira et al., 2014) and mainly to hemoconcentration (Teixeira et al., 2014). This fact is accentuated in the present study, as the volunteers were not allowed to hydrate during the exercises (period between blood collections). However, in the present study, changes in plasma volume were calculated (SG: -8.6; PG: -9.8%) and are similar (-7.5%) to previous searches, which evaluated these modifications immediately after RE (Teixeira et al., 2014), and an extreme triathlon (8.4%) competition (Santos et al., 2022). After adjustments for plasma volume changes of the results after the exercises (RE-%△PV), the increases in erythrocytes (from both groups) and lymphocytes in the SG were not confirmed. This effect of hemoconcentration on absolute values can be corrected when expressed as relative values (percentage). The importance of knowledge about biomarker kinetics is highlighted (Bjerre-Bastos et al., 2022), as some plasma constituents may be redistributed from the bloodstream into the interstitial space during exercise, especially neutrophils (Mendham et al., 2011; Mickey et al., 2024), but other plasma constituents may stay in the circulation concentrated (erythrocytes) (Bjerre-Bastos et al., 2022; Teixeira et al., 2014). In addition to hemoconcentration, these alterations indicate increased muscle stress and adaptation due to the high-intensity exercise components, as reflected in muscle remodeling and metabolic stress (Rosa et al., 2025).

The neutrophil count (absolute and after corrected plasma volume) increased in both groups after the RE session. However, the PG showed relative values of these cells that were 13% higher before and similar after the RE session. These changes are mainly due to the inflammatory response (Teixeira et al., 2014), as the relative values attenuate the effects of hemoconcentration. During and after the RE session, there is an excessive production of reactive oxygen and nitrogen species (RONS) (Brito et al., 2022; Missau et al., 2018). The RONS promote the activation and mobilization of circulating white blood cells, especially the neutrophils (Mendham et al., 2011; Mickey et al., 2024), as they are the most abundant white blood cells and have the fastest response, characterizing the transient leukocytosis observed during and just after the exercises (Teixeira et al., 2014), demonstrated in the present study by the increase in the absolute values of these cells. Furthermore, the RONS current activation of the vascular endothelium favors the migration of neutrophils to the injured muscle tissue (Feng et al., 2021; Mickey et al., 2024). This migration is stimulated by chemotactic factors, such as prostaglandins, tumor necrosis factor (TNF-α), and interleukins, which increase during and immediately after exercise (Teodoro et al., 2025). In healthy adults, moderate-intensity exercise generally does not alter the immune response, but prolonged exercise carried out at high intensity may temporarily modify this response (Shi et al., 2025). The results suggest that exercisers undergoing a high-intensity RE session have a higher relative neutrophil count before exercise, but these cells are rapidly mobilized to repair tissues during and after exercise.

RE session increased monocyte counts (absolute count and after corrected plasma volume) in both groups, but the increase was more pronounced in the PG. The relative values (%) of these cells were 2.5 times higher in the PG after the exercise session. This increase, immediately after RE, has been previously demonstrated, especially in high-intensity exercise (Brito et al., 2022; Missau et al., 2018; Teixeira et al., 2014). Monocytes are blood cells that, during the tissue inflammatory response, migrate through the vascular endothelium and settle in skeletal muscle tissue, where they become macrophages (Luo et al., 2024). Current evidence suggests that exercise exerts a distinct influence on macrophage polarization states, inducing both pro-immune response M1-like activation and cell-repair-focused M2-type activation (Luo et al., 2024; Voskoboynik et al., 2024). Recent network meta-analysis has demonstrated that exercise triggers an immediate M1 surge, while long-term training transitions to sustained M2 activation, but immobilization has been shown to have the opposite effect of exercise by triggering an immediate M2 activation (Voskoboynik et al., 2024). The results of the present study suggest that RE practitioners exhibit a more accelerated elevation in monocyte counts compared to sedentary individuals, possibly due to faster recruitment of these cells to repair muscle tissue. Thus, physical exercise may serve as a stimulus for “innate immune memory” (Netea et al., 2017).

In the present study, the acquired immune system PG response increased immediately after the RE session, as absolute lymphocyte counts, and remained elevated after correction for changes in plasma volume. The acute increase in these cells has already been described in previous studies (Brito et al., 2022; Missau et al., 2018; Shi et al., 2025; Teixeira et al., 2014). However, the lower lymphocyte percentages were observed before (13%) and after (8%) the RE session in the PG. The reduction in the values of these cells before exercise was previously shown (Peake et al., 2017; Shi et al., 2025). Vigorous exercise reduces lymphocyte levels between 1 and 24 hours after exercise (Peake et al., 2017), causes the formation of an “open window” during which immune system functions are relatively diminished, since a decrease in peripheral blood lymphocytes is observed (Peake et al., 2017; Tarnowski et al., 2021). This occurs due to the migration of these cells to more susceptible areas to infection after physical exercise (e.g., lungs, gut, and muscles)(Campbell & Turner, 2018). The diminution of the relative values (%) of lymphocytes, especially in the basal evaluation, found in the present study in the PG, suggests the occurrence of this phenomenon.

Among the limitations of this study are the small sample size, composed only of men, the performance of a single exercise session, the immediate post-exercise assessments, and the absence of measurements of leukocyte phenotype, cytokine profiles (e.g., IL-6, TNF-α, IL-10), and inflammatory markers. These results suggest that both innate and adaptive immunity differ among practitioners and sedentary individuals after the high-intensity RE session; this difference can be attributed to physical training (Netea et al., 2017; Peake et al., 2017; Shi et al., 2025). It should be noted that these relative values are within the expected normal range for the sample, which does not indicate additional risks of infection.

Conclusions

The present study demonstrated that relative leukocyte responses to a high-intensity resistance exercise (RE) session differ between sedentary and physically active individuals. In sedentary individuals, the RE session does not modify the relative (%) neutrophil, monocyte, and lymphocyte counts. In contrast, the practitioner showed a reduction in neutrophil relative values before the exercise session and an increase in monocyte relative values after the exercise session. Practitioners show higher relative neutrophil counts before and monocyte counts after the exercises, but a decrease in circulating lymphocytes both before and after the RE session. Although the study presents a small sample and the data were collected immediately after the exercises, these findings indicate that practitioners present innate and adaptive immune responses that differ from those of sedentary individuals. The results demonstrate that practitioners exhibit innate and adaptive immune responses more quickly than sedentary people.

Acknowledgements

The research group would like to thank the Laboratory of Clinical Analysis of the Santa Casa of Rio Grande Charity Association, the Institute of Biological Sciences (FURG), and the Imaging Center of the University Hospital Dr. Miguel Riet Corrêa Jr. (FURG) for their collaboration on the study and data analysis.

Financing

This study was partially funded by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) (Finance Code 001). The funder played no role in the design, conduct, or reporting of this study.

References

Arbiza, B. C. C., da Silva, A. M. V., de Lima, K. S., Rubin Neto, L. J., Nunes, G. S., Jaenisch, R. B., Puntel, G. O., & Signori, L. U. (2024). Effect of foam rolling recovery on pain and physical capacity after resistance exercises: A randomized crossover trial. *Journal of Bodywork and Movement Therapies*, *37*, 226–232. https://doi.org/10.1016/j.jbmt.2023.11.022

Bjerre-Bastos, J. J., Sejersen, C., Bihlet, A. R., Secher, N. H., Mackey, A. L., Kitchen, C. C., Drobinski, P., Thudium, C. S., & Nielsen, H. B. (2022). An Estimate of Plasma Volume Changes Following Moderate-High Intensity Running and Cycling Exercise and Adrenaline Infusion. *Frontiers in Physiology*, *13*, 1–8. https://doi.org/10.3389/fphys.2022.948087

Bonilla, D. A., Cardozo, L. A., Vélez-Gutiérrez, J. M., Arévalo-Rodríguez, A., Vargas-Molina, S., Stout, J. R., Kreider, R. B., & Petro, J. L. (2022). Exercise selection and common injuries in fitness centers: A systematic integrative review and practical recommendations. *International Journal of Environmental Research and Public Health. 19*, 12710. https://doi.org/10.3390/ijerph191912710

Brihi, J. El, & Pathak, S. (2024). Normal and abnormal complete blood count with differential. In National Institutes of Health (NIH) (Ed.), *National Institutes of Health (NIH)* (Vol. 8). https://www.ncbi.nlm.nih.gov/books/NBK604207/

Brito, E. de, Teixeira, A. de O., Righi, N. C., Paulitcth, F. da S., Silva, A. M. da V., & Signori, L. U. (2022). Vitamins C and E associated with cryotherapy in the recovery of the inflammatory response after resistance exercise: A randomized clinical trial. *Journal of Strength and Conditioning Research*, *36*(1), 135–141. https://doi.org/10.1519/JSC.0000000000003342

Campbell, J. P., & Turner, J. E. (2018). Debunking the myth of exercise-induced immune suppression: Redefining the impact of exercise on immunological health across the lifespan. *Frontiers in Immunology*, *9*(APR), 1–21. https://doi.org/10.3389/fimmu.2018.00648

de Sá, A. C. M. G. N., Bacal, N. S., Gomes, C. S., da Silva, T. M. R., Gonçalves, R. P. F., & Malta, D. C. (2023). Blood count reference intervals for the Brazilian adult population: National Health Survey. *Revista Brasileira de Epidemiologia*, *26*(Suppl 1), 4–11. https://doi.org/10.1590/1980-549720230004.supl.1

Feng, L., Dou, C., Xia, Y., Li, B., Zhao, M., Yu, P., Zheng, Y., El-Toni, A. M., Atta, N. F., Galal, A., Cheng, Y., Cai, X., Wang, Y., & Zhang, F. (2021). Neutrophil-like cell-membrane-coated nanozyme therapy for ischemic brain damage and long-term neurological functional recovery. *ACS Nano*, *15*(2), 2263–2280. https://doi.org/10.1021/acsnano.0c07973

Jesus, E. V. de, Morales, J. M. M., Guimarães, A. C., Costa, O. J. da, Vale, R. G. de S., Bezerra, J. C. P., & Dantas, E. H. M. (2025). Análisis longitudinal de la fadiga oncológica y del perfil hematológico en mujeres con cáncer de mama submetidas en un programa de tratamiento combinado. *Retos*, *71*, 13–22. https://doi.org/10.47197/retos.v71.113072

Lima, K. S. de, Schuch, F. B., Camponogara Righi, N., Chagas, P., Hemann Lamberti, M., Puntel, G. O., Vargas da Silva, A. M., & Ulisses Signori, L. (2023). Effects of the combination of vitamins C and E supplementation on oxidative stress, inflammation, muscle soreness, and muscle strength following acute physical exercise: Meta-analyses of randomized controlled trials. *Critical Reviews in Food Science and Nutrition*, *63*(25), 7584–7597. https://doi.org/10.1080/10408398.2022.2048290

Lima, K. S. de, Schuch, F., Rigui, N. C., Neto, L. J. R., Nunes, G. S., Puntel, G., Chagas, P., Silva, A. M. V. da, & Signori, L. U. (2024). Vitamin E does not favor recovery after exercises: Systematic review and meta- analysis. *International Journal of Sports Medicine*, *45*, 485–495. https://doi.org/10.1055/a-2221-5688

Luo, M., Zhao, F., Cheng, H., Su, M., & Wang, Y. (2024). Macrophage polarization: An important role in inflammatory diseases. *Frontiers in Immunology*, *15*, 1–16. https://doi.org/10.3389/fimmu.2024.1352946

Mcleod, J. C., Currier, B. S., Lowisz, C. V., & Phillips, S. M. (2024). The influence of resistance exercise training prescription variables on skeletal muscle mass, strength, and physical function in healthy adults: An umbrella review. *Journal of Sport and Health Science*, *13*(1), 47–60. https://doi.org/10.1016/j.jshs.2023.06.005

Mendham, A. E., Donges, C. E., Liberts, E. A., & Duffield, R. (2011). Effects of mode and intensity on the acute exercise-induced IL-6 and CRP responses in a sedentary, overweight population. *European Journal of Applied Physiology*, *111*(6), 1035–1045. https://doi.org/10.1007/s00421-010-1724-z

Mickey, D., Valdes Camacho, J., Khan, A., & Kaufman, D. (2024). Immunodeficiency: Quantitative and qualitative phagocytic cell defects. *Allergy and Asthma Proceedings*, *45*(5), 299–304. https://doi.org/10.2500/aap.2024.45.240049

Missau, E., Teixeira, A. de O., Franco, O. S., Martins, C. N., Paulitsch, F. da S., Peres, W., da Silva, A. M. V., & Signori, L. U. (2018). Cold water immersion and inflammatory response after resistance exercises. *Revista Brasileira de Medicina do Esporte*, *24*(5), 372–376. https://doi.org/10.1590/1517-869220182405182913

Netea, M. G., Joosten, L. A. B., Latz, E., Mills, K. H. G., Stunnenberg, H. G., Neill, L. A. J. O., & Xavier, R. J. (2017). Trained immunity: A program of innate immune memory in health and disease. *Science*, *352*(6284), 1–23. https://doi.org/10.1126/science.aaf1098

Peake, J. M., Neubauer, O., Walsh, N. P., & Simpson, R. J. (2017). Recovery of the immune system after exercise. *Journal of Applied Physiology*, *122*(5), 1077–1087. https://doi.org/10.1152/japplphysiol.00622.201

Qiu, Y., Fernández-García, B., Lehmann, H. I., Li, G., Kroemer, G., López-Otín, L., & Xiao., J. (2023). Exercise sustains the hallmarks of health. *Journal of Sport and Health Science, 12*(1), 8-35. https://doi.org/10.1016/j.jshs.2022.10.003

Rosa, G., Mello, D., Vale, R. G. de S., Salustiano, G. C. P., Mallen, da S., Bentes, C. M., Masi, F. Di, Socré, R., Santos, N. C. de M. S., Fortes, M., & Dantas, E. H. M. (2025). Acute effect of concurrent training on hematological and hepatic profile, and muscle injury markers in trained individuals. *Retos*, *69*, 690–698. https://doi.org/10.47197/retos.v69.110879

Santos, C. M. M., Amaral, J. B., Rossi, M., Vieria, R. P., Abad, C. C. C., & Bachi, A. L. L. (2022). Metabolic and immune/inflammatory alterations induced by a triathlon under extreme conditions. *Frontiers in Sports and Active Living*, *4*, 1–15. https://doi.org/10.3389/fspor.2022.915343

Scott, B. R., Marston, K. J., Teo, S. Y. M., Forrest, M. R. L., Jonson, A., Walden, T. P., Galna, B., & Peiffer, J. J. (2023). The intensity of a resistance exercise session can be quantified by the work rate of exercise. *PLoS ONE*, *18*(10), 1–13. https://doi.org/10.1371/journal.pone.0291857

Shi, X., Hu, L., Nieman, D. C., Li, F., Chen, P., Shi, H., & Shi, Y. (2025). Exercise workload: a key determinant of immune health – a narrative review. *Frontiers in Immunology*, *16*(July), 1–15. https://doi.org/10.3389/fimmu.2025.1617261

Steinacker, J. M., Van Mechelen, W., Bloch, W., Börjesson, M., Casasco, M., Wolfarth, B., Knoke, C., Papadopoulou, T., Wendt, J., Al Tunaiji, H., Andresen, D., Andrieieva, O., Bachl, N., Badtieva, V., Beucher, F. J., Blauwet, C. A., Casajus Mallen, J. A., Chang, J. H., Clénin, G., … Pitsiladis, Y. P. (2023). Global Alliance for the Promotion of Physical Activity: the Hamburg Declaration. *BMJ Open Diabetes Research and Care*, *9*(3), 1–9. https://doi.org/10.1136/bmjsem-2023-001626

Tarnowski, M., Kopytko, P., & Piotrowska, K. (2021). Epigenetic regulation of inflammatory responses in the context of physical activity. *Genes*, *12*(9). https://doi.org/10.3390/genes12091313

Teixeira, A. D. O., Franco, O. S., Borges, M. M., Martins, C. N., Guerreiro, L. F., Rosa, C. E. da, Paulitsch, F. S., Perez, W., Silva, A. M. V. da, & Signori, L. U. (2014). The Importance of Adjustments for Changes in Plasma Volume in the Interpretation of Hematological and Inflammatory Responses after Resistance Exercise. *Journal of Exercise Physiology*, *17*(4), 72–83. https://www.asep.org/asep/asep/JEPonlineAUGUST2014_Signori.pdf

Teodoro, T. H., Costa, K. P. M., Prestes, J., Campanholi, J., Navalta, J., & Pereira, G. B. (2025). The effects of acute and chronic exercise on immune markers of TH1/TH2 cells in older adults: a systematic review. *Frontiers in Physiology*, *16*:1453747. https://doi.org/10.3389/fphys.2025.1453747

Van Beaumont W (1972). Evaluation of hemoconcentration from hematocrit measurements. *Journal of Applied Physiology*, *32*(5):712-723. https://doi.org/10.1152/jappl.1972.32.5.71

Voskoboynik, Y., McCulloch, A. D., & Sahoo, D. (2024). Macrophages on the run: Exercise balances macrophage polarization for improved health. *Molecular Metabolism*, *90*, 102058. https://doi.org/10.1016/j.molmet.2024.102058

Weng, P. W., Chung, Y. C., Lin, T. C., Hsu, P. C., Yang, C. T., Lin, S., & Yang, M. T. (2025). Enhancement of Interferon-γ Secretion by Lepidium meyenii Extract Supplementation After Exhaustive Endurance Exercise in Healthy Men: A Double-blind, Placebo-controlled Trial. *International Journal of Medical Sciences*, *22*(2), 398–408. https://doi.org/10.7150/ijms.104812

World Health Organization. (2020). Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, Carty C, Chaput JP, Chastin S, Chou R, Dempsey PC, DiPietro L, Ekelund U, Firth J, Friedenreich CM, Garcia L, Gichu M, Jago R, Katzmarzyk PT, Lambert E, Leitzmann M, Milton K, Ortega FB, Ranasinghe C, Stamatakis E, Tiedemann A, Troiano RP, van der Ploeg HP, Wari V, Willumsen JF (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine*, 54(24):1451-1462. https://doi.org/10.1136/bjsports-2020-102955

Authors' and translators' details:

Leo Jose Rubin Neto	leojose01@hotmail.com	Author
André de Oliveira Teixeira	andreteixeira_ef@yahoo.com.br	Author
Mayumi Silveira Sugano	mayumi.sugano@acad.ufsm.br	Author
Isabele Braga Fernandes	isabele.fernandes@acad.ufsm.br	Author
Leonardo Gelain	leonardo.gelain@acad.ufsm.br	Author
Gustavo Penna Kramer Lima	gustavokramerlima@gmail.com	Author
Antonio Marcos Vargas da Silva	antonio.silva@ufsm.br	Author
Luis Ulisses Signori	l.signori@hotmail.com	Author