The Influence of Caffeine on Rotary Chair and Oculomotor Testing

DOI: 10.3766/jaaa.16118

Kathleen M. McNerney*
Mary Lou Coad†
Robert Burkard†

Abstract

Background: When patients are given instructions before vestibular function testing, they are often asked to refrain from ingesting caffeine 24 h before testing. However, research regarding the effects of caffeine on the outcome of vestibular function testing is limited.

Purpose: To evaluate whether the results from rotational chair tests are influenced by caffeine.

Research Design: Participants were tested after consuming a caffeinated beverage (i.e., coffee containing ~300 mg of caffeine), as well as after abstaining from caffeinated beverages. The participants underwent oculomotor testing, sinusoidal harmonic acceleration testing, optokinetic testing, visual enhancement/suppression testing, subjective visual vertical/horizontal testing, trapezoidal step testing, and unilateral utricular centrifugation testing.

Study Sample: Thirty healthy young controls aged 18–40 yr (mean = 23.28 yr; 9 males, 21 females) participated in the study.

Data Collection and Analysis: Rotational chair tests were completed with the Neuro Kinetics rotary chair (Pittsburgh, PA). VEST 7.0 software was used to collect and analyze the participants' eye movements (I-Portal VOG; Neuro Kinetics). IBM SPSS was used to statistically analyze the results.

Results: Statistically significant differences were found for the results from several oculomotor tests (i.e., vertical saccades [SCs], horizontal SCs, and optokinetics), whereas the remaining rotational chair tests did not reveal any statistically significant differences between sessions. If a statistically significant difference was found, the participants were then stratified based on the amount of caffeine they consumed on a daily basis. This stratification was accomplished based on the guidelines from the International Coffee Organization. When the data were analyzed based on the stratified groups, statistically significant results remained in the no/low caffeine intake group, whereas no statistically significant results remained in the moderate/high caffeine intake group. Clinically speaking, the largest effect was seen in those individuals who did not typically ingest large amounts of caffeine, whereas the results were not found to be significantly different in those individuals who were typical caffeine consumers. This strengthens the argument that it is not necessary to require that individuals refrain from consuming caffeinated beverages before oculomotor/rotary chair testing as the results from typical caffeine consumers are not significantly affected.

Conclusions: Although statistically significant results were found for a number of the oculomotor function tests, the ingestion of caffeine had little influence on the clinical interpretation of the responses. Therefore, the results from the present study indicate that it is not necessary to require that healthy young

*Department of Speech-Language Pathology, SUNY Buffalo State, Buffalo, NY; †Department of Rehabilitation Science, University at Buffalo, Buffalo, NY

Corresponding author: Kathleen M. McNerney, Department of Speech-Language Pathology, SUNY Buffalo State, Buffalo, NY 14222; Email: mcnernkm@buffalostate.edu

The first author (K.M.) received a New Investigator Research Grant from the American Academy of Audiology's Research Grants in Hearing and Balance program; this grant program is funded by the American Academy of Audiology/American Academy of Audiology Foundation Research Grants in Hearing and Balance Program.

Data collection and analysis was completed when the first author was working in the Department of Rehabilitation Science at the University at Buffalo.

This study was presented orally at the American Balance Society Meeting, March 6, 2013, Scottsdale, AZ.

individuals abstain from caffeine before undergoing rotary chair/oculomotor testing. Further research is necessary to determine whether there is also a limited effect of caffeine on rotary chair/oculomotor test results from older individuals, as well as individuals diagnosed with a vestibular impairment.

Key Words: caffeine, rotary chair, rotational chair, vestibular testing

Abbreviations: C = caffeine; HC = high caffeine user; LC = low caffeine user; NC = no caffeine; OPK = optokinetic; RC = rotary chair; SCs = saccades; SHA = sinusoidal harmonic acceleration; SP = smooth pursuit; SVH = subjective visual horizontal; SVV = subjective visual vertical; TST = trapezoidal step test; UUC = unilateral utricular centrifugation; VE = visual enhancement; VNG = videonystagmography; VS = visual suppression

INTRODUCTION

Rotational chair testing can be used clinically in the assessment of the function of the vestibular system. It is capable of providing information that is not obtained via standard videonystagmography (VNG). For example, caloric testing cannot provide information about frequencies above 0.003 Hz (i.e., the frequency of the convection currents in the endolymph resulting from thermal stimulation), which is an extremely low frequency not typically activated during everyday head movements (Barin, 2008). The information obtained from rotational chair testing can provide an indication as to how the vestibular system functions in response to higher frequency accelerations of the head; e.g., from 0.01 to 1.28 Hz, or sometimes 2 Hz (Brey et al, 2008). In addition, evaluation of the phase of eye movements obtained through rotational chair testing can provide information regarding how well someone has compensated for their vestibular impairment (Rubin, 1982).

Tests of oculomotor function are used to evaluate the central pathways which are imperative to the normal function of the vestibular–ocular reflex. These tests (which include smooth pursuit [SP], saccades [SCs], and optokinetics [OPKs]) require one to be able to accurately follow an illuminated dot (or dots) which are projected in front of them. Previous research has shown that the results from oculomotor tests can be affected by severe fatigue or the inability to attend to the stimulus (Hale et al, 2015).

Patients are often asked to refrain from ingesting anything that contains caffeine before undergoing routine vestibular testing (BayCare Clinic Ear; Brey et al, 2008; ENTCare). Previous studies in our laboratory have shown that caffeine has minimal effects on calorics, vestibular-evoked myogenic potentials, and the sensory organization test (McNerney et al, 2014a,b). The present study furthered the evaluation of caffeine on the results from vestibular function testing by examining the effects of caffeine on additional tests which can be administered in the Neuro Kinetics (Pittsburgh, PA) rotary chair.

METHODS

Thirty individuals between 18 and 40 yr of age (9 males, 21 females; mean = 23.28 yr), served as the participants in the present experiment. None of the participants reported a history of vestibular or balance dysfunction. The participants were tested during two separate sessions, which lasted ~2–3 h each. During the caffeine (C) session, individuals were asked not to drink caffeine the morning of the test and before data collection, and they were asked to drink 16 oz. of Starbucks Breakfast Blend coffee which contained ~300 mg of caffeine (McCusker et al, 2003; Caffeine Informer, 2014). A higher amount of caffeine was chosen to determine whether there were any effects of larger amounts of caffeine on rotary chair tests. This would then allow generalization of the results to individuals who drank more than two cups of coffee with lower amounts of caffeine. The participants finished the coffee within ~30 min, which coincided with the peak absorption time (i.e., ~30 min), and the sessions were completed well within the half-life of caffeine, i.e., 2.5–10 h (Dernaro and Benowitz, 1991). During the no caffeine (NC) sessions, the participants were asked not to consume caffeine for 24 h before testing. Testing sessions were counterbalanced across the participants and were separated by at least 1 day. The participants were also asked to keep a caffeine diary over a 7-day time period, which allowed us to evaluate how much caffeine they drank on a daily basis. The participants were asked to insert the number and type/brand of each drink they consumed (i.e., espresso and espresso drinks, brewed coffee, and black tea). An "other" column was included in the event that a particular participant consumed a beverage that was not included on the list. The exact amount of daily intake was then computed by the experimenters using online resources (Mayo Clinic, 2014; Wilstar, 2014). This information was then used to separate the participants into a low caffeine (LC) intake group, which consisted of individuals who consumed no/low amounts of caffeine per day (i.e., 0–200 mg) or a high caffeine (HC) intake group, which consisted of individuals who consumed moderate/high amounts of caffeine per day (i.e., >200 mg). Criteria for stratifying the participants into LC versus HC intake groups were based on data from the International Coffee Organization (2012). This stratification of groups was used to analyze the results from the C versus NC session as a function of caffeine intake when statistically significant results were revealed (i.e., the C versus NC results were compared in the LC intake group and

the C versus NC results were compared in the HC intake group).

The participants were also asked to answer a caffeine withdrawal questionnaire before the NC session, which assessed the severity of 14 common caffeine withdrawal symptoms, e.g., fatigue, fogginess, and irritability (Ozsungur et al, 2009). The participants indicated whether they were experiencing a particular symptom, as well as the severity of that symptom on an 11-point Likert scale (e.g., 0 = no symptom present versus 10 = experiencing this particular symptom on a severe scale).

Rotary Chair Testing

The participants were secured in a Neuro Kinetics rotary chair. I-Portal VOG eye goggles (Neuro Kinetics) were used to record the movements of each individual eye (video-oculography). VEST 7.0 software was used to collect and analyze the participants' eye movements (Neuro Kinetics). The participants first performed the following oculomotor tests.

SP

This test evaluates the ability to track an object with smooth eye movements. This is a test of oculomotor function. SP was tested in the horizontal plane at 0.10 Hz (three cycles), 0.030 Hz (three cycles), 0.050 Hz (four cycles), and 0.75 Hz (six cycles), and in the vertical plane at 0.10 Hz (three cycles), 0.30 Hz (three cycles), and 0.50 Hz (four cycles). The parameters analyzed were gain, phase (°), and asymmetry (%) of eye movements.

SCs

This test evaluates movement of the eyes in response to rapid "jumps" of an illuminated dot. Sixty SCs presented at random times and displacements were presented in the horizontal as well as the vertical planes. Peak velocity (°/sec), latency (sec), accuracy (%), and duration (sec) of eye movements were analyzed. Saccade duration was calculated by computing the difference between when the movement of the eye starts to when the eye reaches target (i.e., stopping) position.

Full-Field Optokinetics (OPK)

This test measures the nystagmus created by repeated stimuli (i.e., Dots which encompass the participant's entire visual field. It resembles the type of lights emitted from a disco ball.) moving in front of the participant. The stimuli were presented at either 20, 40, or 60°/sec. Ramp up/down time was 0.5 sec and peak time was 10 sec for each stimulus speed. Eye velocity gain (normalized to 20°/sec) during each stimulus speed was collected and analyzed.

The participants then underwent the following rotary chair (RC) tests.

Trapezoidal Step Test (TST)

During this evaluation, the horizontal vestibular–ocular reflex is tested. The participants underwent an acceleration phase of 0.8 sec until they reached a peak velocity of 100°/sec. The participants were then rotated for an average of 60 sec. In healthy individuals, when the specified velocity is reached and maintained without further acceleration, the participant falsely perceives that the chair is slowing down, and the evoked nystagmus will eventually stop. Once this occurred, the participants underwent a deceleration step to a complete stop. During this phase, the participants incorrectly perceive that they are rotating in the opposite direction. The participants' eyes were again monitored and recorded for up to 60 sec after the rotary chair was stopped. The participants then underwent the second phase of the TST with the chair rotating in the opposite direction (Shepard, 2009). The parameters analyzed included peak velocity (°/sec), decay time (sec), and gain.

Sinusoidal Harmonic Acceleration (SHA)

During this evaluation, the horizontal semicircular canal is tested in response to repetitive sinusoidal motion of the rotary chair. Several frequencies were tested, including 0.02 Hz (two cycles), 0.04 Hz (three cycles), 0.08 Hz (three cycles), 0.64 Hz (eight cycles), and 1.28 Hz (nine cycles). Gain, phase (°), and asymmetry (%) of the eye movements were measured in relation to the chair movements.

Subjective Visual Vertical/Horizontal (SVV/SVH)

This is a test of otolith function. Healthy individuals are generally very good at setting the line very close to 0°, i.e., on average within 1°–2° (Bronstein, 2008). During this evaluation, the participants were presented with a straight line at an angle of −20° to +20° to true vertical, and −35° to +35° to true horizontal for SVV and SVH, respectively. The participants were then asked to adjust this line using a push button located on either handle of the rotary chair until it was as close to vertical (six trials) and as close to horizontal (six trials) as possible.

Unilateral Utricular Centrifugation (UUC)

This is a test of utricular function, and it can provide independent information on the function of each utricle separately. During this evaluation, the participants were rotated until they reached a maximum velocity of 300°/sec (ramp up time = 60 sec; peak time = 375 sec; ramp down time = 100 sec). They were then shifted to the right 4 cm, back to the center, and then to the left 4 cm. During each shift of the chair, the participants

were asked to perform multiple trials of SVV (i.e., ideally up to three). The average of the SVV deviations during each shift of the chair were collected and analyzed.

Visual Enhancement/Suppression (VE/VS)

During the VE test, the participants are rotated in the chair at 0.64 Hz while OPK stimuli are illuminated on the wall. In a healthy individual, the gain of the eye movement should be greater compared with when the participant is simply being rotated in the dark. The parameters analyzed included eye gain, asymmetry (%), and phase (°). During the VS test, the participants are rotated in the chair and are asked to remain focused on an illuminated dot which spins with the participant. A healthy individual will be able to suppress any nystagmus which is evoked from the movement of the chair. The results from eye gain were analyzed.

For further information regarding the above tests, please see Brey et al (2008).

Statistical Analysis

Statistical analyses via paired *t*-tests were initially completed with IBM SPSS Statistics 20. When statistically significant results were found, individuals were allocated into different groups based on their weekly caffeine consumption (i.e., LC intake group versus HC intake group). Effect size was calculated via a Cohen's *d* for paired tests ($d = [M_{\text{difference}}/\text{SD}_{\text{difference}}]$). A Cohen's *d* of 0.20 or less would be equivalent to a small effect size, a Cohen's *d* of 0.50 would be equivalent to a medium effect size, and a Cohen's *d* of 0.80 would be equivalent to a large effect size (Cohen, 1988; Nolan and Heinzer, 2011). Statistical analyses of the data, which were conducted during the revision of the article, were completed with version 24 of the IBM SPSS Statistics software.

RESULTS

Caffeine Diary

Weekly caffeine consumption varied from 0 to 4,358 mg of caffeine per week. The weekly caffeine intake was divided by 7 to estimate the amount of daily caffeine intake among the participants. The daily caffeine intake ranged from 0 to 623 mg (mean = 162 mg; SD = 141). The NC/LC intake group was composed of 22 participants whose caffeine consumption ranged from 0 to 183 mg per day, whereas the moderate/high caffeine intake group was composed of eight participants whose daily caffeine intake ranged from 231 to 623 mg of caffeine per day.

Caffeine Withdrawal Questionnaire

Overall, the caffeine withdrawal questionnaire revealed very low caffeine withdrawal scores. Of the thirty participants, severity ratings from 27 participants were averaged (the caffeine diary from three participants revealed no caffeine intake and therefore were not included in the severity rating analysis). Out of 140 possible points, the mean of all of the symptom severity ratings combined across all of the participants was 11.41, whereas the average severity rating within participant ranged from 0 to 59. The most commonly reported symptom was tiredness (N = 19), followed by decreased energy/activeness (N = 18), sleepiness (N = 17), and decreased alertness/attentiveness (N = 16). For more information regarding the caffeine withdrawal questionnaire, please see McNerney et al (2014a,b).

Oculomotor Tests

SP

SP testing was completed in the vertical as well as the horizontal planes. The results are displayed in Table 1. Statistical analysis did not reveal any statistically significant differences between the C and NC sessions for any of the frequencies tested, regardless of plane of stimulation.

SCs

The participants underwent SC testing in the horizontal as well as the vertical plane. The mean of the values from the left and right eyes was computed for

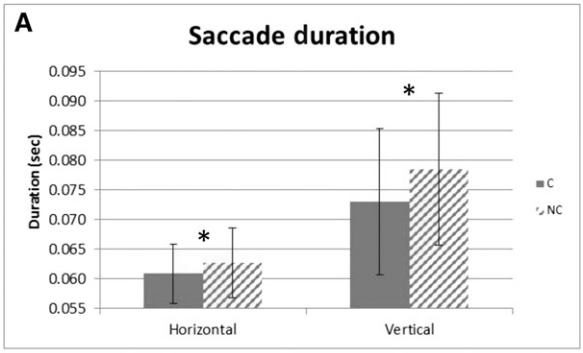
Table 1. Smooth Pursuit

	Horizontal				Vertical		
	0.10 Hz	0.30 Hz	0.50 Hz	0.75 Hz	0.10 Hz	0.30 Hz	0.50 Hz
				C			
Gain	1.00 ± 0.02	1.00 ± 0.02	0.99 ± 0.04	0.94 ± 0.07	1.01 ± 0.03	1.01 ± 0.06	0.96 ± 0.08
Asymmetry (%)	0.61 ± 0.47	1.19 ± 1.29	1.41 ± 1.55	2.42 ± 1.88	2.08 ± 1.80	2.36 ± 2.46	4.23 ± 3.21
Phase (°)	0.42 ± 0.32	0.94 ± 0.83	2.83 ± 1.82	4.28 ± 2.89	1.64 ± 1.26	1.91 ± 2.00	3.75 ± 2.60
				NC			
Gain	1.01 ± 0.03	1.00 ± 0.03	0.99 ± 0.04	0.93 ± 0.08	1.01 ± 0.04	1.02 ± 0.09	0.96 ± 0.10
Asymmetry (%)	0.58 ± 0.54	1.17 ± 0.84	1.48 ± 1.42	2.79 ± 2.81	2.66 ± 2.12	3.39 ± 3.82	3.67 ± 3.51
Phase (°)	0.71 ± 0.82	1.29 ± 1.45	2.45 ± 1.85	4.18 ± 2.85	1.94 ± 1.64	2.00 ± 2.06	2.69 ± 2.08

Note: Mean ± SD results for SP in the horizontal (SPH) as well as the vertical (SPV) planes.

latency, duration, amplitude, peak velocity, and accuracy. Absolute values were obtained for SC amplitude, as well as for peak velocity before the computation of the means across participants. The results from statistical analyses in the horizontal plane revealed statistically significant differences between the C and NC session for saccade duration [$t(29) = -2.13, p = 0.042$; $M_{difference} = -0.002$, $SD_{difference} = 0.005$; Cohen's $d = 0.39$] and peak velocity [$t(29) = 3.499$, $p = 0.002$; $M_{difference} = 16.78$, $SD_{difference} = 26.26$; Cohen's $d = 0.64$], whereas the results obtained in the vertical plane revealed statistically significant differences for SC duration only [$t(29) = -3.17$, $p = 0.004$; $M_{difference} = -0.006$, $SD_{difference} = 0.01$; Cohen's $d = 0.58$]. The results from SC duration and peak velocity are shown in Figures 1A and B. SC latency, amplitude, and accuracy did not reveal any statistically significant differences between the two sessions. The duration of both the horizontal and vertical SCs was slightly longer in the NC versus the C session ($\Delta = 0.002$ sec for horizontal SCs and $\Delta = 0.006$ sec for vertical SCs), and horizontal peak velocity was higher in the C versus NC session (C = 375.03°/sec versus NC = 358.26°/sec).

When the participants were allocated into the LC versus HC intake groups, a statistically significant result remained for vertical saccade duration in the LC group [$t(21) = -3.04, p = 0.006$; $M_{difference} = -0.007$, $SD_{difference} = 0.01$; Cohen's $d = 0.65$], whereas no significant differences were found in the HC group. In regard to the horizontal plane, no statistically significant results were obtained for either group. In contrast, horizontal peak velocity revealed a statistically significant difference in the LC intake group [$t(21) = 3.08$, $p = 0.006$; $M_{difference} = 17.87$, $SD_{difference} = 27.13$; Cohen's $d = 0.66$], whereas no significant differences were found in the HC group.



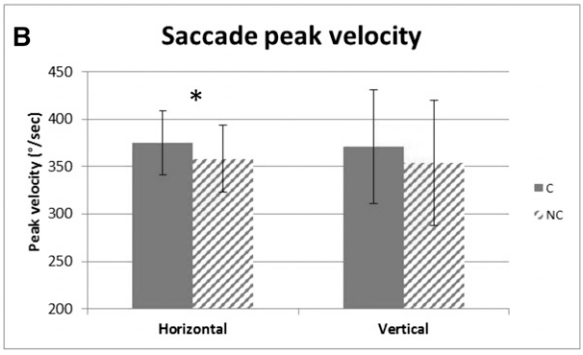


Figure 1. (A) and (B) display the results from SC duration and peak velocity in the horizontal as well as the vertical plane. Significant results are indicated by an * ($p \leq 0.05$).

Optokinetics

Eye velocity gain (normalized to 20°/sec) recorded in response to optokinetic stimuli is shown in Figure 2. Statistical analysis via paired *t*-tests revealed that OPK eye velocity gain was significantly different for the 40°/sec [$t(29) = 2.25$, $p = 0.033$; $M_{difference} = 0.04$, $SD_{difference} = 0.09$; Cohen's $d = 0.41$] and 60°/sec [$t(29) = 2.37$, $p = 0.024$; $M_{difference} = 0.04$, $SD_{difference} = 0.08$; Cohen's $d = 0.43$] stimuli. The mean data indicate that individuals had higher OPK eye velocity gain values in the C versus the NC session for all of the stimuli presented (i.e., 20, 40, and 60°/sec). When the participants were separated into an LC intake group versus an HC intake group, a statistically significant difference remained in both the 40°/sec [$t(21) = 2.8$, $p = 0.011$; $M_{difference} = 0.05$, $SD_{difference} = 0.08$; Cohen's $d = 0.60$] and the 60°/sec [$t(21) = 2.5$, $p = 0.021$; $M_{difference} = 0.05$, $SD_{difference} = 0.09$; Cohen's $d = 0.53$] conditions in the LC intake group, whereas no statistically significant differences remained in the HC intake group.

Rotary Chair Tests

SHA

During SHA, the participants were tested at frequencies of 0.02, 0.04, 0.08, 0.64, and 1.28 Hz. Average eye gain, asymmetry (%), and phase (°) are listed in Table 2. Statistical analyses did not reveal any statistically significant differences between the C and NC sessions.

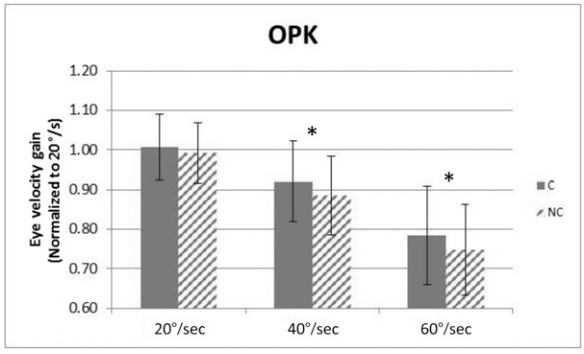


Figure 2. The average eye velocity gain (normalized to 20°/sec) from full-field optokinetic testing for 20, 40, and 60°/sec. Significant results are indicated by an * ($p \leq 0.05$).

Table 2. Sinusoidal Harmonic Acceleration

	C			NC		
	Gain	Asymmetry (%)	Phase (°)	Gain	Asymmetry (%)	Phase (°)
0.02 Hz	0.44 ± 0.12	9.26 ± 6.43	22.11 ± 5.94	0.45 ± 0.11	7.90 ± 4.30	23.58 ± 6.22
0.04 Hz	0.51 ± 0.15	8.14 ± 7.26	10.15 ± 4.65	0.52 ± 0.14	6.89 ± 5.31	10.68 ± 5.16
0.08 Hz	0.53 ± 0.19	7.06 ± 5.82	3.96 ± 3.63	0.55 ± 0.18	7.71 ± 6.08	4.39 ± 3.02
0.64 Hz	0.58 ± 0.18	8.74 ± 6.57	9.51 ± 4.88	0.61 ± 0.16	8.47 ± 6.98	7.73 ± 3.90
1.28 Hz	0.90 ± 0.15	4.21 ± 5.07	14.54 ± 6.46	0.92 ± 0.13	2.79 ± 1.98	12.79 ± 6.19

Note: Mean ± SD results for SHA testing.

VE/VS

Eye gain, asymmetry (%), and phase (°) results in response to the VE test and eye gain in response to the VS test can be found in Table 3. Statistical analyses did not reveal any statistically significant differences between the C and NC sessions for any of the recorded measurements.

TST

Table 4 displays eye gain, peak velocity (°/sec), and decay time (sec) in response to the TST. Statistical analyses did not reveal any significant differences between the C and NC sessions for any of the comparisons.

SVV/SVH

Table 5 displays the results from the SVV and SVH tests. The average of the six trials from the relevant plane was computed. An additional SVV test was added to the protocol to evaluate whether SHA testing influences the results of SVV testing. The participants were evaluated on six SVV trials before undergoing SHA and six SVV trials after undergoing SHA. A paired *t*-test of the SVV results pre- versus post- SHA testing found no statistically significant differences between the two measurements. When evaluating the individual differences in degrees between the estimations made pre- versus post-SHA, the largest individual difference in the C session was 2.21°, and the largest individual difference in the NC session was 2.61°. A paired *t*-test comparing the results between the C and the NC sessions for SVV, pre- versus post-SHA, also did not reveal any statistically significant differences. In addition, analysis of the SVH results did not reveal any statistically significant differences between the two sessions.

UUC

Table 6 displays the results from SVV while the participants were undergoing UUC. The average of the SVV deviations during each shift of the chair were collected and analyzed. Comparison of the mean data from the C versus NC sessions via paired *t*-tests did not reveal any statistically significant differences between the two sessions.

DISCUSSION

Rotational chair testing provides information about vestibular function that cannot be assessed via traditional VNG testing. Although in the present study, oculomotor tests were included in the battery of tests that were administered in the rotary chair, they are typically administered during VNG testing. The only statistically significant results that were found in the present study were obtained during oculomotor testing, which included SCs and optokinetics. The remaining tests administered in the rotary chair did not reveal any statistically significant differences between the C and NC sessions. This provides support for the argument that it is not necessary to require healthy young adults to abstain from drinking caffeine before undergoing rotational chair tests.

Caffeine is absorbed relatively quickly after consumption and is circulated through the body including the brain. It has been shown that caffeine can increase neuronal activity (which can result in increased arousal and attention) by binding to A1 receptors, thereby promoting the release of neurotransmitters such as glutamate, dopamine, and acetylcholine (Einöther and Giesbrecht, 2013). Caffeine has also been shown to increase reaction time as well as accuracy in a variety of studies (Fine et al, 1994; Lorist et al, 1994; Smith et al,

Table 3. Visual Enhancement/Visual Suppression

	C			NC		
	Gain	Asymmetry	Phase	Gain	Asymmetry	Phase
VE	1.07 ± 0.08	1.19 ± 1.16	4.91 ± 1.71	1.06 ± 0.07	1.30 ± 1.17	4.42 ± 1.70
VS	0.14 ± 0.05			0.15 ± 0.06		

Note: Mean ± SD results for the VE as well as VS tests.

Table 4. Trapezoidal Step Test

	Pre-RR	Post-RR	Pre-RL	Post-RL
		Peak Velocity (°/sec)		
C	−65.22 ± 20.27	58.99 ± 14.24	60.19 ± 19.54	−61.18 ± 17.77
NC	−64.12 ± 15.92	63.00 ± 14.86	64.09 ± 15.15	−62.15 ± 13.19
		Decay Time (sec)		
C	15.68 ± 4.51	15.45 ± 4.14	12.94 ± 3.25	14.98 ± 3.94
NC	15.04 ± 4.43	14.63 ± 4.23	11.97 ± 3.98	15.70 ± 5.71
		Gain		
C	0.66 ± 0.20	0.59 ± 0.14	0.60 ± 0.20	0.61 ± 0.18
NC	0.64 ± 0.16	0.63 ± 0.15	0.65 ± 0.15	0.63 ± 0.13

Notes: Mean ± SD results for the TST. Pre-RR = pre-rotary right; Post-RR = post-rotary right; Pre-RL = pre-rotary left; Post-RL = post-rotary left.

1994; Haskell et al, 2005; 2008; Maridakis et al, 2009; Smith, 2009; Einöther and Giesbrecht, 2013). It is therefore not surprising that the tests that revealed a statistically significant difference between the C and NC sessions were tests of central function that have been shown to be affected by attention and fatigue (Hale et al, 2015). The results from oculomotor tests typically revealed faster responses (i.e., higher peak velocity, shorter duration) and higher gain values in the C versus the NC session. It is logical to suggest, therefore, that this is the result of the stimulant property of caffeine. Although statistically significant results were found, it is important to consider the "clinical significance" of these findings.

Normative data are not currently available in the VEST software that was utilized to collect and analyze the data from the Neuro Kinetics chair. Therefore, to determine whether there was a clinically significant difference between the sessions, data from individual participants were evaluated from each session to determine if the results fell within 2 SD of the group mean data obtained during the NC session (Table 7). For any given condition that revealed a statistically significant result, there were no more than two participants who fell outside of the 2 SD range (with the exception of the gain in response to the 60° OPK stimulus, in which three participants fell outside of the group NC session mean ±2 SD range). Further analysis of the data revealed that there were only two participants whose results fell outside of the 2 SD range for more than one condition/session. One of the participants displayed two responses that were outside of the 2 SD range during the NC session and two responses that were outside of the range during the C session. Three of the four outlier responses were obtained during the OPK testing. This particular participant was found to be a low caffeine drinker as per the guidelines stated earlier in this article, and provided low caffeine withdrawal ratings (total severity rating of 7). As oculomotor testing relies heavily on patient/participant participation/attentiveness, it is possible that this particular participant would have needed further instruction and/or addition trials to obtain accurate recordings as the results of OPK gain were consistently below the 2 SD range, regardless of caffeine intake. The other participant fell outside of normal limits for horizontal SC duration during the NC session and horizontal SC peak velocity during the C session. This particular participant was also categorized as a low caffeine drinker and provided low caffeine withdrawal ratings (total severity rating of 1). This is the only participant who fell outside of the 2 SD range for the horizontal SCs. As the horizontal peak velocity for this participant was more than 2 SD below the mean in the "caffeine" condition, and given the known stimulant properties of caffeine, it is unlikely that the results are because of the ingestion of caffeine. If this observation was likely to be due to the stimulant properties of caffeine and not to random variation in the data, we would have expected an increase in peak velocity during the C session and not the observed decrease. In summary, despite the statistically significant differences displayed during several tests of oculomotor function (Figures 1 and 2), there were no clinically significant differences found when comparing the results from both sessions. This would support the conclusion that it is not necessary to require that healthy young adults abstain from ingesting caffeine before undergoing tests of oculomotor function administered in the rotary chair.

Table 5. Subjective Visual Vertical/Horizontal

	C	NC
SVV—Pre-SHA	−0.11° ± 1.71°	−0.53° ± 1.49°
SVV—Post-SHA	−0.10° ± 1.56°	−0.32° ± 1.13°
SVH	−1.07° ± 1.10°	−0.65° ± 1.05°

Note: Mean ± SD for the SVV and SVH tests.

Table 6. Unilateral Utricular Centrifugation

	R	C	L
C	−2.07° ± 3.49°	0.24° ± 2.61°	3.00° ± 3.69°
NC	−2.41° ± 4.33°	0.45° ± 2.89°	3.16° ± 4.30°
	0.33°	−0.21°	−0.16°

Note: Results from SVV while the patient was undergoing UUC, when positioned to the right (R), center (C), and left (L).

Table 7. Oculomotor Test Analysis

NC				
SCs			OPK gain (normalized to 20°/sec)	
Horizontal		Vertical		
Duration (sec)	Peak Velocity (°/sec)	Duration (sec)	40°/sec	60°/sec
S#2(+)	—	S#30(+)	S#8(−), S#30(−)	—
C				
SCs			OPK (normalized to 20°/sec)	
Horizontal		Vertical		
Duration (sec)	Peak Velocity (°/sec)	Duration (sec)	40°/sec	60°/sec
—	S#2(−)	—	S#30(−)	S#6(+), S#21(+), S#30(−)

Notes: Display of the participants who were outside of the 2 SD range for each of the oculomotor tests which revealed a statistically significant difference between the C and NC sessions. An (−) indicates that no participant fell outside of the 2 SD range. A (+) or (−) after the participant number indicates whether the participant fell above or below the 2 SD range.

Further support of the above conclusion is provided through the comparison of the statistical analysis of the results from the LC versus HC groups. When statistically significant results were found between the C and NC sessions for any given measure, the participants were then separated into two groups based on the amount of caffeine they consumed per day. The LC group consisted of 22 individuals, whereas the HC group consisted of eight individuals. Ideally, we would have liked to have equal or near-equal numbers for the LC and HC groups. As we did not assess the amount of caffeine that each individual consumed on a daily basis before enrolling them in the study, we were only able to obtain this information from the caffeine diary that the participants were asked to complete between the C and NC sessions. Despite this, the results revealed that statistically significant differences remained in the LC intake group, whereas no statistically significant differences remained in the HC intake group. It is possible that the lack of significance for the HC intake group was because of a lack of statistical power. However, individuals who do not drink caffeine would not likely start to on the day of the test (i.e., those in the LC group), and individuals who normally ingest moderate to high amounts of caffeine on a daily basis would likely continue with their normal routine (i.e., those in the HC group). This again strengthens the argument that it does not appear necessary to require that healthy young adults abstain from drinking caffeine before undergoing tests of oculomotor function administered in the rotary chair.

CONCLUSIONS

The present study evaluated whether the results from rotary chair tests are influenced by whether an individual ingests caffeine before undergoing testing. Given that statistically significant results were found during tests that are typically completed during a VNG evaluation but not for tests which require a rotary chair to be administered (i.e., SHA, VS/VE, and TST), it does not support the requirement of having young healthy adults refrain from drinking caffeine before undergoing rotary chair testing. In addition, although some of the results from oculomotor testing did reveal some statistically significant differences, none of the changes displayed would be classified as "clinically significant" changes in results. Future research is necessary to determine if the same results would occur in individuals who have been diagnosed with a vestibular impairment, as well as in older individuals. Also, these results are only generalizable to those who consume a moderate dose of caffeine before vestibular assessment. A dose/response curve of caffeine consumption for the various tests of vestibular and oculomotor function might be enlightening.

REFERENCES

Barin K. (2008) Background and technique of caloric testing. In: Jacobson GP, Shephard NT, eds. *Balance Function Assessment and Management*. San Diego, CA: Plural Publishing.

BayCare Clinic's Ear, Nose, and Throat. Retrieved from http://www.baycare.net/media/133993/ent_eng_instructions.pdf. Accessed August 21, 2012.

Brey RH, McPherson JH, Lynch RM. (2008) Technique, interpretation, and usefulness of whole body rotational testing. In: Jacobson GP, Shephard NT, eds. *Balance Function Assessment and Management*. San Diego, CA: Plural Publishing.

Bronstein AM. (2008) Tests of otolith function and vestibular perception. In: Jacobson GP, Shepard NT, eds. *Balance Function Assessment and Management*. San Diego, CA: Plural Publishing, 435–446.

Caffeine Informer. (2014) The Complete Guide to Starbucks Caffeine. http://www.caffeineinformer.com/the-complete-guide-to-starbucks-caffeine. Accessed August 29, 2014.

Cohen J. (1988) Statistical Power Analysis for the Behavioral Sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum.

Dernaro C, Benowitz N. (1991) Caffeine metabolism: disposition in liver disease and hepatic-function testing. Totowa, NJ: Humana Press, 513–539.

Einöther SJL, Giesbrecht T. (2013) Caffeine as an attention enhancer: reviewing existing assumptions. *Psychopharmacology (Berl)* 225(2):251–274.

ENTCare. Retrieved from http://www.entcare.org/PatientEducation/PatientEducation/Electrostagmography.html. Accessed August 21, 2012.

Fine BJ, Kobrick JL, Lieberman HR, Marlowe B, Riley RH, Tharion WJ. (1994) Effects of caffeine or diphenhydramine on visual vigilance. *Psychopharmacology (Berl)* 114(2):233–238. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med3&AN=7838913.

Hale T, Trahan H, Parent-Buck T. (2015) Evaluation of the patient with dizziness and balance disorders. In: Katz J, Chasin M, English K, Hood L, Tillery K, eds. *Handbook of Clinical Audiology*. Philadelphia, PA: Wolters Kluwer, 408.

Haskell CF, Kennedy DO, Milne AL, Wesnes KA, Scholey AB. (2008) The effects of L-theanine, caffeine and their combination on cognition and mood. *Biol Psychol* 77(2):113–122. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med5&AN=18006208.

Haskell CF, Kennedy DO, Wesnes KA, Scholey AB. (2005) Cognitive and mood improvements of caffeine in habitual consumers and habitual non-consumers of caffeine. *Psychopharmacology (Berl)* 179(4):813–825. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med5&AN=15678363.

International Coffee Organization. (2012) www.ico.org. Accessed August 21, 2012.

Lorist MM, Snel J, Kok A, Mulder G. (1994) Influence of caffeine on selective attention in well-rested and fatigued subjects. *Psychophysiology* 31(6):525–534 http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med3&AN=7846213.

Maridakis V, O'Connor PJ, Tomporowski PD. (2009) Sensitivity to change in cognitive performance and mood measures of energy and fatigue in response to morning caffeine alone or in combination with carbohydrate. *Int J Neurosci* 119(8):1239–1258. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med5&AN=19922353.

Mayo Clinic. (2014) Caffeine: how much is too much? http://www.mayoclinic.com/health/caffeine/nu00600. Accessed July 30, 2014.

McCusker RR, Goldberger BA, Cone EJ. (2003) Caffeine content of specialty coffees. *J Anal Toxicol* 27(7):520–522.

McNerney K, Coad ML, Burkard R. (2014a) The influence of caffeine on calorics and cervical vestibular evoked myogenic potentials (cVEMPs). *J Am Acad Audiol* 25(3):261–267.

McNerney KM, Coad ML, Burkard RF. (2014b) The influence of caffeine on the sensory organization test. *J Am Acad Audiol* 25(6):521–528.

Nolan S, Heinzer T. (2011) *Essentials of Statistics for the Behavioral Sciences*. 1st ed. New York, NY: Worth Publishers.

Ozsungur S, Brenner D, El-Sohemy A. (2009) Fourteen well-described caffeine withdrawal symptoms factor into three clusters. *Psychopharmacology* 201(4):541–548.

Rubin W. (1982) Harmonic acceleration tests as a measure of vestibular compensation. *Ann Otol Rhinol Laryngol* 91(5 Pt 1):489–492. Retrieved from http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med2&AN=6982652.

Shepard NT. (2009) Evaluation of the patient with dizziness and balance disorders. In: Katz J, Medwetsky L, Burkard R, Hood L, eds. Handbook of Clinical Audiology. 6th ed. Baltimore, MD: Wolters Kluwer | Lippincott Williams & Wilkins, 467–496.

Smith A. (2009) Effects of caffeine in chewing gum on mood and attention. *Hum Psychopharmacol* 24(3):239–247.

Smith A, Kendrick A, Maben A, Salmon J. (1994) Effects of breakfast and caffeine on cognitive performance, mood and cardiovascular functioning. *Appetite* 22(1):39–55. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med3&AN=8172489.

Wilstar. (2014) Caffeine content of popular drinks. http://wilstar.com/caffeine.htm. Accessed July 30, 2014.