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Exertion Does Not Affect the Optic Nerve Sheath Diameter in Healthy Participants

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Abstract

The purpose of this study was to determine if exertion influences the ONSD in healthy individuals. Healthy adults were eligible for inclusion. Activities were performed by each participant for 60 seconds and were as follows: sprinting, holding a 10-pound weight with both arms outstretched parallel to the floor, a Valsalva maneuver, a plank position, and positioning the head down thirty degrees with the participant in the supine position. Two-dimensional ultrasound images visualizing the optic nerve sheath (ONS) were recorded in three orientations and averaged to determine the mean ONSD 3 millimeters posterior to the retina. Baseline measurements ranged from 3.57 to 4.90 millimeters. Post-exertion measurements ranged from 3.60 to 4.93 millimeters. Based on a one sample paired t-test the difference between baseline and post-activity measurements were not significant. This study demonstrates that ONSD measurements by ultrasound do not change in healthy individuals in response to exertion.

Keywords: Ultrasound; ONSD; Exertion; ICP

Introduction

The optic nerve sheath (ONS) is continuous with the dura mater of the meninges and it is widely accepted that its diameter is directly related to intracranial pressure (ICP): ONS dilation is a strong indicator of an increase in ICP [1-5]. Measurement of the optic nerve sheath diameter (ONSD) by ultrasound is increasingly being used because ultrasound is accessible, portable, and can be done at bedside as a point of care diagnostic tool, and can be performed quickly and non-invasively [3].

These characteristics make ultrasound easier to use than traditional methods of determining increases in ICP such as lumbar puncture and ventriculostomy [4,5]. Favorable prognosis for patients with elevated ICP is dependent on prompt discovery and intervention [6]. Ultrasound has an additional benefit in that it can be used in out-of-hospital settings allowing for increases in ICP to be measured before patients arrive to the emergency department so that necessary medical interventions can be decided and initiated early [3].

Some studies of healthy individuals have shown that activities such as coughing, jugular compression, and abdominal compression can cause an elevation of ICP but none of these studies evaluated whether or not these activities can cause a change in ONSD measurement by ultrasound [7-9].

Other studies have shown that ONSD measurement by ultrasound can be influenced by hypertension and ICP can be influenced by head positioning, however these studies were conducted on patients with abnormal physiology or intracranial pathology [5,10]. In these patients the normal ICP regulating reflexes and structure of the meninges may be disturbed [11-13]. Therefore, existing studies evaluating factors that can change the ONSD in these patients may not be applicable to healthy individuals.

Existing studies evaluate either activities that can change ICP in healthy individuals but do not take into account ONSD measurements or they evaluate factors that can change ONSD measurements but are not performed in healthy individuals. This has left a gap in the literature regarding whether or not certain activities can affect the ONSD in healthy individuals.

However, new studies are emerging that investigate healthy subjects and ONSD measurements. One such study examined if positional changes can affect ONSD as measured by ultrasound in healthy individuals and concluded that altering head position did not cause a change [14].

To our knowledge no studies have been performed on healthy individuals to determine if exertion can cause a change in the ONSD measurement. Understanding if exertion can cause a change in the ONSD in healthy individuals would be clinically relevant in evaluating a patient who has sustained head trauma while exerting him or herself.

For example, if a person were to strain in some way prior to sustaining head trauma – such as sprinting before being tackled, or performing a Valsalva maneuver before a car accident – clinicians using ONSD measurements by ultrasound to indicate ICP need to know if the exertion itself is the cause of a dilated ONSD or if the dilated ONSD is due directly to the increase in ICP secondary to the head trauma.

Our objective in this study was to determine if exertion could influence the ONSD as measured by ultrasound. We hypothesized that exertion in healthy individuals would not cause a significant change in the ONSD as measured by ultrasound.

Methods

This research was a cross-sectional observational study examining the effect of exertion on the ONSD. Healthy adult participants (age 18 and older) who had no history of lung disease, heart disease, traumatic brain injury (TBI), ocular disease or trauma, and who were physically capable to exercise for short periods of time were eligible for inclusion in the study.

Exclusion criteria included inability to provide consent, known heart disease, known lung disease, prior history of TBI, prior history of ocular disease or trauma, or inability to perform the exercises.

To determine the number of participants needed for the study, a sample size calculation was performed based on a two-sided one-sample t-test to compare pre- and post-measurements. The effect size was estimated from Haykowsky's article measuring ICP changes in response to exercise and the Valsalva maneuver [7].

Based on the effect size, a sample size of 10 subjects can confer 95% power (1-beta) at a significance level alpha= 0.05. The sample size calculation was carried out using R version 3.1.0.

Each participant had ultrasound measurements taken of his or her ONSD pre-exertion and immediately post-exertion. Participants that had a change greater than 0.30 millimeters from their baseline were required to wait for a rest period of fifteen minutes and then measurements were repeated.

The value of 0.20 millimeters was used as the value to indicate a change from baseline due to intra-observer ONSD measurement variations of 0.10 millimeters from single operators [2]. Each participant's vital signs were taken before and immediately following each activity. No oral fluids were allowed during the observational period and all ultrasound measurements were taken with the subject in the same position before and after each activity.

Due to the limited number of published materials determining if exertion can affect ICP in a healthy population, the activities included were speculated to cause exertion in a healthy individual. The order of activities was varied for each participant.

The activities performed by each participant were as follows: sprinting, holding a 10-pound weight with both arms outstretched parallel to the floor, a Valsalva maneuver, a plank position, and positioning the head down thirty degrees with the participant in a supine position.

Based on the study conducted by Romagnuolo et al. where positional changes were evaluated for their influence on the ONSD in healthy individuals, 60 seconds was chosen for the duration of each activity to allow for equilibration of ICP change to each activity [14]. Participants were encouraged to exert themselves to the fullest extent during each activity and the time of the activity was extended when participants did not show signs of strain.

Ultrasound measurements of the ONSD were obtained using a Phillips HDI4000 ultrasound machine on the "Small Parts" setting using a 12-5 MHz linear array probe.

Two-dimensional images visualizing the ONS were recorded in three different orientations respective to the participant's eyelid – one horizontal, one vertical, and one at 45 degrees – and the ONSD measurements in each plane were averaged to determine the mean ONSD 3 millimeters posterior to the retina.

This study used three planes to measure the ONSD based on a study that has shown the ONS is not uniform circumferentially and can preferentially dilate in certain portions due to increased ICP [13]. When performing the ONSD measurements the probe angle was manipulated to ensure that the measurements were taken at the maximum diameter and crisp views of the ONS boundaries were obtained.

To determine the effect of the exertional activities on the ONSD, we compared the measurement of the ONSD before exertion and immediately after exertion to determine if a significant difference existed between the resting ONSD measurement and the post-exertion ONSD measurement. A one-sample paired t-test was employed for this purpose because it is designed to compare pre- and post-intervention responses for the same individuals.

This study was approved by the Institutional Review Board (IRB) at the researchers' academic institution.

Results

Ten participants were enrolled in this study. Four were male and six were female. Participants included seven whites, one Pakistani, one Indian, and one Taiwanese. Ages ranged from 21 years to 24 years with the average being 22.8 years. All participants were able to provide consent, had no history of heart disease, lung disease, TBI, ocular disease, or trauma and were able to perform the exertion exercises.

Table 1 compares the results of the ONSD, measured in millimeters, from before exertion ("Baseline" in Table 1), to immediately after exertion ("Immediate" in Table 1). Baseline measurements (pre-exertion) ranged from a minimum of 3.57 millimeters to a maximum of 4.90 millimeters. Immediately post-exertion measurements ranged from a minimum of 3.60 millimeters to a maximum of 4.93 millimeters.

Table 2 shows the comparison results from a one-sample paired t-test. The entire 95% confidence intervals span 0 indicating the difference between baseline measurements and immediately post-exertion measurements was not significant.

			Participant Number									
			1	2	3	4	5	6	7	8	9	10
ONSD Measurement (in mm)	**Sprint**	Pre	4.47	4.73	3.63	4.83	4.37	4.8	3.73	3.77	4.7	4.2
		Post	4.3	4.7	3.67	4.83	4.3	4.8	3.77	3.8	4.67	4.3
		Change	-0.17	-0.03	0.04	0	-0.07	0	0.04	0.03	-0.03	0.1

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		Pre	4.2	4.83	3.77	4.83	4.26	4.8	3.77	3.8	4.67	4.2
		Post	4.47	4.77	3.8	4.7	4.47	4.8	3.73	3.77	4.57	4.2
	Weight	Change	0.27	-0.06	0.03	-0.13	0.21	0	-0.04	-0.03	-0.1	0
		Pre	4.3	4.57	3.67	4.7	4.4	4.8	3.77	3.9	4.57	4.23
		Post	4.3	4.6	3.87	4.83	4.33	4.8	3.8	3.8	4.6	4.2
	Valsalva	Change	0	0.03	0.2	0.13	-0.07	0	0.03	-0.1	0.03	-0.03
		Pre	4.8	4.67	3.6	4.9	4.46	4.8	3.77	3.87	4.6	4.23
		Post	4.8	4.8	3.6	4.86	4.47	4.8	3.83	3.83	4.57	4.23
	Plank	Change	0	0.13	0	-0.04	0.01	0	0.06	-0.04	-0.03	0
		Supine	4.86	4.73	3.57	4.76	4.47	4.8	3.77	3.77	4.57	4.2
		Neg 30 Deg	4.66	4.93	3.6	4.63	4.5	4.8	3.77	3.73	4.67	4.2
	Head Inversion	Change	-0.2	0.2	0.03	-0.13	0.03	0	0	-0.04	0.1	0

Table 1: ONSD measurements for activities.

Physiologic Activity	**Mean Difference (mm)**	**95% CI**	**p-value**
Sprint	-0.009	(-0.0617, 0.0437)	0.7084
Weight	0.015	(-0.0769, 0.1069)	0.7206
Valsalva	0.022	(-0.0413, 0.0853)	0.4522
Plank	0.009	(-0.0279, 0.0459)	0.5941
Head Inversion	0.001	(-0.0802, 0.0782)	0.9778

Table 2: Comparison results from the paired t-test.

Conclusion

In current emergency practice the ONSD measurement by ultrasound can be used at the bedside to initially determine if there is a risk for increased ICP, and in cases where indicated, further intervention can then be employed. However, favorable prognosis for patients with elevated ICP is dependent on prompt discovery and intervention, which makes ONSD measurement by ultrasound appealing in out-of-hospital settings to help clinicians detect elevated ICP before patients arrive at the emergency department.

It is known that the first occurrences of mild traumatic brain injury (mTBI), or increases in ICP, generally have no long-term clinical implications but repeated occurrences of mTBI have long-term consequences and increased mortality [6]. By utilizing ONSD measurement by ultrasound in an out-of-hospital setting to assess injury, such as the sideline at a football game, a healthcare provider can quickly and non-invasively determine whether or not an injured player has sustained an mTBI, and whether or not he or she should continue playing or if immediate treatment is needed. However, a healthcare provider utilizing this tool to indicate pathologic increases in ICP needs to know whether a dilated ONSD is due to the exertion by the athlete or if it is due to a true increase in ICP as the result of an injury.

For ultrasound measurement of the ONSD to be a useful tool that indicates pathologic increases in ICP it must be known whether or not physiologic factors can influence the ONSD in healthy individuals. Our results show that the pre-exertion and immediately post-exertion ONSD measurement differences for healthy individuals were not statistically significant leading to the conclusion that the ONS for participants in this study was not influenced by the exertional activities that were performed.

This study demonstrates that ONSD measurements by ultrasound do not change with exertion in healthy individuals. Because the ONSD of the healthy participants in this study did not change in response to various forms of exertion we conclude that the ONSD as measured by ultrasound is not influenced by exertion in healthy individuals.

Limitations

This study has limitations that restrict its generalizability. Limitations of this study include: having a single sonographer take all of the measurements, measuring only one eye of each participant, small study sample size, inability to determine the level of exertion by each participant, and not obtaining conventional measurements of ICP. In addition, only healthy individuals were included in the study, and although activities that were thought likely to cause exertion in healthy individuals were chosen, it was not clearly determined if participants exhausted themselves fully.

In order to increase the generalizability of this research, further studies need to be conducted. These studies will need to include a larger and more diverse sample including participants of various ages, medical histories, and levels of fitness. Future studies should also include a measurement that quantifies the level of exertion by each participant from each activity to ensure that all participants perform the activities to a similar level of exhaustion.

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