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Original Article

The effects of body positions on the inversion gravity table on cardiovascular parameters in healthy adults

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Abstract
Problem Statement. In present, the study of the cardiovascular effects of the exposure of the body to various positions during inversion therapy represents a challenging research topic. **Purpose.** To investigate the peripheral hemodynamic effects of the successive exposure of the body to positions specific to the use of the inversion table during physical therapy sessions. **Methods.** We realized a prospective observational study on a group of 20 young adults (9 women and 11 men, mean age 28.1 ± 10.10 years).

For each subject, we repeatedly determined the blood pressure and pulse rate in three successive positions on an inversion table, in the following order: vertical orthostatic position, supine horizontal position and vertical Trendelenburg position. **Results.** We revealed a specific pattern of the dynamics of the cardiovascular variables, which as a whole indicates the slight average decrease of pulse rate, systolic blood pressure, diastolic blood pressure, mean blood pressure and a slight increase of ratio between systolic and diastolic blood pressure and of the pressure difference between high and low blood pressure, between the three measurements done. The protocol of changing 3 different postures elicits a statistically significant influence in all parameters, excepted SBP, for certain combinations of comparison of mean scores ($p < 0.05$).
Conclusions. The results of our study demonstrated that the adoption of extreme positions in relation to the gravitational field definitely influences the human body in terms of the investigated cardiovascular parameters.
Key words: blood pressure, pulse rate, orthostatic position, supine position, Trendelenburg position, healthy subjects.

Introduction

Blood pressure (BP) is a highly regulated physiological variable, based on central and peripheral control mechanisms, with a high level of integration and redundancy (Joyner & Limber, 2014). The complex processes for BP regulation in the systemic and pulmonary circulation have improved over time as a result of human evolution in the context of permanent exposure to environmental stress factors (Schulte et al., 2015). Also, the human predisposition for hypertension is a consequence, in part, of our evolution process (Young, 2007). Among the environmental factors, an important role in the analysis of hemodynamics is represented by gravity. Thus, the pressure required to perfuse the capillaries in different tissues has an evolutionary mark in mammals, as a result of the exposure of the organisms to gravity (White &Seymour, 2014).

The influence of gravity on blood circulation has been the subject of numerous studies, with direct applicability in different fields of medicine. For the most part, everyday human activities involve body positions between orthostatism and supine, with exposure to normal gravity. In certain special situations (for example, certain occupations, sports activities, etc.), the human body can exit the normal gravitational stress and may be exposed to greater or lesser gravitational accelerations. Such situations refer to immersion, travel by car, space flights, etc. There is a special interest in the evaluation of the cardiovascular changes induced by exposure to microgravity especially in aerospace medicine (Seibert et al., 2018).

Keeping extreme positions of the body, in unusual situations, also determines a series of systemic physiological changes, which can sometimes migrate to the pathological sphere. Therefore, stress positions in exceptional, extreme and torturous environments can lead to acute or chronic neurological, circulatory or joint damage (Leach, 2016). On the other hand, the dosage exposure of the body to certain stress positions can be used for therapeutic purposes, for example in cardiopulmonary physical therapy (Albarrati et al., 2018).

Certain procedures that require reverse body positions have been generically included in concepts as gravity inversion therapy or gravity-assisted inverted spinal traction (Klatz et al., 1983).

From the mentioned stressful positions, special attention was paid to the Trendelenburg position. Classically, the Trendelenburg position is defined as a pelvis-up and head-down position steep head down and was proposed in the 1870s by German surgeon Friedrich Trendelenburg as a mean of improving access to pelvic pathology (Martin, 1995; Bernstein et al., 1999). In practice, the Trendelenburg position (with head-down) and the reverse version (reverse Trendelenburg, with head-up) have multiple variants of clinical application,

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depending on the angle of inclination of the head and torso, the position of the limbs, etc. As a result, the usefulness of the position has been extensively studied, the results sometimes being contradictory. Basically, this method of posturing the patient is especially recommended in acute hypotension and/or shock, due to hemodynamics effects of improving venous return, although there are also opinions that question the effectiveness of the intervention (Bridges & Jarquin-Valdivia, 2005). Some authors have proven that the Trendelenburg position increased mean arterial pressure (MAP) and cardiac output after one minute of head-down tilt (Geerts et al., 2012). At the same time, other studies disprove the above described effect on MAP in normotensive individuals (Sibbald et al., 1976; Terai et al., 1995). Moreover, the position was also proposed as a screening tool for the presence of a low cerebrospinal fluid pressure syndrome in daily headache patients (Rozen et al., 2008), as a challenge test in patients with repeated syncope (the Tilt test), or as a method of therapeutic intervention in acute phase of ischaemic stroke (Gauthier et al., 2018), in intensive care or in other surgical situations (Kompanje et al., 2012).

Especially in physical therapy, there are variants of using body posture on an inversion table mostly in patients with chronic low back pain (Kim et al., 2013). Usually, inversion postures are static, but some authors have proposed exercise programs during gravity inversion (Vehrs et al., 1988). Unfortunately, these programs are not very well standardized in terms of evidence-based practice and, also, the benefits concerning the risks for patients are not clearly defined. Thereby, the study of the cardiovascular effects of the exposure of the body to various positions during inversion therapy represents a challenging research topic. For that reason, the objective of the paper is focused on investigating the peripheral hemodynamic effects of the successive exposure of the body to positions specific to the use of the inversion table during physical therapy sessions.

Material & methods

Participants

We realized a prospective observational study on a group of 20 young adults (9 women and 11 men, mean age 28.1 ± 10.10 years). Subjects were voluntary enrolled in a session of testing after giving the informed consent, in respect to the ethical principles of research. The inclusion criteria consisted of healthy individuals, with no significant pathological history in the last three months. The exclusion criteria included factors that could interfere with the procedural experimental design, like participants' fear of adopting inverted positions and emotional lability, which could produce vegetative reactions at the cardiovascular level.

Procedure

For each subject, we repeatedly determined the blood pressure in three successive positions on an inversion table, in the following order: vertical orthostatic position (VOP), supine horizontal position (SHP) and vertical Trendelenburg position (VTP). For the posturing of the subjects, we used a gravitational inversion table, KiroMed Zeta (KIROMED Kft., Debrecen, Hungary). For each subject, a preliminary training was carried out regarding the imposed requirements, adjusting the inversion device according to the height of the body. As a working technique, first, we asked our participants to maintain SHP for 15 minutes, while obtaining a state of relaxation. Then, the subjects were successively placed in the three positions for 30 seconds (VOP, SHP, VTP). After every 30 seconds, we measured the blood pressure in the respective position. The duration of each measurement was on average 30 seconds.

Blood pressure measurement was performed with the help of an ambulatory blood pressure monitor Contec ABPM50 (Contec Medical Systems Co., Ltd, China) with PC software for data recording. The device has good references regarding the accuracy of the measurements (Mena, 2013). The registered variables were: pulse rate (PR, beats/min), systolic blood pressure (SBP, mm Hg), diastolic blood pressure (DBP, mm Hg), mean blood pressure (MBP, mmHg) and the pressure difference between high and low blood pressure (PP). MBP is defined as the average arterial pressure during a cardiac cycle and reflects the vital tissue perfusion (Sainas et al., 2016). The measurements were taken at the brachial artery of the left upper arm, according to the instructions provided by the manufacturer.

The tests were performed for each participant in the morning, between 8-12 a.m., after a night of restful sleep and a regular breakfast. We chose this option because the BP values can be influenced by the circadian rhythm, the level of fatigue of the individual and the postprandial state after a plentiful meal (Nelsem et al., 2008; Ahuja et al., 2009).

Data collection and statistical analysis

The recorded data were statistically processed using the IBM SPSS 20.0 program. It should be mentioned that apart from the variables provided by ABPM50 we calculated the ratio between SBP and DBP. This indicator is correlated with the harmonious state of resting of the individual and may be useful for determining the level of sympathetic or parasympathetic hemodynamic activation (Yetkin et al., 2014; Iconaru et al., 2019).

For statistical analysis, we initially calculated the mean and standard deviation (SD), and then we applied inferential analysis of the results. In this regard, the type of data distribution (Gaussian or abnormal distribution) was determined by the Shapiro-Wilks test. Next, using ANOVA with repeated measures we obtained the statistical significance of the evolution of the parameters for a threshold p set at 0.05. Results are presented as mean ± standard deviation (SD).

Results

Following the testing, a series of data were collected that are presented in Table 1, as statistical indicators.

Table 1 – Statistical indicators of the recorded data

Position	Statistical indicator	PR beats/min	SBP mm Hg	DBP mm Hg	SBP/DBP	MBP mm Hg	PP mm Hg
VOP	mean	83.00	134.80	85.30	1.58	100.85	49.50
	SD	15.28	13.66	7.56	0.12	8.50	10.17
SHP	mean	71.50	128.90	75.40	1.72	91.40	53.50
	SD	9.18	13.33	8.93	0.13	9.60	8.63
VTP	mean	72.85	127.35	71.65	1.79	89.50	55.70
	SD	8.57	13.25	8.28	0.17	11.00	9.63

Legend: PR – pulse rate; SBP – systolic blood pressure; DBP – systolic blood pressure; MBP – mean blood pressure, PP – pressure difference between high and low blood pressure; SD – standard deviation; VOP – vertical orthostatic position; SHP – supine horizontal position, VTP – vertical Trendelenburg position.

Data analysis confirms that the subjects are normotensive, all parameters indicating the maintenance of physiological status in the three adopted positions. To determine the statistical significance of the evolution of the subjects in the three positions, we applied tools of inferential analysis. After determining the type of data distribution using the Shapiro-Wilks test, we found a normal distribution for all tested variables.

Therefore, we chose for the statistical processing of the data to use the ANOVA with repeated measures to understand whether there is a difference in every dependent variable amongst participants according to the body postures, as independent variables. The necessary assumptions to run the ANOVA analysis were checked using SPSS Statistics.

For those situations when sphericity could not be assumed after applying the Mauchly's test, we used the Greenhouse-Geisser correction for the Tests of Within-Subjects Effects. For the same test, we calculated the effect size as Partial Eta Squared and the Observed Power.

The results of the Tests of Within-Subjects Effects were statistically significant and we continued the analysis with the Bonferroni post hoc test, in order to discover which specific means of our variables differed.
The results from the inferential statistical analysis are centralized in Table 2 and Table 3.

Table 2 – The results of Tests of Within-Subjects Effects for comparing significant difference between the means for the 3 different postures

Parameter	Sphericity	Type III sum of squares	df	Mean Square	F	p value	Partial Eta Squared	Observed Power
PR	Greenhouse-Geisser correction	1580.633	1.303	1212.87	21.482	0.000*	0.531	0.998
SBP	Sphericity assumed	618.1	2	309.05	4.761	0.014*	0.2	0.76
DBP	Sphericity assumed	1989.30	2	994.65	24.703	0.000*	0.565	1
SBP/DBP	Sphericity assumed	0.432	2	0.216	15.653	0.000*	0.452	0.999
MBP	Greenhouse-Geisser correction	1478.233	1.517	974.258	13.325	0.000*	0.412	0.984
PP	Sphericity assumed	395.2	2	197.6	5.087	0.011*	0.211	0.789

Legend: PR – pulse rate; SBP – systolic blood pressure; DBP – systolic blood pressure; MBP – mean blood pressure, PP – pressure difference between high and low blood pressure; dF – the degrees of freedom in the source; * – statistical significant differences.

We can observe that the mean scores of all recorded parameters had a statistically significant overall dynamic for the 3 different postures at $p<0.05$, with Partial Eta Squares showing large effect sizes (values higher than 0.13) and Observed Powers greater than 80% for most cases.

Post hoc tests using the Bonferroni correction revealed that the protocol of changing 3 different postures elicits a statistically significant influence in all parameters, excepted SBP, for certain combinations of comparison of mean scores (Table 3). The found differences between mean scores are not very wide, but indicate the existence of specific hemodynamic adaptive changes.

Table 3 – Results of Bonferroni post hoc pairwise comparisons

Parameter	Postures	Mean difference	SE	p value	95% CI	
					Lower bound	Upper bound
PR	VOP/SHP	11.5	2.006	0.000*	6.234	16.766
	SHP/VTP	-1.35	1.094	0.696	-4.221	1.521
	VOP/VTP	10.15	2.412	0.001*	3.819	16.481
SBP	VOP/SHP	5.9	2.609	0.107	-0.948	12.748
	SHP/VTP	1.550	1.836	1	-3.27	6.37
	VOP/VTP	7.45	3.049	0.073	-0.554	15.454
DBP	VOP/SHP	9.90	1.897	0.000*	4.92	14.88
	SHP/VTP	3.75	1.864	0.000*	-1.142	8.642

	VOP/VTP	13.65	2.238	0.176	7.776	19.524
SBP/DBP	VOP/SHP	-0.134	0.033	0.002*	-0.22	-0.049
	SHP/VTP	-0.204	0.034	0.000*	-0.295	-0.114
	VOP/VTP	-0.07	0.043	0.372	-0.184	-0.044
MBP	VOP/SHP	9.45	2.003	0.000*	4.191	14.709
	SHP/VTP	1.9	1.988	0.003*	-3.319	7.119
	VOP/VTP	11.35	2.945	1	3.618	19.082
PP	VOP/SHP	-4	2.051	0.198	-9.383	1.383
	SHP/VTP	-2.2	1.858	0.753	-7.076	2.676
	VOP/VTP	-6.2	1.999	0.018*	-11.449	-0.951

Legend: PR – pulse rate; SBP – systolic blood pressure; DBP – systolic blood pressure; MBP – mean blood pressure, PP – pressure difference between high and low blood pressure; VOP – vertical orthostatic position; SHP – supine horizontal position, VTP – vertical Trendelenburg position; * – statistically significant differences among conditions ($p < 0.05$); SE – standard error; 95% CI - 95% confidence interval for difference.

Discussion

For the chosen research design, the results revealed a specific pattern of the dynamics of the variables, which as a whole indicates the slight average decrease of PR, SBP, DBP, MBP and a slight increase of SBP/DBP and PP between the three measurements done. The analysis of the results must be done with caution, especially since there are significant differences of mean scores in the post-hoc test only for 5 parameters, and for these parameters, the pairwise comparisons are not completely statistically significant. There are significant statistical differences of mean scores between VOP and SHP in case of PR, DBP, SBP/DBP, and MBP, between VOP and VTP in case of PR and PP, and between SHP and VTP in case of DBP and MBP.

Our results are partially overlapping with those of other researches of this type. For example, a study conducted on subjects suspended in the inversion for 7 minutes revealed that after the initial inversion HR was significantly decreased, while SBP and DBP were increased significantly (Ballantyne et al., 1986). Another study, which used an experimental design based on inversion traction for 2 minutes, revealed that both SBP and DBP increased significantly compared to the orthostatic position (Haskvitz & Hanten, 1986). Also, in another study that involved prolonged inversion of subjects for 5 minutes, no significant changes in HR and SBP occurred between 2.5 and 5 minutes of inversion (Zito, 1988). Instead, there are authors who describe the significant growth of both HR and SBP and DBP (Souza, 1987; Heng et al., 1992). Also worth mentioning are the studies that disprove MAP growth at the heart level in normotensive subjects, during a 10-20 degrees head-down tilt (Sibbald et al., 1976; Terai et al., 1995).

In our case, the comparison was done in context of three successive positions, and the time allocated to each position did not exceed one minute, including the period assigned for the measurements. The situation is much more plausible in terms of the frequency encountered in physical therapy practice. Moreover, prolonged posture in the Trendelenburg position is difficult to tolerate by some subjects, and may have harmful side effects, especially in patients with cardiovascular disease, in which case the method is contraindicated (Heng et al., 1992).

Regarding the mechanisms involved in the dynamics of the analysed hemodynamic parameters, particular aspects were brought up especially the vagotonic effect (deVries & Cailliet, 1985), the workload increasing of the heart (Vehrs et al., 1985), the increased venous return and involvement of the Frank-Starling mechanism that increase the cardiac output and tissue perfusion, specifically for vital organs (Summers et al., 2009). Obviously, the adaptation of the human body to the change of posture is done quickly, giving the chance to adopt systemic reactions with a protective effect, oriented especially on the tissues with the risk of exposure to ischemia. The influence of gravity on the level of blood hemodynamics is, however, permanent, being the result of a long evolutionary phylogenetic and ontogenetic process.

The fact that not all research has highlighted a unique model of the behaviour of hemodynamic parameters in the context of the posture of the human body suggests that the models of cardiovascular regulation have a high level of complexity, with wide interindividual variations. For sure, there are other categorical variables that can impact on cardiovascular dynamics, such as: anthropometric characteristics (weight, height, body mass index, body fat percentage, volumes of body fluids), level of redundancy of homeostatic physiologically control mechanisms, chronic effects of exposure to physical exertion and/or postural training, psychogenic components, hormonal status (especially in the female, in relation to the ovarian cycle), impregnation of the organism with certain substances from the food intake (for example, caffeine), exposure to nicotine following smoking, etc. More broadly, the aging process, morbidity and/or administration of certain drugs categorically influence cardiovascular hemodynamics during body posture changes.

The present study focused on the investigation of healthy subjects, therefore it has as imposed limits only the research of physiological mechanisms of regulation of the cardiovascular parameters in the context of the human body posture. From the recorded results, however, future themes for further research can be drawn up, on wider samples of subjects, or by discussing composite variables.

Conclusions

The results of our study demonstrated that the adoption of extreme positions in relation to the gravitational field definitely influences the human body in terms of the investigated cardiovascular parameters. Essentially, the successive transition from orthostatism to the supine position and then to the Trendelenburg position in a relatively short time, according to the applied testing protocol, determines the slight mean decrease of PR, SBP, DBP, MBP and a slight increase of SBP/DBP and PP. The dynamics of the evolution of the parameters presents distinctive elements from the point of view of the statistical significance of the differences of the mean scores between the three imposed positions, which suggests the interference of some additional factors on cardiovascular hemodynamics. The study argues the importance of understanding the mechanisms of cardiovascular adaptation of the human body to postural changes, given that there are a variety of clinical applications of gravitational inversion.

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