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# The Immediate Effects of the Manual Therapy Traction Manipulations on Parameters of Cardiorespiratory System Functioning

**Oleksandr Romanchuk**

Faculty of Physical Therapy and Occupational Therapy, Ivan Boberskij Lviv State University of Physical Culture, Lviv, Ukraine

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**Abstract** The aim of this study was to determine the changes in the cardiorespiratory system activity under the influence of traction manipulations in the thoracic spine. The study involved 26 adults, including 18 women aged 39.6 ± 12.1 years and 8 men aged 36.3 ± 8.3 years. The mean age of patients was 38.6 ± 11.2 years. The work used an integral method of studying the cardiorespiratory system - spiroarteriocardiorhythmography (SAKR). SACR registration was performed before and after traction manipulations in the thoracic spine directly in the procedure of manual therapy. The study of the immediate effect of traction manipulations of SMT in the thoracic spine on the cardiorespiratory system allowed establishing the main significant effects: decrease in HR (min$^{-1}$) from 85.1 (77.1; 94.2) to 79.5 (69.8; 87.6), p=0.000, decrease in duration of QTC (s) from 0.419 (0.404; 0.434) to 0.413 (0.401; 0.427), p=0.012, decrease in CO (dm$^3$) from 5.2 (4.6; 5.8) to 4.9 (4.4; 5.6), p=0.000, SI (dm$^3$/m$^2$) from 3.05 (2.75; 3.30) to 2.90 (2.62; 3.20), p=0.000, increase in Vexp (L/s) from 0.28 (0.22; 0.34) to 0.31 (0.25; 0.39), p=0.030. The obtained data suggest that the main effects of traction manipulations on the thoracic spine are associated more with the changes in hemodynamic parameters of blood circulation due to activation of expiratory muscles and chest mobility, when the suction mechanisms of the chest and cardiovascular function of diaphragm are activated.

**Keywords** Cardiorespiratory System, Spinal Manual Therapy

## 1. Introduction

Spinal manual therapy (SMT) is a method of physical therapy, which involves direct contact between a physical therapist and a patient, when through the use of massage, manipulation and mobilization techniques, passive physical exercises he affects different parts of the human body. Current research considers, first of all, the effects of SMT, associated with the impact on pain intensity and the patient's motor functions. These include hypoalgesia, sympathicotonia, decreased spinal rigidity, increased muscle strength and endurance [1]. On the other hand, there are a number of scientific publications that describe and systematize the total effects of SMT associated with peripheral, spinal and supraspinal mechanisms [2]. Emphasis is placed on the fact that SMT significantly reduces the level of cytokines in the blood and serum during joint manipulations [3], provides the changes in blood level of β-endorphin, anandamide, N-palmitoylethanolamide, serotonin [4], endogenous cannabinoids [5], activations the muscles proprioceptors [6], reduces pain [7], improves the afferentation [8], changes the muscle activity [9], and reduces a supraspinal areas activation responsible for central pain [10]. A number of authors have shown the improvement of autonomic and opioid reactions [11; 12], dopamine synthesis [13], and the «CNS» condition [14]. The positive effect on the psycho-emotional state of patients was also observed [15]. Some studies have shown that SMT improves athletic performance, reduces spasticity of the athletes with cerebral palsy, increases forced vital lung capacity and forced exhalation, improves lung function and activity of the patients with chronic obstructive pulmonary disease, moreover it is even included into the respiratory treatment protocols [16-19]. Some attention was paid to the autonomic effects of SMT, which include the changes in heart rate variability (HRV), peripheral blood flow and skin conduction [20-22].

However, no any works have been found to determine the combined changes of the cardiovascular, respiratory, autonomic nervous system, taking into account the use of different techniques of SMT.

## 2. Objectives

The aim of this study was to determine the principal changes in the cardiorespiratory system activity under the influence of traction manipulations in the thoracic spine.

## 3. Methods

The study was conducted on the basis of the clinical sanatorium. VP Chkalov (Odesa, Ukraine) during 2003-2005. 26 adults were involved in the study, including 18 women aged 39.6 ± 12.1 years and 8 men aged 36.3 ± 8.3 years. The mean age of patients was 38.6 ± 11.2 years. All patients were diagnosed with osteochondrosis of the thoracic spine, which was confirmed by radiographic examination. A number of patients that had concomitant diseases was 9 women who had autonomic dystonia syndrome, 2 men had stage 1 hypertension. Most patients complained of intermittent pain in the thoracic spine associated with both physical activity and prolonged sitting. The characteristics of morphometric parameters of patients are presented in Table 1.

**Table 1.** Morphometric parameters of patients

| Parameters | Men (n=8) | Women (n=18) |
|---|---|---|
| Body length, cm | 172,0 (171,0; 173,0) | 164,0 (160,0; 168,0) |
| Body mass, kg | 82,0 (70,0; 90,0) | 61,0 (50,0; 68,0) |
| BMI, kg/m$^2$ | 28,4 (23,7; 30,4) | 23,1 (19,4; 26,6) |

The study of the cardiorespiratory system was conducted in the first days of a resort treatment during the first procedure of SMT before and after the use of traction manipulations directly in the physician office.

The device of studying the cardiorespiratory system defined as spiroarteriocardiorhythmograph (SACR) has been used. Its simultaneously records the heart rate, rhythms of systolic and diastolic pressure at each heartbeat and respiratory rhythms, which provides significant time savings to determine the functional state of the heart, vessels and respiration, as well as identifies the important parameters of their interaction [23]. ECG recording in 1 lead allowed to determine the indicators of heart rate variability (HRV) according to the spectral analysis of the sequence of RR intervals is total power (TP, ms$^2$), power in the very low frequency range (VLF, ms$^2$), power in the low frequency range (LF, ms$^2$) and power in the high frequency range (HF, ms$^2$) and their derivatives (LFn, n.u., HFn, n.u., LF/HF) [24-26]; according to cardiointervalometry it is possiple to define the heart rate (HR, min$^{-1}$), durations and intervals of PQRST-complex – P (s), PQ (s), QRS (s), QT (s), QTC (s), ST (n.u.); indicators of systemic hemodynamics [27-29] – end-diastolic volume (EDV, cm$^3$), end-systolic volume (ESV, cm$^3$), stroke volume (SV, cm$^3$), cardiac output (CO, dm$^3$), stroke index (SI, cm$^3$/m$^2$), cardiac index (CI, dm$^3$/m$^2$), general peripheral vascular resistance (GPVR, dyn/s/cm$^{-5}$). According to the pulse wave recording with the help of a photoplethysmographic sensor on the finger by the Penaz method [30, 31], blood pressure (SBP, mmHg; DBP, mmHg) and its variability (SBPV and DBPV) in the ranges similar to HRV were determined as a total power of SBPV and DBPV ($TP_{SBP}$, mmHg$^2$ and $TP_{DBP}$, mmHg$^2$), power in the very low-frequency range ($VLF_{SBP}$, mmHg$^2$ and $VLF_{DBP}$, mmHg$^2$), power in the low-frequency range ($LF_{SBP}$, mmHg$^2$ and $LF_{DBP}$, mmHg$^2$) and power in the high-frequency range ($HF_{SBP}$, mmHg$^2$ and $HF_{DBP}$, mmHg$^2$) and their derivatives – $LF_{SBP}$n, n.u., $HF_{SBP}$n, n.u., LF/$HF_{SBP}$, $LF_{DBP}$n, n.u., $HF_{DBP}$n, n.u., LF/$HF_{DBP}$ [32-35]. Additionally by using the spectral method determined the index of arterial baroreflex sensitivity (BRS, ms/mmHg) – α-coefficient, which was calculated in high ($BRS_{HF}$) and low ($BRS_{LF}$) frequencies ranges [36-38].

$$BRS_{LF} = \sqrt{} LF_{HRV}\ (ms^2)/LF_{SBP}\ (mmHg^2) \qquad (1)$$

$$BRS_{HF} = \sqrt{} HF_{HRV}\ (ms^2)/HF_{SBP}\ (mmHg^2) \qquad (2)$$

The ultrasonic sensor of the SACR device allows to measure flows of air on inspiration and expiration and to define the average parameters of a respiration pattern (PR): duration of inspiratory (Tin, s), duration of expiratory (Tex, s), tidal volume ($V_T$, L), volumetric inspiratory velocity (Vin, L/s), volumetric expiratory velocity (Vex, L/s), the fraction of inspiration in the respiratory cycle (Ti/(Ti+Te) (c.u.), as well as the volume of minute respiration ($V_E$); and calculate the parameters of respiration variability (RV): total power of respiration ($TP_R$, (L/min)$^2$), respiration power in the very low-frequency range ($VLF_R$ (L/min)$^2$), respiration power in the low-frequency range ($LF_R$ (L/min)$^2$) and respiration power in the high frequency range ($HF_R$ $(L/min)^2$) and their derivatives – $LF_Rn$, $HF_Rn$, $LF/HF_R$ – in n.u. [39, 40]

Indicators of frequency and volume synchronization of the cardio-respiratory system were also calculated – Hildebrandt index (IH) and the ratio of CO to $V_E$ (IVS) [41, 42].

$$IH = HR\ (min^{-1})/RR\ (min^{-1}) \quad (3)$$

$$IVS = CO\ (dm^3)/\ V_E\ (L) \quad (4)$$

All studies were carried out in a sitting position, and the duration of registration of the cardiorespiratory system parameters was 2 minutes before and 2 minutes after manipulation.

This study involved the determination of changes in the cardiorespiratory system in the SMT procedure, which had several parts. In the first part of the procedure, acupressure was performed in a supine position on the abdomen and back, taking into account muscle tension and pain points. In the second part of the procedure, mobilization and manipulation techniques were performed, which involved the use of manipulations and mobilizations in the supine and sitting positions. After the transition from the supine position to the sitting position and a minute break to adjust the device, the first recording of the cardiorespiratory system indicators using the SACR device took place. After registration, a manipulative effect was performed on the thoracic spine, which involved the use of traction manipulations for the upper, middle and lower thoracic spine according to the method of Yumeiho [43-45]. After the manipulations and adjustment of the device, the cardiorespiratory system parameters were re-registered using SACR. Then the SMT procedure continued. In general, the duration of the SMT procedure was about one hour.

The processing of the received results was carried out with the help of STATISTICA program for Windows (version 10.0), Microsoft Excel 2012. The comparison of quantitative indices in studied groups was realized using non-parametric criterion of Wilcoxon.

## 4. Results

Table 2 presents the changes in the electrical activity of the heart, which indicate that under the influence of traction manipulations there is a significant decrease in HR ($min.^{-1}$) from 85.1 (77.1; 94.2) to 79.5 (69.8; 87.6), p=0.000, which is accompanied by a decreased duration of QTC (s) from 0.419 (0.404; 0.434) to 0.413 (0.401; 0.427), p=0.012. Such changes may characterize the improvement in contractile function of the heart, which is realized through the improvement of electrical systole of the ventricles against the background of slowing HR.

**Table 2.** Changes in cardiointervals and ECG-segments under the influence of traction manipulations

| Parameters | Before | After | T | Z | p-value |
|---|---|---|---|---|---|
| HR, $min^{-1}$ | 85.1 (77.1; 94.2) | 79.5 (69.8; 87.6) | **20.0** | **3.95** | **0.000** |
| P,s | 0.093 (0.086; 0.103) | 0.092 (0.088; 0.101) | 145.5 | 0.46 | 0.647 |
| PQ,s | 0.123 (0.112; 0.143) | 0.123 (0.108; 0.145) | 128.0 | 0.93 | 0.353 |
| QR,s | 0.033 (0.031; 0.034) | 0.033 (0.031; 0.034) | 104.5 | 0.38 | 0.702 |
| QRS,s | 0.087 (0.081; 0.094) | 0.086 (0.081; 0.097) | 105.5 | 0.99 | 0.323 |
| QT,s | 0.351 (0.327; 0.375) | 0.356 (0.338; 0.376) | **53.5** | **2.93** | **0.003** |
| QTC,s | 0.419 (0.404; 0.434) | 0.413 (0.401; 0.427) | **77.0** | **2.50** | **0.012** |
| ST,n.u. | 0.029 (-0.064; 0.109) | 0.049 (-0.032; 0.083) | 155.5 | 0.51 | 0.611 |

**Table 3.** Changes in heart rate variability under the influence of traction manipulations

| Parameters | Before | After | T | Z | p-value |
|---|---|---|---|---|---|
| TP, $ms^2$ | 1361.6 (712.9; 3422.3) | 1180.8 (635.0; 3636.1) | 175.0 | 0.013 | 0.990 |
| VLF, $ms^2$ | 376.4 (240.3; 640.1) | 400.5 (132.3; 841.0) | 163.0 | 0.317 | 0.751 |
| LF, $ms^2$ | 387.0 (185.0; 702.3) | 379.2 (153.8; 876.2) | 155.0 | 0.521 | 0.603 |
| LFn,n.u | 49.2 (31.7; 65.4) | 47.4 (31.4; 60.5) | 136.0 | 1.003 | 0.316 |
| HF, $ms^2$ | 311.2 (148.8; 1354.2) | 630.7 (121.0; 1552.4) | 121.0 | 0.829 | 0.407 |
| HFn,n.u. | 46.0 (25.4; 59.1) | 43.6 (32.5; 59.2) | 169.0 | 0.165 | 0.869 |
| LFHF, $ms^2/ ms^2$ | 1.11 (0.49; 2.56) | 1.00 (0.64; 1.69) | 109.0 | 0.882 | 0.378 |

Given the HRV indicators (Table 3), it should be noted that significant changes in HRV indicators under the influence of traction manipulations on the thoracic spine, in general, did not occur.Certain rearrangements of regulatory manifestations can be observed from the high-frequency component of HRV (HF, ms2), but they are not significant. Based on data from other researchers, it can be assumed that this effect is associated with a variety of manifestations of osteochondrosis of the thoracic spine, which were observed in this group of patients and there are related to the manifestations of pain, mobility of individual segments and the presence of subluxations. It should be noted that a previous analysis of HRV even of the patients with spinal injuries did not reveal significant differences between patients with injuries, parathletes and virtually healthy individuals [46]. At the same time, a number of authors have shown that 6-week osteopathic treatment, which consisted of breathing exercises and SMT, is useful for increasing HRV compared with no treatment and can cause favorable autonomic modulation (predominance of parasympathetic over sympathetic) [21]. This is the basis for further refinement of the results, taking into account the effectiveness of SMT in the presence of spinal diseases complications.

The Penaz method allows determining fluctuations in blood pressure at each heart rate. The differences in the sequential values of systolic and diastolic arterial pressure determine the variable series of values, then they were analyzed by the Fourier spectral analysis of which the blood pressure variability is calculated [47, 48] separately for SBP and DBP. In our previous studies, criteria were developed to assess the variability of systolic and diastolic blood pressure in virtually healthy young people and athletes [49]. Features of its changes in different levels of somatic health are shown, taking into account the level of physical capacity [50-52] are shown. Changes in SBPV and DBPV under the influence of physical training were also studied [35]. According to the data known and obtained by us, the increase in SBPV and DBPV is prognostically unfavorable [53, 54]. It is evident that this usually indicates a violation of the baroreflex regulation mechanisms [55-57]. Table 4 presents changes in SBPV and DBPV.

Absolute values of systolic and diastolic blood pressure are within the norm and do not change under the influence of traction manipulations. Among the significant changes in SBPV and DBPV, only the decrease in the relative contribution of regulatory effects on DBP in the high-frequency range (HFDBPn, n.u.) from 25.4 (15.1; 41.5) to 22.9 (16.0; 28.9), p=0.038, deserves the attention. The latter may characterize the increase in the relative effects of the sympathetic link ANS [35] on vascular tone under the influence of traction manipulations. Other indicators of SBPV and DBPV do not change significantly.

**Table 4.** Changes in systolic and diastolic blood pressure variability under the influence of traction manipulations

| Parameters | Before | After | T | Z | p-value |
|---|---|---|---|---|---|
| SBP, mmHg | 124.4 (109.6; 134.6) | 123.8 (114.1; 139.5) | 143.5 | 0.511 | 0.609 |
| DBP, mmHg | 74.6 (69.3; 84.9) | 75.9 (69.6; 84.7) | 126.0 | 0.982 | 0.326 |
| $TP_{SBP}$, $mmHg^2$ | 23.5 (16.8; 38.4) | 23.5 (15.2; 39.7) | 130.5 | 0.861 | 0.389 |
| $TP_{DBP}$, $mmHg^2$ | 10.2 (5.8; 15.2) | 6.8 (4.8; 13.7) | 136.0 | 0.713 | 0.476 |
| $VLF_{SBP}$, $mmHg^2$ | 10.2 (5.8; 17.6) | 9.0 (4.8; 13.7) | 150.0 | 0.336 | 0.737 |
| $VLF_{DBP}$, $mmHg^2$ | 3.8 (2.3; 9.6) | 3.6 (1.7; 6.8) | 141.0 | 0.876 | 0.381 |
| $LF_{SBP}$, $mmHg^2$ | 6.3 (4.4; 13.0) | 7.6 (3.6; 10.2) | 154.0 | 0.229 | 0.819 |
| $LF_{DBP}$, $mmHg^2$ | 2.3 (1.4; 4.8) | 2.9 (1.4; 3.6) | 166.5 | 0.229 | 0.819 |
| $LF_{SBP}$n,n.u. | 52.3 (39.8; 71.0) | 58.8 (49.0; 73.5) | 152.0 | 0.597 | 0.551 |
| $LF_{DBP}$n,n.u. | 68.6 (52.2; 82.4) | 73.0 (65.1; 79.6) | 122.0 | 1.359 | 0.174 |
| $HF_{SBP}$, $mmHg^2$ | 5.8 (2.3; 7.8) | 3.8 (2.3; 9.0) | 139.0 | 0.314 | 0.753 |
| $HF_{DBP}$, $mmHg^2$ | 0.9 (0.4; 1.7) | 0.6 (0.4; 1.4) | 104.5 | 1.019 | 0.308 |
| $HF_{SBP}$n,n.u. | 38.2 (26.0; 50.4) | 31.8 (21.0; 48.9) | 135.5 | 0.414 | 0.679 |
| $HF_{DBP}$n,n.u. | 25.4 (15.1; 41.5) | 22.9 (16.0; 28.9) | **94.0** | **2.070** | **0.038** |
| $LFHF_{SBP}$, $mmHg^2/mmHg^2$ | 1.45 (0.92; 2.72) | 1.84 (1.00; 3.46) | 159.0 | 0.419 | 0.675 |
| $LFHF_{DBP}$, $mmHg^2/mmHg^2$ | 2.69 (1.19; 5.52) | 3.10 (2.34; 4.84) | 121.0 | 1.384 | 0.166 |

Analyzing the results of changes in RV indicators (Table 5), it should be noted that their changes occurred only at the level of the tendency to decrease low-frequency effects ($LF_R$, $(L/min)^2$) on the formation of respiratory rhythm from 23.5 (13.7; 72.3) to 18.1 (10.9; 57.8), p=0.058. Although our previous studies have shown the informativeness of RV in the differentiation of patients with different courses of bronchial asthma [40], under the influence of training loads in the development of overexertion of cardiovascular regulation [39, 58, 59], as well as controlled breathing [49].

The changes in the respiration pattern were more significant (Table 6), which were characterized by a significant increase in respiratory rate (RR, $min^{-1}$) from 18.7 (15.5; 21.5) to 20.2 (17.1; 23.7), p=0.003, which occurred due to a decrease in duration exhalation (Texp, s) from 1.82 (1.59; 2.24) to 1.58 (1.35; 1.94), p=0.000. There was a significant increase in volumetric expiratory velocity (Vexp, L/s) from 0.28 (0.22; 0.34) to 0.31 (0.25; 0.39), p=0.030, and the fraction of inspiration in the respiratory cycle (Ti/(Ti+Te) from 0.42 (0.39; 0.45) to 0.44 (0.41; 0.51), p=0.002. Other parameters such as tidal volume ($V_T$, L) and minute tidal volume ($V_E$, L) did not change significantly. Although, traction manipulation of SMT leads to the improvement of the expiratory force. It's probably due to improved chest mobility and increased activity of respiratory muscles.

The obtained results are supplemented by the data of the analysis of systemic hemodynamic parameters (Table 7), which indicate that due to traction of the thoracic spine there is a significant decrease in CO ($dm^3$) from 5.2 (4.6; 5.8) to 4.9 (4.4; 5.6), p=0.000, SI ($dm^3/m^2$) from 3.05 (2.75; 3.30) to 2.90 (2.62; 3.20), p=0.000, and increase of GPVR ($dyn/s/cm^{-5}$) from 1398.7 (1298.6; 1581.6) to 1476.0 (1282.9; 1775.8), p=0.013. This may confirm the results of DBPV analysis, which showed a redistribution of the activity of ANS in the direction of increasing sympathicotonic effects. It turned out to be informative that the traction effect on the thoracic spine does not affect the sensitivity of the arterial baroreflex in the low-frequency range $BRS_{LF}$ (ms/mmHg) – 8.7 (5.3; 12.0) against 8.3 (5.4; 11.6), p=0.829, nor in the high-frequency range $BRS_{HF}$ (ms/mmHg) – 9.6 (6.9; 15.2) vs. 10.6 (6.1; 14.7), p=0.424. At the same time, the indicators of synchronization of the cardiovascular and respiratory systems have changed: significantly IH (n.u.) from 4.63 (3.98; 5.31) to 4.05 (3.54; 4.62), p=0.000; at the trend level – IVS ($dm^3/L$) from 0.543 (0.413; 0.760) to 0.452 (0.396; 0.515), p=0.052.

**Table 5.** Changes in the variability of spontaneous respiration under the influence of traction manipulations

| **Parameters** | **Before** | **After** | **T** | **Z** | **p-value** |
|---|---|---|---|---|---|
| $TP_R$, $(L/min)^2$ | 815.3 (605.2; 1281.6) | 699.7 (590.5; 1413.8) | 164.0 | 0.292 | 0.770 |
| $VLF_R$, $(L/min)^2$ | 10.9 (4.0; 21.2) | 11.2 (2.9; 16.0) | 158.0 | 0.121 | 0.904 |
| $LF_R$, $(L/min)^2$ | 23.5 (13.7; 72.3) | 18.1 (10.9; 57.8) | 101.0 | 1.892 | 0.058 |
| $LF_R$n,n.u. | 3.5 (1.5; 14.3) | 2.4 (1.3; 9.7) | 96.5 | 1.776 | 0.076 |
| $HF_R$, $(L/min)^2$ | 663.1 (372.5; 1062.8) | 564.1 (357.2; 761.8) | 168.0 | 0.190 | 0.849 |
| $HF_R$n,n.u. | 83.6 (59.9; 94.4) | 84.4 (56.2; 93.7) | 161.5 | 0.356 | 0.722 |
| $LFHF_R$, $(L/min)^2/(L/min)^2$ | 0.058 (0.017; 0.203) | 0.032 (0.017; 0.109) | 87.0 | 1.800 | 0.072 |

**Table 6.** Changes in the patterns of respiration under the influence of traction manipulations

| **Parameters** | **Before** | **After** | **T** | **Z** | **p-value** |
|---|---|---|---|---|---|
| Tinsp,s | 1.36 (1.21; 1.65) | 1.33 (1.14; 1.59) | 160.5 | 0.054 | 0.957 |
| Texp,s | 1.82 (1.59; 2.24) | 1.58 (1.35; 1.94) | **25.0** | **3.822** | **0.000** |
| Vt, L | 0.515 (0.450; 0.690) | 0.520 (0.440; 0.650) | 134.5 | 1.041 | 0.298 |
| Vinsp, L/s | 0.38 (0.29; 0.45) | 0.41 (0.30; 0.51) | 155.0 | 0.521 | 0.603 |
| Vexp, L/s | 0.28 (0.22; 0.34) | 0.31 (0.25; 0.39) | **90.0** | **2.172** | **0.030** |
| Ti/(Ti+Te) | 0.42 (0.39; 0.45) | 0.44 (0.41; 0.51) | **52.0** | **3.137** | **0.002** |
| RR, $min^{-1}$ | 18.7 (15.5; 21.5) | 20.2 (17.1; 23.7) | **41.0** | **2.950** | **0.003** |
| Ve, L | 10.1 (7.3; 11.4) | 10.7 (7.7; 12.5) | 117.0 | 1.486 | 0.137 |

**Table 7.** Changes in parameters systemic hemodynamics and their derivatives under the influence of traction manipulations

| Parameters | Before | After | T | Z | p-value |
|---|---|---|---|---|---|
| EDV, cm$^3$ | 92.6 (79.6; 110.2) | 92.4 (77.9; 111.0) | 149.0 | 0.673 | 0.501 |
| ESV, cm$^3$ | 32.1 (25.6; 39.4) | 30.7 (25.1; 40.3) | 154.5 | 0.533 | 0.594 |
| SV, cm$^3$ | 61.2 (50.1; 70.8) | 59.7 (51.5; 73.7) | 108.0 | 1.714 | 0.086 |
| CO, dm$^3$ | 5.2 (4.6; 5.8) | 4.9 (4.4; 5.6) | **22.5** | **3.513** | **0.000** |
| SI, cm$^3$/m$^2$ | 36.2 (29.8; 40.4) | 36.2 (32.4; 40.7) | 107.0 | 1.740 | 0.082 |
| CI, dm$^3$/m$^2$ | 3.05 (2.75; 3.30) | 2.90 (2.62; 3.20) | **25.0** | **3.437** | **0.000** |
| GPVR, dyn/s/cm$^{-5}$ | 1398.7 (1298.6; 1581.6) | 1476.0 (1282.9; 1775.8) | **78.0** | **2.476** | **0.013** |
| BRS$_{LF,}$ ms/mmHg | 8.3 (5.4; 11.6) | 8.7 (5.3; 12.0) | 167.0 | 0.216 | 0.829 |
| BRS$_{HF,}$ ms/mmHg | 10.6 (6.1; 14.7) | 9.6 (6.9; 15.2) | 144.0 | 0.800 | 0.424 |
| IH, n.u. | 4.63 (3.98; 5.31) | 4.05 (3.54; 4.62) | **19.0** | **3.975** | **0.000** |
| IVS, dm$^3$/L | 0.543 (0.413; 0.760) | 0.452 (0.396; 0.515) | 99.0 | 1.943 | 0.052 |

# 5. Discussion

SMT has a long history of application. Today, health care providers are increasingly aware of the impact of SMT on the manifestations of disability, pain and function of various systems, but the impact of SMT on the functional systems of the body is less clear [2]. The latter does not allow unifying manual influences taking into account the existing pathology of internal organs, especially cardiovascular. The effects of SMT on the respiratory system are associated with improved tidal volumes, and there are no insufficient data on cardiovascular effects [16-19]. A number of authors have shown changes in the autonomic regulation of cardiac rate according to HRV. It has been established that HRV varies depending on the area of the body where the manipulation is performed [21]. Manipulations for pain in the upper thoracic and the lower cervical regions increase HRV, and in asymptomatic volunteers reduce HRV. In acute neck pain, HRV after SMT also decreases, regardless of its location in the neck [2].

An important component of this study was the ability to measure the activity of the cardiorespiratory system in the combined mode of registration of indicators directly during the SMT procedure, which was possible due to the technical features of the SACR device and its use in the field.

Summarizing the results, it can be argued that traction manipulations in the thoracic spine have several significant effects on the cardiorespiratory system. These effects are associated with a decrease in the activity of the cardiovascular system, which is realized through a decrease in HR (min$^{-1}$), improved contractile function of the heart QTC (s), a decrease in CO (dm$^3$), SI (dm$^3$/m$^2$) during an increase in GPVR (dyn/s/cm$^{-5}$).

Characteristic of our study was the absence of significant changes in the rhythmic parameters of the cardiorespiratory system. Their determination by the parameters of HRV, SBPV, DBPV and RV showed that before and after traction manipulations in this cohort of subjects there was a significant variability of responses to the intervention, which did not allow characterizing clearly the impact. This applied, first of all, to all HRV indicators. SBPV and DBPV values also did not change significantly after manipulations. The only indicator that agreed with the data of the study of systemic hemodynamics, which had significant dynamics, was the relative contribution of high-frequency effects on diastolic blood pressure (HF$_{DBP}$n, n.u.), the decrease of which caused the predominance of low-frequency effects. The same effect was obtained by us in the study of changes in DBPV under the influence of exercise. This may indicate the mechanism of formation of the predominance of sympathicotonic effects on vascular tone.

Changes in the performance of the respiratory system were informative. At the tendency level, there was a decrease in low-frequency effects on RV, which corresponded to a significant increase in RR due to accelerated exhalation. This response differs from changes under the influence of training loads, when against the background of constant low-frequency effects there is an increase in high-frequency effects, and the duration of exhalation increases [58;59]. The regulatory provision of respiration in obstructive processes in the bronchial tree is also different, when the total power of RV at rest is significantly greater, and in tests it is significantly reduced against the background of a significant slowing of exhalation [40]. This was accompanied by a change in the frequency (IN, n.u., p=0.000) and a tendency to change the volume (IVS, dm$^3$/L, p=0.052) synchronization of the cardiovascular and respiratory systems. The probable mechanism of such acceleration of exhalation and changes of synchronization is connected with improvement of mobility in costovertebral joints and change of muscular activity which promote bigger amplitude of movements in costovertebral joints at spontaneous breathing. That is, analyzing the changes in the cardiovascular and respiratory systems, we can affirm that traction manipulations on the thoracic spine cause a restructuring of regulatory support due to systemic hemodynamics, rather than autonomous effects, as observed in manipulations on the cervical spine. Intensification of hemodynamic changes is most likely due to improved mobility in the costovertebral joints against the background of improved respiratory muscle activity, especially exhalation. The latter can activate the suction function of the chest and cardiovascular function of the diaphragm, which is reflected in the indicators of systemic hemodynamics.

## 6. Conclusions

The study of the immediate effect of traction manipulations of SMT in the thoracic spine on the cardiorespiratory system allowed establishing several significant effects: decrease in HR ($min^{-1}$) against the background of decrease in QTC (s), CO ($dm^3$), SI ($dm^3/m^2$) and increase in GPVR ($dyn/s/cm^{-5}$); decrease in Texp (s), which is accompanied by an increase in Vexp (L/s) and RR ($min^{-1}$); changes in the synchronization of the cardiorespiratory system - IH (n.u.) and IVS ($dm^3/L$); absence of regulatory changes of the ANS in terms of spectral indicators of heart rate, systolic and diastolic blood pressure, as well as spontaneous respiration.

On the whole, the obtained data suggest that the main effects of traction manipulations on the thoracic spine are associated more with changes in hemodynamic parameters of blood circulation due to the activation of expiratory muscles and chest mobility, when the suction mechanisms of the chest and cardiovascular function of diaphragm are activated. The changes in an activity of the ANS regulatory effects were less significant.

## Conflicts of Interest

Authors have declared that competing interests don't exist.

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