REVISTA PORTUGUESA DE
ENFERMAGEM DE
REABILITAÇÃO

VOL. 6, Nº 2

Original article reporting clinical or basic research

DOI - 10.33194/rper.2023.275 | Electronic identifier – e275

Submission date: 21-08-2022; Acceptance date: 06-11-2023; Publication date: 07-11-2023

TREINO EM PLANO INCLINADO E A ADAPTAÇÃO CEREBROVASCULAR À POSIÇÃO ORTOSTÁTICA PÓS LESÃO ENCEFÁLICA: ESTUDO MULTICASO

INCLINE PLANE TRAINING AND CEREBROVASCULAR ADAPTATION TO THE ORTHOSTATIC POSITION AFTER BRAIN INJURY: MULTI-CASE STUDY

ENTRENAMIENTO EN PLANO INCLINADO Y ADAPTACIÓN CEREBROVASCULAR A LA POSICIÓN ORTOSTÁTICA DESPUÉS DE UNA LESIÓN CEREBRAL: ESTUDIO DE CASOS MÚLTIPLESPLES

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How to cite: Areias D, Pereira JA, Marta Carvalho J, Celeste Dias. Treino em plano inclinado e a adaptação cerebrovascular à posição ortostática pós lesão encefálica: estudo multicaso. Rev Port Enf Reab [Internet]. 1 de Julho de 2023 [citado 12 de Novembro de 2023];6(2):e275. Available in: https://rper.aper.pt/index.php/rper/article/view/275

TECHNICAL FILE

eISSN: 2184-3023 pISSN: 2184-965X

www.rper.pt

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RESUMO

Introdução: A disfunção autonómica é uma condição frequente pós lesão encefálica (LE) e indica a capacidade de assegurar a autorregulação cerebral, que, quando presente, assegura o fluxo sanguíneo cerebral adequado às necessidades da pessoa. O treino de reabilitação em plano inclinado relaciona-se com a recuperação sensorial, autonómica e de equilíbrio. Pretende-se avaliar a adaptação cerebrovascular na pessoa em situação crítica (PSC) pós LE submetida ao treino de ortostatismo através de plano inclinado.

Metodologia: Estudo multicaso retrospetivo, realizado numa Unidade de Neurocríticos. Amostra constituída por (n=7). Aplicou-se um programa de reabilitação utilizando o plano inclinado, com elevação da cabeceira até 60° em dois momentos. As variáveis recolhidas foram: Escala de Coma de Glasgow, pressão arterial, frequência cardíaca (FC) e oximetria cerebral (CO). Através de análise retrospetiva estudaram-se: variabilidade da frequência cardíaca (VFC) e sensibilidade do barorreflexo (SB).

Resultados: Mediana ECG 11, SAPS II 31±23 e estadia média de 67±26 dias. Em posição supina, a VFC e a SB foram diminuídas. Identificaram-se diferenças estatisticamente significativas na FC durante a elevação da cabeceira até 60° na primeira sessão (p=0,03). Não foi identificada nenhuma diferença estatística nas variáveis calculadas (p>0,05).

Discussão: Comparativamente com o primeiro treino, verificou-se melhoria na regulação do equilíbrio simpático-vagal observado no segundo treino, através dos valores de CO mais elevados.

Conclusão: O treino de ortostatismo com recurso a plano inclinado demonstrou ser uma opção segura na reabilitação da PSC pós LE, pois verificou-se melhoria na adaptação cerebrovascular do primeiro para o segundo treino.

Descritores: Lesões Encefálicas; Frequência Cardíaca; Sistema Nervoso Autônomo; Enfermagem em Reabilitação; Posição Ortostática.

ABSTRACT

Introduction: Autonomic dysfunction is a common condition after brain injury (BI) and is related to the ability to ensure cerebral self-regulation, which, when present, ensures cerebral blood flow adequate to the person's needs. Rehabilitation training on an inclined plane is related to sensory, autonomic and balance recovery. In this sense, we intend to evaluate cerebrovascular adaptation in people in critical condition (PCS) after BI undergoing standing training using an inclined plane.

Methodology: Retrospective multi-case study, carried out in a Neurocritical Care Unit. Sample consisting of (n=7). A rehabilitation program was applied using an inclined plane, with elevation of the headrest up to 60° in two moments. The variables collected were: Glasgow Coma Scale, blood pressure, heart rate (HR) and cerebral oximetry (CO). Through retrospective analysis, the following were studied: heart rate variability (HRV) and baroreflex sensitivity (BS).

Results: Median ECG 11, SAPS II 31±23 and average stay of 67±26 days. In the supine position, HRV and BS were decreased. Statistically significant differences were identified in HR during elevation of the headrest up to 60° in the first session (p=0.03). No statistical difference was identified in the calculated variables (p>0.05).

Discussion: Compared to the first training, there was an improvement in the regulation of sympathetic-vagal balance observed in the second training, through higher CO values.

Conclusion: Standing training using an inclined plane proved to be an effective and safe option in the rehabilitation of PCS after BI, as there was an improvement in cerebrovascular adaptation from the first to the second training.

Descriptores: Brain Injuries; Heart Rate; Autonomic Nervous System; Rehabilitation Nursing; Standing Position.

RESUMEN

Introducción: La disfunción autonómica es una condición común después de una lesión cerebral (LE) y está relacionada con la capacidad de asegurar la autorregulación cerebral, que, cuando está presente, asegura un flujo sanguíneo cerebral adecuado a las necesidades de la persona. El entrenamiento de rehabilitación en plano inclinado está relacionado con la recuperación sensorial, autonómica y del equilibrio. En este sentido, pretendemos evaluar la adaptación cerebrovascular en personas en estado crítico (PEC) tras LE sometidos a entrenamiento de pie mediante un plano inclinado.

Metodología: Estudio retrospectivo de múltiples casos, realizado en una Unidad de Cuidados Neurocríticos. Muestra compuesta por (n=7). Se aplicó un programa de rehabilitación mediante plano inclinado, con elevación del reposacabezas hasta 60° en dos momentos. Las variables recogidas fueron: escala de coma de Glasgow, presión arterial, frecuencia cardíaca (FC) y oximetría cerebral (OC). Mediante análisis retrospectivo se estudió: la variabilidad de la frecuencia cardíaca (VFC) y la sensibilidad barorrefleja (SB).

Resultados: Mediana de ECG 11, SAPS II 31±23 y estancia media de 67±26 días. En posición supina, la VFC y la SB disminuyeron. Se identificaron diferencias estadísticamente significativas en la FC durante la elevación del reposacabezas hasta 60° en la primera sesión (p=0,03). No se identificó diferencia estadística en las variables calculadas (p>0,05).

Discusión: En comparación con el primer entrenamiento, se observó una mejora en la regulación del equilibrio simpático-vagal en el segundo entrenamiento, a través de valores más altos de CO.

Conclusión: El entrenamiento de pie utilizando un plano inclinado demostró ser una opción eficaz y segura en la rehabilitación de la CEP después de LE, ya que hubo una mejora en la adaptación cerebrovascular del primer al segundo entrenamiento.

Descriptores: Lesiones Encefálicas; Frecuencia cardiaca; Sistema Nervioso Autónomo; Enfermería en Rehabilitación; Posición de Pie.

INTRODUCTION

Autonomic dysfunction that interferes with internal homeostasis, namely cardiovascular control, can occur after brain injury (BI) of different etiologies[1,2,3]. The first study to explore the relationship between heart rate (HR) pattern and the occurrence of severe brain injury dates back to 1965[1]. The authors found that the decrease in heart rate variability (HRV), occurring at any time post-injury, is an accurate indicator of a poor prognosis[1].

The relationship between brain and heart, as well as the modulation of sinus HR regulated by the autonomic nervous system (ANS) has been studied for some time[2,3]. Several neurological changes can be associated with ANS dysfunction, which makes HR assessment a method that can be applied to people with BI[4].

In a healthy heart, the sinus node dictates the basal HR, which is modulated by the parasympathetic and sympathetic nervous system and allows the HR to remain within a certain range of values (60 to 100 bpm)[5]. After the occurrence of BI, there is activation of the ANS with an increase in circulating catecholamines, which can result in cardiac arrhythmias, and in turn, autonomic imbalance[6]. HR changes in response to mental or physical stress and severe diseases such as BI[5].

HRV reflects changes in the intervals between R-R waves in beats that are regulated by the ANS[4]. The absence of HRV in patients after severe BI can result in brain death or a vegetative state, with HRV being lower in people in coma[7,8].

Adaptation to changing body position, namely the supine position, is mediated by the ANS through HRV and the baroreflex[9]. When we acquire the orthostatic position, there is a movement of around 500-1000ml of blood to the lower segments of the body[10]. Adaptation to the orthostatic position is identified by the carotid and aortic baroreceptors, which will trigger the sympathetic reflex of increased HR, cardiac contractility and peripheral vasoconstriction. The increase in cardiac output leads to obliteration of the ventricular chamber, in turn stimulating the parasympathetic reflex, which results in vasodilation and a decrease in HR[10]. In cases where there is ANS dysfunction, a lower HRV is expected[2,3].

HRV analyzed through the HR domain allows us to identify the high-frequency component (HF) that reflects vagal efferent activity (parasympathetic), while the low-frequency component (LF) reflects sympathetic activity under vagal influence. The LF/HF ratio is considered the mirror of the sympathetic-vagal balance[2,3,8].

Baroreflex sensitivity (BS) is calculated through the time domain of the baroreflex in the R-R intervals versus systolic blood pressure[9]. High sympathetic activity or ANS dysfunction is correlated with BS dysfunction[9,11], and changes in baroreflex activity are associated with a worse outcome in patients with BI[12].

Rehabilitation in Intensive Care Units (ICU) is associated with improved functional results, allowing a reduction in hospitalization time with lower economic and social costs[13,14]. When the standing test is performed, readaptation of the cerebral blood circulation becomes necessary. In this movement, hemodynamic adaptation can affect cerebral blood flow (CBF) and, consequently, its function. The phenomenon that ensures constant CBF within a limited range of blood pressure variation and that responds to variations in cerebrovascular resistance is called cerebral self-regulation (CSR)[15].

Benefits identified in standing training include stimulation of vestibular, sensorimotor and visual function, resulting from an adaptive response of the ANS(16). During the standing position, axial tonic activity connects the entire body, which results in improved autonomic control, oxygenation, ventilation, wakefulness, stretching of the muscles of the lower limbs and reduction of spasticity and improvement of muscle strength(17,18). The inclined plane as a rehabilitation tool is associated with improved arousal and consciousness(13), minimizes the adverse effects of immobility, namely pressure ulcers, improves recovery and reduces morbidity, promoting a better outcome for the person(17,18).

The physiological mechanism of adaptation to the standing position can be continuously monitored through cerebral oximetry (CO) using Near Infrared Spectroscopy (NIRS) and analyzing its correlation with blood pressure (BP)(19). The correlation coefficient between CO and BP is called cerebral oximetry reactivity index (COx).

By carrying out this study we intend to describe the cerebrovascular physiological adaptation in the reacquisition of the orthostatic position in PSC after BI, subjected to inclined plane training. In this way, we want to answer the research question: Does standing training, using an inclined plane rehabilitation program, improve brain physiological adaptation to the standing position in PSC after BI?

METHODOLOGY

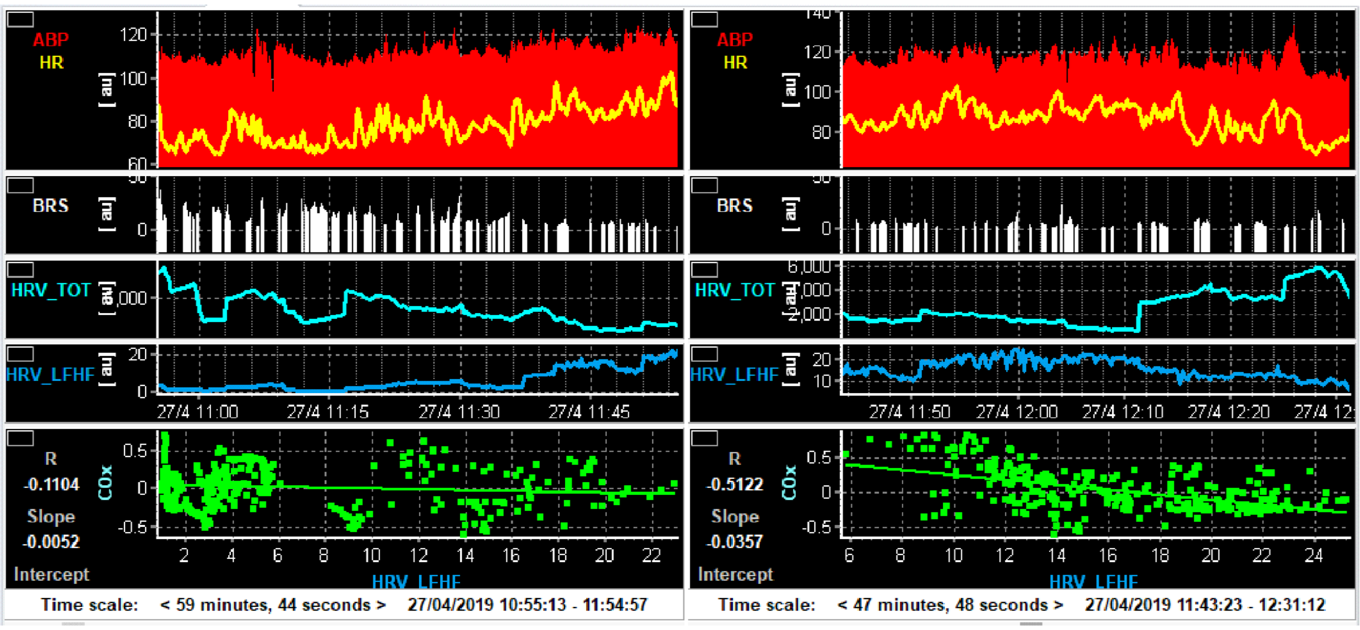
Data collection for this study was carried out in the first half of 2019 in a Neurocritical Care Unit (NCU) of a Hospital in the North Zone of Portugal, having been previously approved by the ethics committee (opinion no. 313/17 of January 25, 2018). The inclusion criteria were defined: age between 18 and 80 years old, traumatic or non-traumatic brain injury less than three months ago, both genders, in the current episode of hospitalization, present a score on the Glasgow Coma Scale (GCS) <8 or subject to sedoanalgesia, at the beginning of the inclined plane protocol present an GCS ≥8, without clinical evidence of infection, with tolerance to the rehabilitation program in force in the Intensive Medicine Service and with hemodynamic stability greater than 24 hours. Exclusion criteria included: body weight greater than 130 kg and/or height greater than 210 cm, unstable or non-union fractures, rib fractures or thoracic skin injuries, contraindication for weight bearing on the lower limbs and the existence of deep vein thrombosis, hemodynamic instability or neurological in the last 48 hours, with external ventricular or lumbar drainage or previous history of orthostatic intolerance. The remaining patients were accepted. Baseline neurological status was calculated using the Glasgow Coma Scale (GCS) in the first session. As a complement, the Simplified Acute Physiologic Score (SAPS II) scale was used to determine the severity of the disease and predict hospital mortality.

A multi-case, descriptive, correlational and retrospective study of a quantitative nature was carried out. The variables collected included GCS, HR, BP and CO analyzed using NIRS. An offline retrospective analysis of COx, HRV and baroreflex was then carried out.

Systemic variables were acquired using a Philips Intellivue MP70® multiparameter monitor. NIRS was monitored with INVOS 5100C®, Covidien. All data were recorded using a laptop with ICM+® software, version 8.5. CO was defined as an average between the left and right NIRS values. COx was calculated as a Pearson correlation coefficient between BP and NIRS.

COx values can vary between -1 and +1 and values below 0.3 indicate preserved ARC(20). An example of data monitoring is shown in figure 1.

Figure 1 – Offline analysis screen for monitored data BP, HR, BS, VFR_TOT, HRV_LF/HF and COx.



To study HRV, HR domain analysis was used and an R-R spectral power time series was calculated in the BF band (0.04-0.15Hz), AF (0.15-0.4Hz), total power (0.04-0.4Hz) and the LF/HF ratio. In turn, to calculate Baroreflex Sensitivity (BS), a cross-correlation was carried out between BP and the R-R time series. BS is presented in mms/mmHg. In both cases, tolerance for ectopia was 20%.

The four researchers, two belonging to the medical team, and two belonging to the UCNC rehabilitation nursing team, submitted the PCS to the incline of the plane from 0° to 60°, with increments of 15° at intervals of 15 minutes, followed by descent to zero with the same cadence, but at 5-minute intervals (Figure 1). In case of hemodynamic instability, defined by changes ± 20% of the baseline HR, BP and/or change in the state of consciousness, the test would be aborted.

The values collected are presented as mean and standard deviation (mean ± SD) or median and interquartile range (med; IQT). The non-parametric Wilcoxon test was performed to compare the mean values of LP, HR, left NIRS, right NIRS, CO, COx, HRV, LF and HF components, LF/HF ratio, BS and BS index (BSi) throughout the 2 sessions.

Friedman's non-parametric test with post-hoc comparisons was performed to equate the mean values of each variable at different amplitudes during training. All statistical data were performed on the SPSS Platform, version 21.0 for Windows®. Values of $p<0.05$ were considered statistically significant.

RESULTS

Seven patients with BI (3 Traumatic Brain Injury, 3 Cerebral Hemorrhage, 1 Acute Hydrocephalus) were analyzed in the period between January and June 2019. The average age was 58±24 years and 6 (86%) were men. The median GCS in the first session was 11(1). The mean SAPS II on admission was 31±23 with a predicted in-hospital mortality of 24%. The average length of stay in the Unit and Hospital was 67±26 and 107±26, respectively.

Demographic data are presented in table 1.

Table 1 - Demographic characteristics

N	Gender n	Age m±sd	Diagnosis n	SAPSII	P_SAPS II %	Estadia UCNC m±sd	Hospital Stay m±sd	GCS med ! IQT
7	6M | 1F	58±24	3 CH 3 TBI 1 AH	31±23	24±30	67±26	107±26	11 | 1

SAPS II, Simplified Acute Physiologic Score; P_SAPS II, mortality prediction; GCS: Glasgow Coma Scale; HC: Cerebral Hemorrhage; TBI: Traumatic Brain Injury; AH: Acute Hydrocephalus; m±sd: mean and standard deviation; med | IQT: median and interquartile range

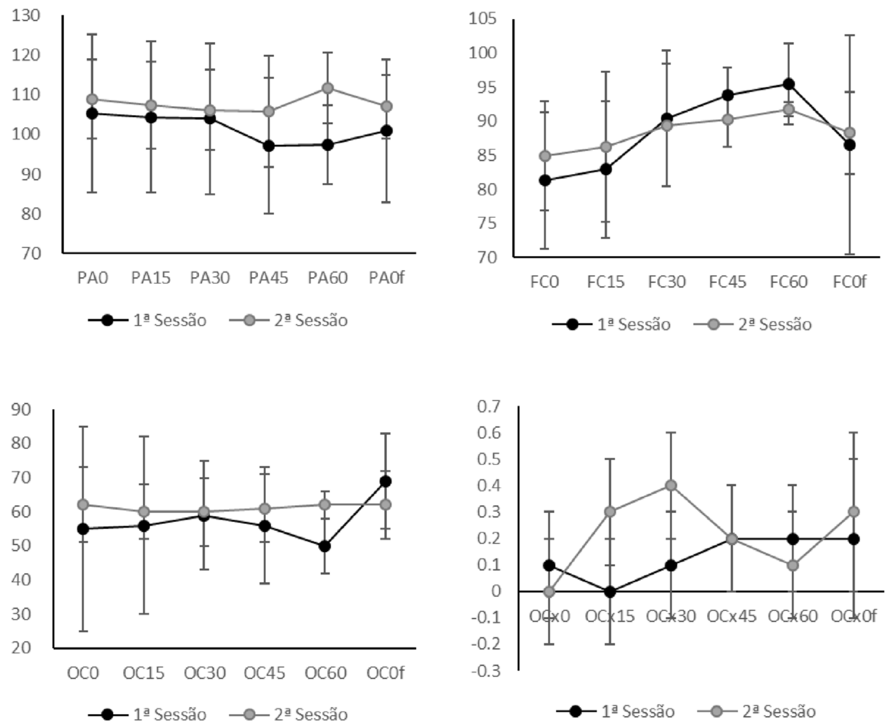
The mean and standard deviation of the physiological variables: BP, HRV and NIRS (left and right) in the range of 0°, 15°, 30°, 45°, 60° and at the end of the protocol, for the first and second session, are shown in table 2 and figure 2.

Table 2 - Monitoring of data recorded during the elevation phase of the standing test in the first and second session at 0°, 15°, 30°, 45°, 60° and at the end of the protocol.

	Variables	0° start	15° rise	30° rise	45° rise	60° rise	0° end
1st Session (n=7)	BP	105±20	104±19	104±19	97±17	97±10	101±18
	HR	81±10	83±10	90±10	94±4	95±6	87±16
	NIRS_E	57±30	52±28	63±15	62±14	54±11	68±12
	NIRS_D	61±33	59±32	60±25	51±28	47±17	69±21
2nd Session (n=4)	BP	109±10	107±11	106±10	106±14	112±9	107±8
	HR	85±8	86±11	89±10	90±4	92±1	88±6
	NIRS_E	62±10	61±7	61±9	61±10	63±10	64±11
	NIRS_D	61±13	59±10	59±11	61±9	60±1	61±11

Mean and Standard Deviation of BP (Blood Pressure), HR (Heart Rate), NIRS_E (left cerebral oximetry with near-infrared spectroscopy) and NIRS_D (right cerebral oximetry with near-infrared spectroscopy).

Figure 2 - Linear graph showing mean and standard deviation for BP, HR, CO and COx at amplitudes of 0°, 15°, 30°, 45°, 60° and end of the protocol, in relation to the first and second sessions.



Statistically significant differences between amplitudes during standing were only identified for HR in the first session with a progressive increase between 15°, 45° and 60° (p=0.037).

The mean and standard deviation for the calculated variables - CO, COx, VHR LF, VHR HF, VHR LF/HF, VHR TOT (total power), BS and BSi in the amplitudes 0°, 15°, 30°, 45°, 60 ° and at the end of the protocol, for the first and second session, are presented in table 3 and figure 3. It should be noted that among the calculated variables, no statistical difference was found (p>0.05).

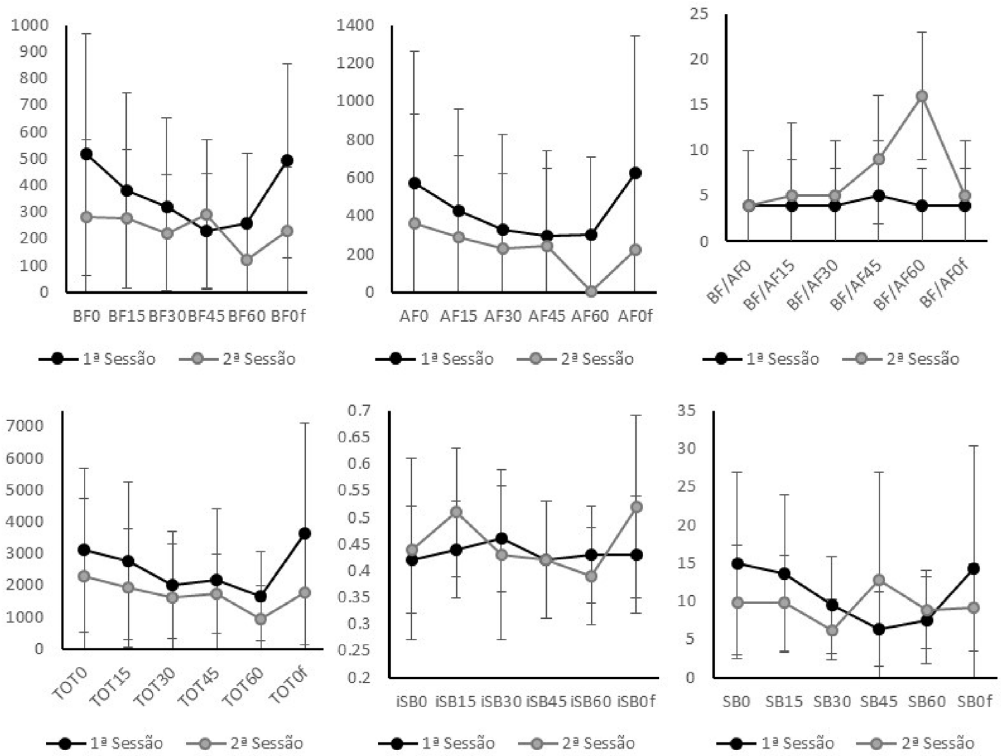
Table 3 - Variables calculated during the elevation phase of the standing test in the first and second sessions at 0°, 15°, 30°, 45°, 60° and at the end of the protocol.

	Variables	0º start	15° rise	30° rise	45° rise	60° rise	0° end
1st Session (n=7)	CO	55±30	56±26	59±16	56±17	50±8	69±14
	COx	0,1±0,2	0±0,2	0,1±0,2	0,2±0,2	0,2±0,2	0,2±0,3
	VHR_LF	517±453	381±365	318±335	230±214	259±262	493±364
	VHR_HF	575±690	428±530	328±500	293±446	305±403	629±716
	VHR_LF/HF	4±6	4±5	4±4	5±6	4±4	4±4
	VHR_TOT	3115±2576	2774±2464	2030±1679	2173±2261	1656±1410	3628±3482
	BSi	0,42±0,10	0,44±0,09	0,46±0,10	0,42±0,11	0,43±0,09	0,43±0,11
	BS	15±12	14±10	9±6	6±5	8±6	14±16

	Variables	0° start	15° rise	30° rise	45° rise	60° rise	0° end
2nd Session (n=4)	CO	62±11	60±8	60±10	61±10	62±4	62±10
	COx	0±0,2	0,3±0,2	0,4±0,2	0,2±0,2	0,1±0,2	0,3±0,3
	VHR_LF	283±288	276±260	222±217	293±280	120±138	230±238
	VHR_HF	359±572	289±423	228±393	246±406	6±6	224±412
	VHR_LF/HF	4±6	5±8	5±6	9±7	16±7	5±6
	VHR_TOT	2292±2431	1922±1850	1632±1663	1737±1245	932±1082	1773±1904
	BSi	0,44±0,17	0,51±0,12	0,43±0,16	0,42±0,11	0,39±0,09	0,52±0,17
	BS	10±8	10±6	6±4	13±14	9±5	9±6

Mean and Standard Deviation of CO (Cerebral Oximetry), COx (Cerebral Oximetry Index), HRV LF (Low Frequency Component of Heart Rate Variability), HRV HF (High Frequency Component of Heart Rate Variability), HRV LF/ HF (Ratio between the Low and High Frequency components of Heart Rate Variability), HRV TOT (total power Heart Rate Variability), BSi (Baroreflex Sensitivity index) and BS (Baroreflex Sensitivity).

Figure 3 - Linear graph demonstrating mean and standard deviation for the Low and High Frequency components of Heart Rate Variability (HRV_BF, HRV_AF), ratio (BF/AF), total power (TOT), Baroreflex Sensitivity index (iSB) and Baroreflex Sensitivity (SB) at amplitudes of 0°, 15°, 30°, 45°, 60° and the end of the protocol, in the first and second sessions.



DISCUSSION

This study analyzed the cerebrovascular response that occurs to adapt to the orthostatic position through an inclined plane, in PCS after BI.

The data demonstrate a decrease in the LF and HF components and an increase in the LF/HF ratio, as well as an increase in HRV, which suggests the predominance of the sympathetic nervous system in PCS after BI. The HF component is considered as a mirror of the parasympathetic tone and the LF/HF ratio as the balance between ANS components. The results obtained are consistent with studies that demonstrate a decrease in LF and HF components in cases of severe BI [8]. Studies carried out in critically ill patients with traumatic BI, cerebral hemorrhage and subarachnoid hemorrhage show an increase in HRV, HF component and a decrease in the LF/HF ratio, suggesting an increase in vagal activity[7]. In turn, studies carried out in people with acute cerebral ischemia demonstrate a decrease in HRV, LF and HF and an increase in the LF/HF ratio[21,22].

The decrease in BS and BSi supports sympathetic predominance in the post-BI person. The decrease in BS and ANS dysfunction was found in studies carried out in people with acute BI[23].

During the period of reacquisition of the orthostatic position, an increase in HR was observed with statistical significance between 15° and 45° as well as at the 60° level. The observed tachycardia is a factor that may indicate sympathetic predominance in PCS with BI[21]. The same pattern was not, however, observed in BP.

Cerebral oximetry was found to be decreased despite being normal, and the values analyzed increased during standing, suggesting a favorable cerebral adaptation to the standing position. In fact, CSR, expressed by COx, remained mostly below 0.3 during standing, which is reflected in preserved CSR, despite periodic moments of deregulation occurring, moments possibly related to a delay in the dynamics of self-regulation[24]. As previously discussed, HRV and BS were decreased before standing and maintained a relatively stable linear progression.

Through offline data analysis, it was observed that the CSR remained mostly preserved with COx values below 0.3 throughout the test.

In the developed protocol, safety measures were applied in an attempt to prevent hemodynamic instability during standing. The measures adopted included the suspension of the test in the event of HR and BP variability >20% of baseline or changes in the state of consciousness. There is, however, no safety protocol regarding ARC, other than that carried out during the clinical assessment of the neurological status.

Since ARC is a vital process, it would be appropriate, in future training, to introduce online processing of COx to allow continuous monitoring of self-regulation.

After analyzing the data, it was possible to understand the function of the inclined plane as a rehabilitation tool in the training of autonomic and cardiovascular control of PCS after BI. The results obtained did not demonstrate statistically significant differences between the sessions carried out, a condition that could be associated with the reduced number of participants and sessions achieved. It is understood, however, that in PCS submitted to two sessions, there was a greater sympathetic-vagal balance between sessions, a situation that may suggest an improvement in autonomic control with continued training. However, as no statistically significant differences were found in the data analysis, no other conclusions can be formulated.

LIMITATIONS OF THE STUDY

The small study sample should be considered one of the main limitations. It is, however, a pilot study on systemic and cerebral physiological adaptation during standing training on an inclined plane and whose results may allow future investigations in larger cohort studies, with a systematic application of the inclined plane training protocol.

It is worth noting that antihypertensive medication may have been used to treat PSC during training, however, a strength of this study was the fact that the patients analyzed were not sedated or ventilated, a factor that has been proven affect HRV per se[25]. The analysis of the personal and medical history of the study participants was not analyzed, which may also contribute to changes in the response to the training carried out.

Another limitation noted is the lack of monitoring of CSR during the procedure and its comparison with a validated standard method such as continuous bilateral monitoring of cerebral blood velocity with Transcranial Doppler, which could also be the scope of future study.

CONCLUSION

The results of this study carried out on patients with BI undergoing standing training demonstrated that it is possible to apply the inclined plane safely in the ICU context. The increase in the LF/HF ratio, HRV and decrease in SB suggests sympathetic predominance after BI, which supports the hypothesis of ANS dysfunction with a predominance of the sympathetic system, when injuries of this type occur.

Standing training carried out by a nurse specializing in Rehabilitation Nursing is a relevant tool in training to reacquire the standing position in PCS after BI, as it was verified through the analysis carried out at the end of the study, an improvement in autonomic control and cardiovascular response to verticalization.

It is understood that, despite some variations identified in the adaptation to the standing position during standing training using the inclined plane, there is maintenance and/or improvement in the person's condition after implementing this training, with regard to the response seen in the OC of the PCS analyzed.

We then verified that there was an improvement in cerebrovascular adaptation in the reacquisition of the orthostatic position after applying the rehabilitation program, through inclined plane training in PCS after BI, which answers the identified research question.

Monitoring CSR with CO during standing training seems appropriate, however, it requires further investigation.

The application of the post-BI PCS rehabilitation protocol using an inclined plane demonstrated to be a safe tool in improving cerebrovascular physiological adaptation to the orthostatic position, as improvements were seen in CO during the training carried out, which can, in itself only, relate to the improvement of the CSR of the PCS in this condition.

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ETHICAL DISCLOSURES

Contribution of the author(s):

ConceptualizaTION: DA, JAP, JMC, CD;

Methodology: DA, JAP, JMC, CD;

Validation: DA, JAP, JMC, CD;

Formal analysis: DA, JAP, JMC, CD;

Investigation: DA, JAP, JMC, CD;

Data processing: DA, JAP, JMC, CD;

Original draft preparation: DA, JAP, JMC, CD;

Writing and editing: DA, JAP, JMC, CD;

Review: DA, JAP, JMC, CD.

All authors read and agreed to the published version of the manuscript.

Financing:

This work did not receive any financial contribution or grant.

Ethics Committee:

Study authorized by the Ethics Committee of Centro Hospitalar Universitário de São João (opinion no. 313/17 of January 25, 2018).

Declaration of informed consent:

Written informed consent to publish this work was obtained from participants.

Interest conflicts:

The authors declare no conflict of interest.

Provenance and peer review:

Not commissioned; externally peer reviewed.