The Effects of Oscillating Inversion on Systemic Blood Pressure, Pulse, Intraocular Pressure, and Central Retinal Arterial Pressure

Robert M. Goldman, DO; Robert S. Tarr, PhD;
Burton G. Pinchuk, OD; Robert E. Kappler, DO

In brief: The effects of gravity inversion oscillation procedures on systemic blood pressure (BP), pulse rate, intraocular pressure, and central retinal arterial pressure were studied. Twenty healthy men oscillated between the upright and inverted state from 80 to 150 times during a 15-minute period. Measurements were made in the completely inverted stage of a cycle at 5, 10, and 15 minutes. Systemic BP fell throughout the 15-minute oscillation period. Both systolic and diastolic pressure were significantly reduced in each measurement period. Pulse rate also decreased on inversion and throughout the oscillation period. Intraocular pressure rose initially, then fell slightly, but was still elevated above preinversion values. The authors conclude that full inversion using an oscillation procedure presents no risk to normotensive healthy subjects.

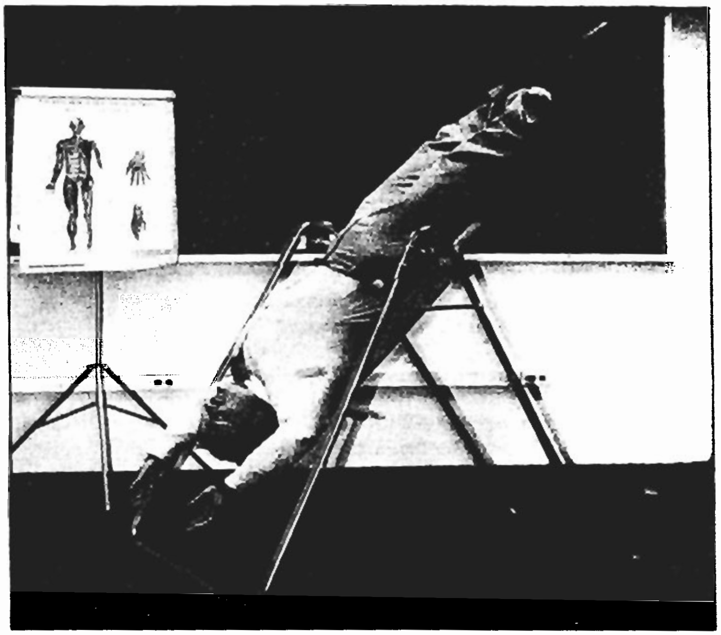

Figure 1. The decreases in systolic and diastolic systemic BP and pulse rate may result from the calm and relaxation that oscillation affords.

Gravity inversion refers to the practice of hanging suspended in the fully inverted (−90° head-down) position. More appropriately called static gravity inversion, this procedure uses boots that clamp around the ankle joint and permit an individual to hang from a horizontal bar. Since its development in the late 1960s, static gravity inversion has been used for many unlikely applications, including weight lifting while in the inverted position.[1,2] However, early reports of periorbital petechiae,[3] headaches, and a sensation of head pressure,[2-4] prompted several studies on the effects on blood pressure (BP), intraocular pressure, and central retinal arterial pressures.[4-6] These studies reported increases in all of these pressures. The mechanism underlying the increase in systemic BP seems to be a CNS response to the anxiety associated with inversion procedures[5] and not solely a result of an increased cardiac

continued

Dr. Goldman is in the osteopathic and internal medicine division, Dr. Tarr is in the physiology division, Dr. Pinchuk is in the ophthalmology department, and Dr. Kappler is professor and chair of osteopathic medicine at the Chicago College of Osteopathic Medicine.

In inversion oscillation a person is placed on a counterweighted tilt board that rotates freely in a circular plane.

preload caused by venous return.[5,7-10]

The fully inverted state can also be accomplished using oscillation inversion techniques. In oscillation inversion a person is placed on a counterweighted tilt board that rotates freely in a circular plane. Figure 1 illustrates the operation of a gravity oscillator. The subject controls the rate of rotation with small movements of the legs and back. Oscillation procedures were developed to minimize the discomfort that can be experienced with static inversion and to provide dynamic force on the skeleton. Since the subject has control of the inversion procedure, and since the length of time in the fully inverted state is determined by the patient's tolerance, there is less of the anxiety and/or sensation of prolonged cranial congestion that is common during static inversion.

Static inversion procedures were initially very popular.[1,2,4,11] Lately, the newer oscillation procedures have become increasingly widespread. Because static inversion increases BP, intraocular pressure, and central retinal pressure and because the increases in BP are thought to be related to anxiety, this study measures these pressures during gravity oscillation procedures.

Methods

Twenty healthy men (average age 25 years, weight 179 lb, and height 5 ft 10 in.) volunteered to be subjects. None had any history of hypertension or glaucoma. The subjects were briefly trained to operate gravity oscillation equipment. Their systemic BP, pulse rate, intraocular pressure, and central retinal arterial pressure were measured in the upright seated position. The subjects were then allowed to oscillate for 15 minutes. Each full cycle (from upright to fully inverted and back to upright) was at least six seconds. Thus, each subject was fully inverted 80 to 150 times during the 15 minutes. At 5, 10, and 15 minutes the systemic BP, pulse rate, intraocular pressure, and central retinal arterial pressure were measured while the subject was inverted.

Pulse rates were taken from the radial pulse of the right wrist. A Propper sphygmomanometer and a Littmann cardiology stethoscope were used to measure BP with the right arm supported laterally at heart level for all measurements. Intraocular pressure was measured using a MacKay-Marg Model 12 applanation tonometer. Ophthalmodynamometry was used to measure central retinal arterial pressure.[12] In this technique the instrument probe of the tonometer was placed on the sclera of the anesthetized eye (one to two drops of 0.5% proparacaine HCl) just adjacent to the limbus. The arteries were visualized using a direct ophthalmoscope at the optic disk. The pressure was recorded at first pulsation of the arteries. The pressure on the globe was then continually increased until pulsation ceased. The first pulsation was recorded as the diastolic pressure, and the latter was the systolic pressure.

Means and standard errors were calculated for the following variables: systemic systolic and diastolic BPs, pulse rate, central retinal systolic and arterial pressures, and intraocular pressure. Statistical significance was determined using a Student's t-test suitable for paired data with $p < .05$ (two-tailed test) considered significant.[13]

Results

Both systolic and diastolic BP decreased on inversion. Systolic pressure fell from 123 ± 1.6 (upright) to 121 ± 1.2 mm Hg (inverted position, measured at five minutes). Diastolic pressure fell from 81 ± 0.7 to 80 ± 0.6 mm Hg. BP in the inverted position was significantly lower at each successive recording (table 1).

Average pulse rate before inversion was 69 ± 1.8 beats·min^{-1}. At five minutes inverted it was 66 ± 1.9 beats·min^{-1}. At ten minutes pulse was 65 ± 1.8, and at 15 minutes it was 64 ± 1.9 beats·min^{-1}. The decreases from initial to five minutes and from five to ten minutes were statistically significant. The decrease seen between the 10- and 15-minute measurement times was not statistically significant (table 1).

Both systolic and diastolic central retinal pressure increased on inversion (table 2). At the five-minute measurement point the systolic pressure had risen from 54 ± 3.1 to 91 ± 3.2 mm Hg, and the diastolic pressure rose from 32 ± 2.8 to 50 ± 3.2 mm Hg. No statistically significant changes occurred during the 15-minute oscillation period.

Intraocular pressure increased on inversion. Average intraocular pressure was 17 ± 0.3 mm Hg in the upright position and 33 ± 0.8 mm

Table 1. Systolic and Diastolic Systemic Blood Pressure (BP) and Pulse Rate in 20 Men Before and During Inversion (Mean ± SE)

	Preinversion (Upright)	Inverted 5 Minutes	Inverted 10 Minutes	Inverted 15 Minutes
Systolic BP (mm Hg)	123 ± 1.6	121 ± 1.2*	120 ± 1.0*	118 ± 1.0*
Diastolic BP (mm Hg)	81 ± 0.7	80 ± 0.6*	79 ± 0.5*	78 ± 0.5*
Pulse rate	69 ± 1.8	66 ± 1.9*	65 ± 1.8†	64 ± 1.9†

*Significantly different ($p < .05$) from both preinversion and adjacent time columns.
†Significantly different ($p < .05$) from preinversion only.

Table 2. Central Retinal Systolic and Diastolic Pressures and Intraocular Pressure in 20 Men Before and During Inversion (Mean ± SE)

	Preinversion (Upright)	Inverted 5 Minutes	Inverted 10 Minutes	Inverted 15 Minutes
Systolic central retinal pressure (mm Hg)	54 ± 3.1	91 ± 3.2*	91 ± 3.2*	90 ± 3.2*
Diastolic central retinal pressure (mm Hg)	32 ± 2.8	50 ± 3.2*	49 ± 3.4*	49 ± 3.2*
Intraocular pressure (mm Hg)	17 ± 0.3	33 ± 0.8†	32 ± 0.7†	31 ± 0.7*

*Significantly different ($p < .05$) from preinversion only.
†Significantly different ($p < .05$) from both preinversion and adjacent time columns.

Hg after five minutes of oscillating inversion. The pressure dropped from to 32 ± 0.7 mm Hg at 10 minutes and 31 ± 0.7 mm Hg at 15 minutes. These decreases in intraocular pressure observed were small but statistically significant (table 2).

Discussion

Studies in both normotensive[4,6] and hypertensive[5] subjects using static inversion showed increases in BP, pulse rate, intraocular pressure, and central retinal arterial pressure. Analysis of these increases,[4-6] however, suggested that the elevated BPs resulted from centrally mediated neural events, probably the anxiety attendant with inversion. The extensive literature from carefully controlled tilt table experiments verifies this hypothesis: Tilting does not cause an increase in BP because the increase in venous return observed in tilted subjects is offset by a reflex-mediated decrease in heart rate.[6-9,14-16] Thus, in the static inversion studies, the rise in both heart rate and BP suggests some process other than the increase in cardiac preload caused by inversion.[5]

In this study the subjects reported a calm, relaxed feeling of well-being while operating the oscillation equipment. Their ability to control the degree and duration of inversion and avoid a prolonged (static) inversion posture resulted in a relatively anxiety-free situation. The decreases in systemic BPs and pulse rates observed presumably reflect this feeling of tranquility. The fact that BP continued to fall throughout the 15-minute inversion period is especially significant because it suggests that the procedure can relax subjects even beyond resting levels.

The increases in intraocular pressure and central retinal arterial pressure reported here, as in previous studies on static inversion, are hydrostatic effects.[4-6] That is, in the inverted position, the column of blood between the heart and head will cause an increase in pressure in the vessels of the head. Venous distension will allow accumulation of blood in the extracranial vessels. Increase in intraocular pressure presumably occurs as a result of an

continued

increased resistance to aqueous outflow from an elevation of episcleral venous pressure similar to that seen when a person changes from a sitting to a supine position.[17-19] It is well documented that the increase in cerebral (intracranial) BP is balanced by increased interstitial hydrostatic pressure.[5,8,14,20] Even in the vessels of the eye, however, the increased BP is balanced by increases in intraocular pressure.[21]

See related article on page 85.

Further, the risk of stroke expressed in previous studies appears to be exaggerated. There have been no reports of stroke, cerebrovascular accident, or any serious injury with properly functioning gravity inversion equipment. Protection against brain hemorrhage may be afforded by the concomitant increase in cerebrospinal fluid (CSF) and the "closed box" system of the skull.[22] One may be at greater risk of stroke during strenuous weight training or severe anxiety in the upright posture, which would not provide those protective CSF elevations. The unexpected finding in the present study of a progressive decrease in intraocular pressure as the oscillation period continued is most interesting and invites further study. It may reflect the decrease in systemic BP.

In conclusion, oscillating inversion procedures, unlike static inversion, decrease both systolic and diastolic systemic BP and pulse rate. These decreases may result from the relaxed and calm emotional state that oscillation procedures afford. We conclude that full inversion using an oscillation procedure presents no risk to normal subjects.

Acknowledgments

We thank Richard Bell, PhD, and Amor Lowsitisukd, MS, from the Chicago College of Osteopathic Medicine for their help in preparing the statistical analysis of the data.

Address correspondence to Robert M. Goldman, DO, Chicago College of Osteopathic Medicine, 5200 S Ellis Ave, Chicago 60615.

References

1. Hang ten: flipping over gravity boots. Time 1983; 121(May 2):61
2. Klein FC: On sports. Wall Street Journal 1982;(Oct 21):28
3. Plocher DW: Inversion petechiae, letter. N Engl J Med 307(Nov 25):1406-1407
4. Klatz RM, Goldman RM, Pinchuk BG, et al: The effects of gravity inversion procedures on systemic blood pressure, intraocular pressure, and central retinal arterial pressure. J Am Osteopath Assoc 1983; 82(July):853-857
5. Klatz RM, Goldman RM, Pinchuk BG, et al: Effects of gravity inversion on hypertensive subjects. Phys Sportsmed 1985;13(March):85-89
6. LeMarr JD, Golding LA, Crehan KD: Cardiorespiratory responses to inversion. Phys Sportsmed 1983; 11(November):51-57
7. Katkov VE, Chestukhin VV, Lapteva RI, et al: Central and cerebral hemodynamics and metabolism of the healthy man during head-down tilting. Aviat Space Environ Med 1979;50(February):147-153
8. London GM, Levenson JA, Safar ME, et al: Hemodynamic effects of head-down tilt in normal subjects and sustained hypertensive patients. Am J Physiol 1983;245(August):H194-H202
9. Siddbald WJ, Patterson NAM, Holliday RL, et al: The Trendelenburg position: hemodynamic effects in hypotensive and normotensive patients. Crit Care Med 1979;7:218-224
10. Taylor J, Weil MH: Failure of the Trendelenburg position to improve circulation during clinical shock. Surg Gynec Obstet 1967;124(May):1005-1010
11. Back specialists hit "inversion" fad. Medical World News 1983;24(March):49-50
12. Chusid JG: Correlative Neuroanatomy and Functional Neurology. Los Altos, CA, Lange Medical Publications, 1973
13. Keppel G: Design and Analysis: A Researcher's Handbook. Englewood Cliffs, NJ, Prentice-Hall, 1973
14. Badeer HS, Rietz RR: Vascular hemodynamics: deep rooted misconceptions and misnomers. Cardiology 1979;64(4):197-207
15. Gazenko OG, Shumakov VI, Kakurin LI, et al: Central circulation and metabolism of the healthy man during postural exposures and arm exercise in the head down position. Aviat Space Environ Med 1980; 51(February):113-120
16. Razin A: Upside-down position to terminate tachycardia of Wolff-Parkinson-White syndrome, letter. N Engl J Med 1977;296(Jun 30):1535
17. Anderson DR, Grant WM: The influence of position on intraocular pressure. Invest Ophthalmol 1973; 12(March):204-212
18. Galin MA, McIvor JW, Magruder GB: Influence of position on intraocular pressure. Am J Ophthalmol 1973:720-723
19. Leith AB: Episcleral venous pressures in tonography. Br J Ophthalmol 1963;47:271-278
20. Henry JP, Gauer OH, Kety SS, et al: Factors maintaining cerebral circulation during gravitational stress. J Clin Invest 1951;30:292-301
21. Duke-Elder S: System of Ophthalmology. St. Louis, CV Mosby Co, 1968, vol 4, pp 7-13
22. Henry JD: The physiology of negative acceleration. 1950 Air Material Command, Wright Patterson Air Force Base Report TR 5953