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MODIFICATIONS OF LOWER LIMBS CENTRAL AND PERIPHERAL HEMODYNAMICS DUE TO INTERMITTENT PNEUMATIC COMPRESSION EFFECTS

Abstract. High prevalence of cardiovascular diseases [1] implies continuous improvement of noninvasive physical techniques particularly perfectioning of compression therapy techniques [2]. Intermittent pneumatic compression (IPC) widely used thought multipurpose physical rehabilitation in vascular surgery, dermatologic surgery, and sport medicine (Wesley C. et al. 2015). Compression therapy (CT) is an established treatment method with very low rate of complications in research various facets of vascular and skeletal muscle physiology [3]. However, despite the widely accepted usage of IPC, the exact consensus on the IPC pressure and time parameters is not established yet. The study was aimed to evaluate hemodynamic effects of intermittent pneumatic compression on the lower extremities and identify most effectiveness external pressure parameter and optimal procedure timing. The study was included healthy 30 volunteers, 17+ years of age. Vascular assessment included determination of the resting ankle-brachial pressure index (ABI) and entered into intermittent pneumatic pressure correction program. According of ABI pressures of 40, 80, and 100 mmHg, and the procedure time limit at 20 minutes were applied. Outcome was considered succeed if blood pressure was dropped during and after procedure by increasing the expelled blood volume flow during a given period. To investigate the blood flow velocity during IPC, impedance cardio-vasography (ICVG) was implied. A summary of the 20-minute testing with different IPC of pressure indicators in the chambers led to the following outcomes. Correlational analysis of systolic-diastolic index with the maximum value of systolic amplitude manifested minor changes [0,3886±0,02157 (mean ± SD)] from the respective rest value. The amplitude of the systolic wave, which is mainly determined by the pulse blood filling, increases [0,1661±0,02959 mean ± SD)] from the respective rest value that is, the larger the volume of the muscle tissue blood filling per unit time. The increase time of fast blood filling and systolic amplitude for about 15 and 20 minutes of recovery after procedure was observed to be statistically significant (the correlation coefficient is 0.7705). Peaks in the low frequency (LF) ranging from 0.04 Hz to 0.15 Hz is were increase for about 5-10 min in recovery period. The low frequency/high frequency ratio, which consists of the ratio of the powers is used to quantify the sympathovagal balance. IPC devices for prevention hypertension is gradually becoming a standard second-order therapy, for instance, in particular, for patients with a high risk of bleeding. However, further studies for determining a more accurate time of inflation and deflation in the chambers of IPC devices are required.

Keywords: timing, hemodynamics, lower extremity, intermittent pneumatic compression, ankle-brachial pressure index, cardio-vasography impedance, parameters.

Problem statement. Intermittent pneumatic compression (IPC) is the method often used in sports and medicine, as evidenced by numerous bibliographic data from PubMed. Despite a clinical investigations of influence IPC on different types of hemodynamic a mutual consensus on the pressure and timing parameters was not established.

Analysis of recent research and publications. IPC is a widely used as preventive procedure for deep venous thrombosis (DVT). In the early 1930s, IPC was shown to have a positive effect on lower-extremity blood flow of the calf and foot [4]. The upright position of the human being and the physical force of gravity make the venous return from the leg difficult. In the leg, venous blood has to be pumped up against gravity towards the heart. This is achieved mainly by the action of the venous pump consisting of two major components: the (active) muscle contractions followed by movement of the joints and the (passively reacting) venous valves that prevent retrograde blood flow. Failure of the venous pumping mechanism can occur because of a lack of movement (immobility), an incompetence of the venous valves or a combination of the two [5]. A better understanding of lower limb hemodynamics based on the normal physiology principles of venous blood circulation as parts of the body and largely clarify the mechanism of various pathological situations, leading to the development of diseases with vein lesions and insufficiency of regional venous outflow. The arterial hemodynamic of the lower extremities depends from stroke volume of the heart since the venous hemodynamic depend on the gravity and force of calf muscle contraction.

At pathology of the lower extremities, namely primary varicosity affects the contraction of the calf muscles, such as the heart with normal stroke volume, but with increased preload due to blood reflux in heart chambers. As for deep vein varicosity it's similar to a heart with reduced stroke volume due to venous destruction. in the aftermath of which there is a reduce in the volume of the deep veins of the lower extremities increased postload due to powerful outflow resistance cad by venous obstruction, and increased preload due to venous reflux in the lower extremities that is a manifestation of a degenerative process in the venous wall and supporting fascial structures, which progressively dilate over time after exposure to high physiological pressures [6].

The absolute capacity of the lower extremities venous bed, the presence into two separate interconnected systems (superficial and deep) complex multi-channel bed structures in the joint area, mobility particularly frequently gives rise to critical situations. There are many reports of how give an indirect assessment of blood volume.

During physical rehabilitation the intermittent pneumatic compression (IPC) has a proven role as methods with very low rate of complications in research various facets of vascular and skeletal muscle physiology.

The clinical device efficiency has been reported by a number of studies in the fields of vascular surgery, dermatologic surgery, and sport medicine [7]. There is agreement that IPC pressure is dissipated when applied to tissue. Forces such as tissue resistance and blood pressures should be considered when applying IPC and suggest that a direct relationship exists between the level of pressure needed to impact fluid uptake and the level of resistance the tissue affords [8]. With more recent clinical studies demonstrating augmentation of arterial inflow with IPC.

The purpose of the article to evaluate hemodynamic effects of intermittent pneumatic compression on the lower extremities and identify most effectiveness external pressure parameter and optimal procedure timing.

Presentation of the main material. The study of IPC efficacy on the venous system was conducted on healthy volunteers. The group of 30 volunteers were physically fit and were in age of 17+ years of age, height: 172.3 ± 6.5 cm; weight: 78.0 ± 7.9 kg) were physically fit to participate in this study. All participants signed informed consent forms before participating in the study and were made aware of their right to withdraw from the study at any time without prejudice. Study protocols and procedures were approved by the European Convention on Human Rights and Biomedicine (04.04.1997), Helsinki Declaration of the World Medical

Association on ethical principles of scientific medical research involving human (1994-2008) and Order of Ministry of Health-care (Ukraine) № 690 from 23.09.2009. A ankle-brachial pressure index (ABPI) was taken on all subjects, and subjects were excluded from the study if it was below 0.8.

The Device and Equipment. PRX 2020 (Compression Mego Aftek AC Ltd, Israel) was used as the IPC device. It had a fixed cuff pressure and deflation time. Arterial blood pressure was measured with Korotkov's auscultative method by mercury tonometer (Riester, Germany) attached to the left arm. Heart Rate was monitored from a Cardio Trainer Polar H9 (Polar Electro Oy, Finland). For monitoring hemodynamic changes were applied impedance cardiography (ICG) method: (XAI-medica, Kharkiv, Ukraine).

Peripheral hemodynamic was studied by the electrodes on the lower extremities directly below the knee joint, and another one slightly proximal to the ankle joint.

Statistical analysis due to the normality of sample distribution (by Shapiro-Wilk test) was made by parametric methods. Correlation analysis was carried out with the definition of Spearman's nonparametric coefficient by ANOVA method. All data are expressed as means ± SD for all subjects.

A summary of the 20-minute testing with different IPC of pressure indicators in the chambers led to the following outcomes. Correlational analysis of systolic-diastolic index with the maximum value of systolic amplitude manifested minor changes on 5-10 min of procedure [0,3886±0,02157 (mean ± SD)] from index values [0,1661±0,02959 (mean ± SD)] on 5-10 min of procedure corresponding changes of systolic amplitude indicating long-term permanent adaptation of the general blood flow after IPC intervention with correlation coefficient of 0.9981 (Fig.1) (Table 1)

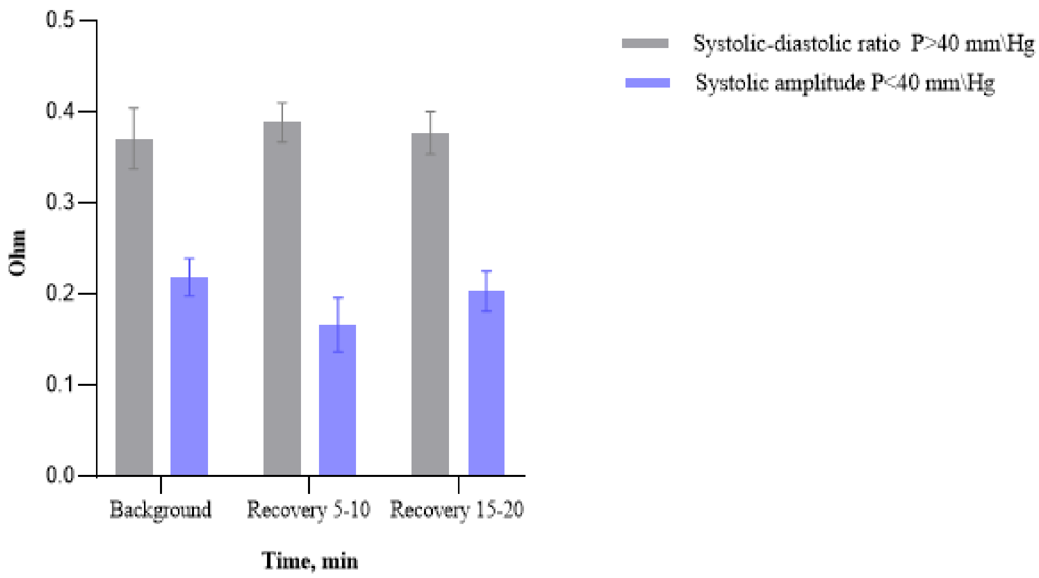

Fig.1. *Systolic-diastolic ratio and Systolic amplitude. The results are shown the changes of Systolic -diastolic ratio and Systolic amplitude, r = -0,9981*

Table 1

Correlation analysis of systolic-diastolic index with the maximum value of systolic amplitude

Indicators	Conditions		
	Background	Recovery 5-10	Recovery 15-20
Systolic-diastolic index P> 40 mm/Hg	0,371±0,033	**0,388** ±0,021*	0,377± **0,023***
Systolic amplitude P<40 mm/Hg	0,218±0,020	**0,166**±0,029*	**0,203**±0,021*

Values (mean ± SD) show the changes of Systolic-diastolic index and Systolic amplitude
*Values that are different from the respective rest value.

Veritable correlation as well, as in the following consequences, was perceived clearly at the pressure limit in the IPC chambers device below or above 40 mm Hg. Other pressure outcomes between 60 mm Hg and 80 mm Hg were not reliable.

The increase systolic amplitude and based impedance for about 15 and 20 minutes of recovery after procedure was observed to be statistically significant (the correlation coefficient is 0.7705). The amplitude of the systolic wave, which is mainly determined by the pulse blood filling, increases (0.2125±0.020 Ohm) compared to the background period (0.2084±0.020 Ohm) (Table 2) that is, the larger the volume of the muscle tissue blood filling per unit time, the greater the increase of amplitude [9,10]. About it also evidenced by the Based Impedance primarily concerned with the determination of left ventricular stroke volume (Fig-2).

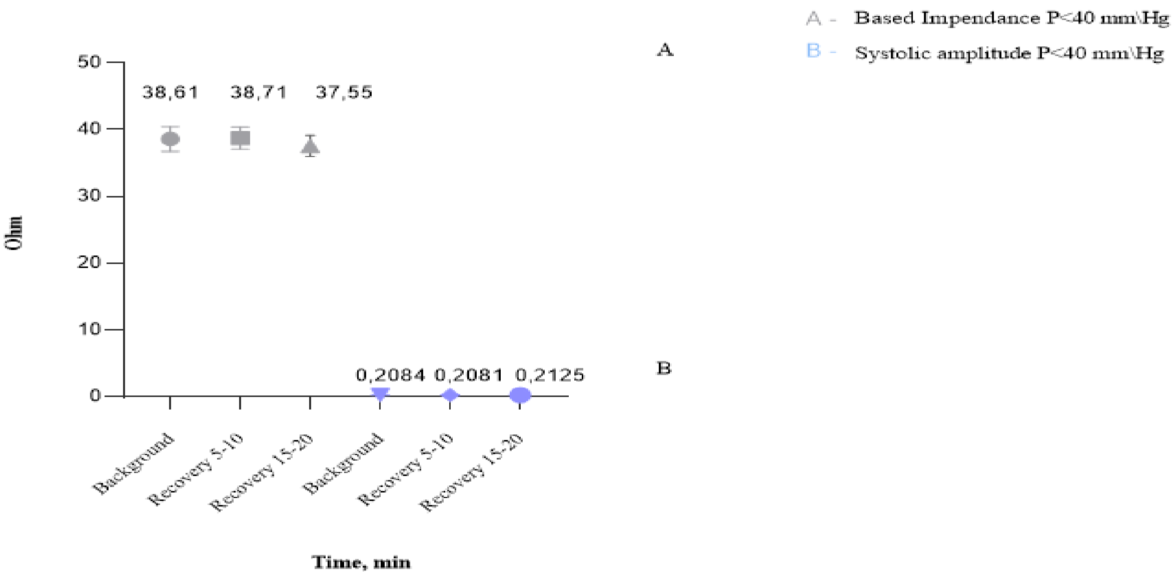

Fig.2. *The relationship between the changes of based impedance and the changes of systolic amplitude, r = 0,7705*

Table 2

Correlation analysis of based impedance and systolic amplitude

Indicators	Conditions		
	Background	Recovery 5-10	Recovery 15-20
Based impedance P> 40 mm/Hg	**38.610**±1.820	**38.720**±1.660	**37.560**±1.560 *
Systolic amplitude P>40 mm/Hg	**0.208**±0.020	**0.208**±0.015	**0.212**±0.020 *

Values (mean ± SD) show the changes of Based impedance and Systolic amplitude
*Values that are different from the respective rest value.

Compared with the background condition, compression resulted in increased time of fast blood filling [0,03571±0,004427(mean ± SD)] and systolic amplitude [0,1810±0,02559(mean ± SD)] for about 15 and 20 minutes of recovery after procedure. The correlation coefficient is 0.7705 (Fig-3), which can be considered as increase the elasticity and tone of the vascular wall of the large femoral arteries and the contractile function of the cardiac myocardium [10] on the pressure parameters more than 40 mm Hg. The decrease in the tone of small and medium arteries is indicated by increase in the average rate of slow blood filling from [1,052±0,1354(mean ± SD)] till [308±0,1373*(mean ± SD) for about 15 and 20 minutes of recovery.

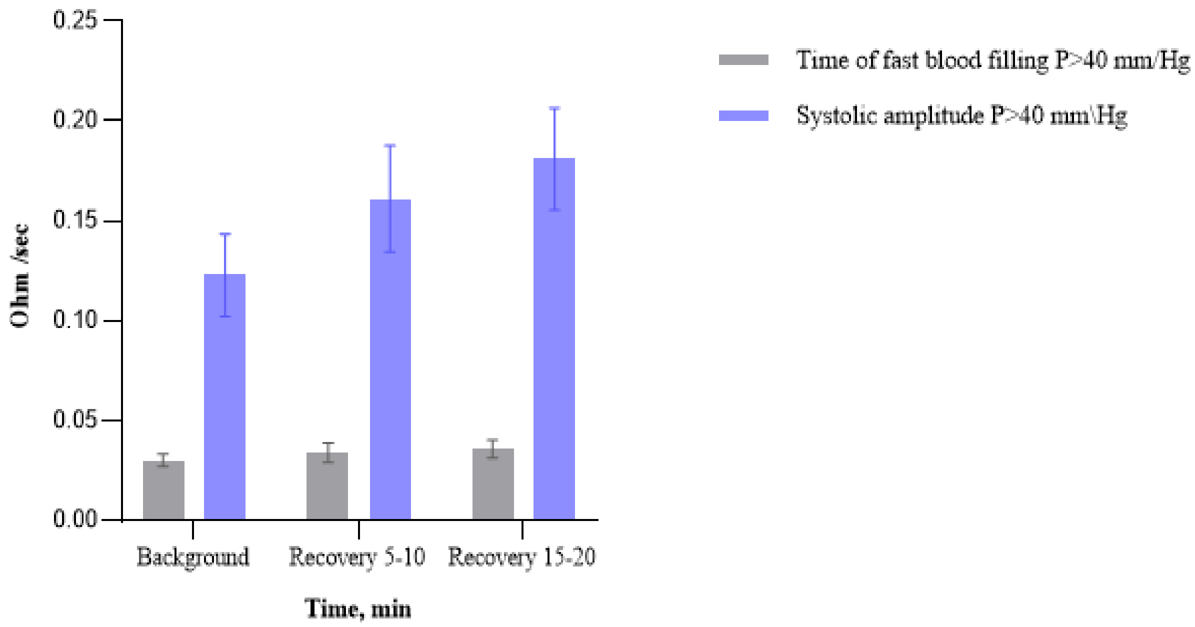

***Fig.3.** The relationship between the changes of fast blood filling and the changes of systolic amplitude, r = 0,9998*

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Table 3

Correlation analysis of time of fast blood filling and systolic amplitude

Indicators	Conditions		
	Background	Recovery 5-10	Recovery 15-20
Time of fast blood filling P> 40 mm/Hg	0,030±0,003	**0,033**±0,004	**0,035**±0,004 *
Systolic amplitude P>40 mm/Hg	0,122±0,020	**0,161**±0,026	**0,181**±0,025 *

Values (mean ± SD) show the changes of the time of fast blood filling and systolic amplitude

Peaks in the low frequency (LF) ranging from 0.04 Hz to 0.15 Hz is were increase for about 5-10 min in recovery period (Fig.5). Obtained changes in vascular tone indirectly indicate a shift in sympathovagal balance towards the predominance of sympathetic influences, that is, it reveals an increased tension in the mechanisms of regulation of cardiovascular activity corresponds to the indicators given in another authors [11]. The LF/HF ratio, which consists of the ratio of the powers is used to quantify the sympathovagal balance [11-13]. Based on the correlated analysis of sympatho-vagal balance, we can assume that with increasing cuff pressure and lack of heart rate variability to achieve a stable adaptive sympathetic tone, which theoretically allows to achieve a long-term hypotensive non-invasive effect (Fig.6).

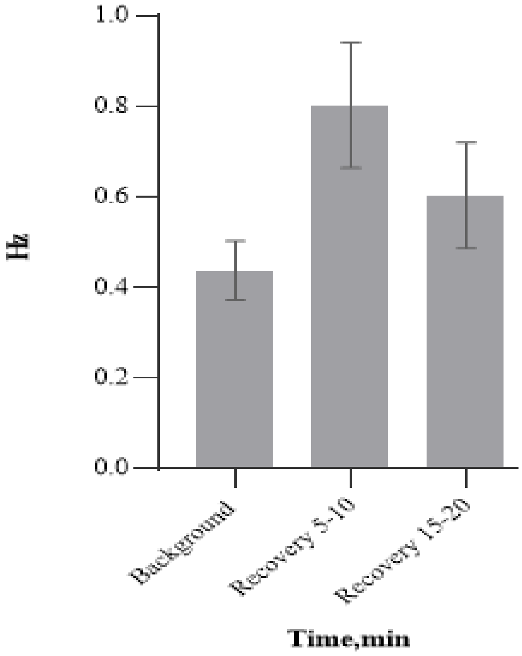

Fig.5. *Low frequency (LF), P=40 mm/Hg*

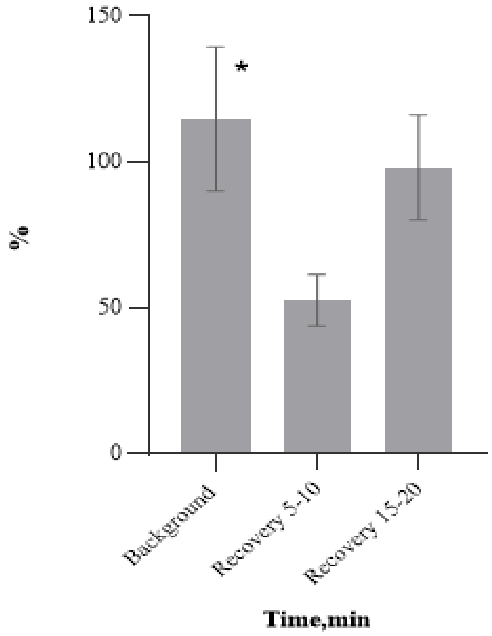

Fig.6. *The sympathetic-parasympathetic balance (LF/HF ratio), P=40mm/Hg*

Conclusion. Assuming of the current study objectives were to determine most effectiveness external pressure parameter on to peripheral and central blood flow and optimal procedure timing findings, and on the gained results. Considering the equal time procedure intervention (average time 20 minutes of active ICP) with different compression values (below 40 mm Hg - up to 80 mm Hg) effects on the central blood flow in to magistral arteries of lower limbs was observed. Changes of systolic amplitude indicating long-term permanent adaptation of the general blood flow after IPC intervention. Would be assumed that, depending on the compression parameters, the procefure time also depends if it was supposed to achieve an effect on the central hemodynamics. In case study, the recommended is that with an increase in cuff pressure, the recommended time should within 20 minutes or less. And vice versa - to achieve a lesser effect on central hemodynamics - the compression in the cuffs should be reduced to values less than 40 mm Hg and, accordingly, the procedure time should be increased.

Based Impedance changes [Fig 2] allow us to conclude than long adaptive effects with high compression index primarily concerned with the determination of left ventricular stroke volume due to the effect on the elastic component of the large arteries and ventricles itself [14]. Small and medium arteries tone decrease is indicated by increase in the average rate of slow blood filling. It makes sense to assume that it is advisable to increase the procedure time at lower values in the chambers of the IPC corresponds to our previous conclusion. Based on the correlated analysis of sympatho-vagal balance, we can assume that with increasing cuff pressure and lack of heart rate variability to achieve a stable adaptive sympathetic tone, which theoretically allows to achieve a long-term hypotensive non-invasive effect. Correlation of indicators [Fig 3] to increase the tone of the process of medium and small hummingbirds is possible due to the average pressure in the cuffs below 40 mm Hg and by replenishing the time. In our case, more than 20 minutes. Linear increase in the average rate of slow blood donation P>40 mm Hg on the 5-10 min of recovery [1,192±0,1457(mean ± SD)] and on the 15-20 min of recovery [1,308±0,1373 (mean ± SD)] from the respective rest value can only indicate confirmation of this hypothesis. Applying IPC devices for prevention hypertension is gradually becoming a standard second-order therapy, particularly for patients with a high risk bleeding. However, further studies for determining a more accurate time of inflation and deflation in the chambers of IPC devices are required.

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