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Physiological and focal cerebellar substrates of abnormal postural sway and tremor in alcoholic women

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Abstract

Background—Posturography analysis of static balance reveals marked sway and tremor in sober alcoholic men related selectively to anterior superior vermis volume but can be attenuated by simple visual or tactile cues or alterations in stance. Whether alcoholic women, whose ataxia can persist with prolonged sobriety, exhibit the same physiological signature of balance instability and relation to cerebellar vermician volume as alcoholic men or can benefit from stabilizing factors is unknown.

Methods—Groups comprised 15 alcohol dependent women, alcohol-free (median=3 months), and 29 control women. Groups were matched in age (mean=49.4 years), demographic features, and upper limb speed and strength and underwent balance platform testing and MRI scanning.

Results—Alcoholic women exhibited excessive sway path length (~.6 SD), more dramatic in the anterior-posterior than medial-lateral direction. Truncal tremor, measured as peak sway velocity frequency, was disproportionately great in the 5-7 Hz band of alcoholics. Controls and alcoholics exhibited sway and tremor reduction with visual, tactile, or stance stabilizing conditions, which aided both groups equally well; thus, alcoholic women never achieved normal stability. Smaller anterior superior vermician volumes selectively correlated with longer sway path and higher 5-7 Hz peak sway velocity.

Conclusions—The sway and tremor abnormalities and the selective relations between greater sway and 5-7 Hz tremor and smaller volumes of the anterior superior vermis had not heretofore been described in abstinent alcoholic women. Reduction in sway and tremor with stabilizing factors indicate that adaptive mechanisms involving sensorimotor integration can be invoked to compensate for vermician-related dysfunction.

Keywords

MRI; cerebellum; vermis; balance; tremor; alcohol; gender; posturography

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DISCLOSURES/CONFLICTS OF INTEREST

The authors reported no biomedical financial interests or potential conflicts of interest.

Introduction

One of the most salient characteristics of acute alcohol intoxication is instability of gait and balance, precursing falls. Less appreciated is a persistent impairment in postural stability in chronic alcoholism detectable even following months of sobriety, thus enduring as a liability for falling. In abstinent alcoholic men, the impairment can be moderate to severe, with a group effect size of 1.5 standard deviations (SD) from controls (1). Physiological analysis of upright stance in sober alcoholic men and control men tested on a force platform has revealed abnormally longer sway paths and truncal tremor prominent in two frequency bands, 2-5 Hz and 5-7 Hz, which are known from lesion and animal model studies to arise from cerebellar damage per se (2-5) or thalamocerebellar circuitry disruption (6). Consistent with these brain structure-function relations, greater sway path length in these alcoholic men related selectively to smaller volumes of the anterior superior cerebellar vermis. Alcohol-related damage to these cerebellar lobules is well-documented neuropathologically (7-11) and neuroradiologically (12-17). Direct support for a selective anterior vermian substrate of voluntary, upright postural control derives from PET ^{15}O studies of healthy subjects (18,19). Despite the presence of a brain structural substrate of the instability detected in the alcoholic men, both sway and tremor were attenuated by stabilizing conditions of vision, light touch, and broad-based stance (20).

Significant differences between men and women in brain structural and functional patterns of sparing and deficit are well documented in chronic alcoholism, thus precluding simple generalization of findings between the sexes. For example, some brain structural and neuropsychological data support the “telescoping” model of alcoholism in women (21-23) who characteristically drink less than alcoholic men yet can show a similar degree of brain structural dysmorphology (24,25, but see 26,27), possibly attributable to differences in body composition (28) and alcohol metabolism rates (29). Regarding cerebellar signs, we have shown that neither alcoholic men nor women are impaired in upper limb measures of ataxia, paced tapping, eye-hand coordinated tracing, or preparation or execution time, yet alcoholic men but not women move slowly to achieve accurate arm movement trajectories (30). Ataxia of stance and gait, although significant in both alcoholic men and women, was substantially greater in the men yet endured even in women who remained sober for 4 years (31).

Whether abstinent alcoholic women exhibit the same physiological signature of static posture as alcoholic men or can benefit from simple visual or tactile information or alterations in stance has not been tested. Also not established is evidence for a selective relation between measures of sway and tremor and anterior superior vermian volume in alcoholic women. To address these unknowns, this controlled study used quantitative methods of posturography, with and without use of stabilizing conditions, and MRI in alcoholic women with sustained sobriety and age-matched control women. Posturographic measures of sway path length and tremor in alcoholic women were then correlated with MRI-derived volumes of vermis and comparison regions also known to be affected in chronic alcoholism—cerebellar hemispheres (17) and corpus callosum (32)—to determine specificity of potential correlations between balance measures and vermian volumes. Callosal structure was tested because studies of normal aging report that supratentorial white matter degradation are common predictors of imbalance and falling in the elderly (33-36, reviewed in 37).

Materials and Methods

Subjects

Alcoholic women were recruited from local rehabilitation centers and met DSM-IV criteria for alcohol substance dependence; 15 women (age 33 to 63 years) met study criteria. The control group comprised 29 women (age 34 to 63 years), recruited from the local community and drawn from a larger group of women whose posturography data were previously reported

in a study of normal aging (38). All subjects underwent structured interview to identify the following exclusionary criteria: presence of DSM-IV (39) Axis I diagnoses of Bipolar Disorder or Schizophrenia, history of nonalcohol substance dependence, alcohol-related amnesic disorder, CNS trauma, loss of consciousness for greater than 30 minutes, seizures not related to alcohol withdrawal, neurodegenerative disease, or serious medical condition. All subjects were volunteers, gave written informed consent, obtained according to the Declaration of Helsinki and the Ethical Committee of Stanford University School of Medicine and SRI International, to participate in this study and were paid a modest stipend. Before testing, all participants had breath alcohol determination and were not tested if the level exceeded 0.

The groups did not differ significantly in age, handedness, education, socioeconomic status, estimated premorbid IQ (National Adult Reading Test (40)), dementia screening tests (all participants scored well within the normal range), or on tests of upper limb strength or motor speed (Table 1). Consistent with the established pattern of general cognitive and visuospatial abilities (41-43), the alcoholic group had a lower Performance IQ ($t(40)=3.801$, $p=.0005$) but not Verbal IQ ($t(40)=1.126$, $p=.2667$) than the controls. On average, the alcoholics consumed about 12 times more alcohol over their lifetime ($t(41)=6.468$, $p=.0001$) and had a lower body mass index ($t(42)=2.249$, $p=.0298$) than the controls. Length of sobriety of 13 alcoholic women ranged from 17 to 97 days (mean $\pm$ SD=47.1 $\pm$ 24.6 days); two women reported 356 and 393 days of sobriety. Median of the total group of 15 women was 90.7days. Years of alcoholic drinking ranged from 5 to 37 years (15 $\pm$ 9.2 years).

Posturography Analysis and Test Conditions

Balance was assessed with a microcomputer-controlled force plate measurement device (model 9284; Kistler, Amherst, NY, U.S.A) with multiple transducers and analog-digital converters. Data were sampled at 50 Hz; the resultant native data were 30-sec trials of 1500 center of pressure displacements (x-y pairs). The sway path length was expressed as the line integral following 10 Hz non-recursive lowpass filtering (7 terms, -50 db Gibbs).

As previously described (20,38), the six conditions of static balance testing were visual (eyes open or closed), stance (feet apart or feet together), and touch (touch or no touch). These conditions yielded eight combinations: 1) eyes open+feet apart+touch; 2) eyes open+feet apart+no touch; 3) eyes open+feet together+touch; 4) eyes open+feet together+no touch; 5) eyes closed+feet apart+touch; 6) eyes closed+feet apart+no touch; 7) eyes closed+feet together+touch; 8) eyes closed+feet together+no touch. In the touch condition, subjects were given tactile positional information by placing their right-hand index finger on a device made of a break-away piece of plastic tubing, incapable of bearing body weight and affixed to a vertical pole, also made of plastic tubing and adjustable to the height of a subject. In all non-touch conditions, subjects relaxed their arms and hands at their sides. Subjects stood barefoot in the center of the platform for three, 30-sec trials for each of the eight sets of conditions, the order balanced across subjects. Figure 1 presents examples of sway paths without any stabilizing conditions and with all three stabilizing conditions.

MRI Acquisition and Analysis

All alcoholics and controls underwent MRI structural scanning. Before quantitative analysis, images were read by a clinical neuroradiologist to identify space occupying lesions or other dysmorphology indicative of neuropathology that could interfere with morphometric analysis. Additional review of images identified studies of quality too poor for quantification; data of one control were excluded.

Cerebellar Anterior Superior Vermis and Hemispheres—Cerebellar morphometric quantification was based on semi-automated segmentation using the image intensity histogram

of thin-slice, late-echo, coronal fast spin-echo (FSE) images (94, 2mm thick slices; TR/TE=11050/98ms, matrix=256×192), which were resampled into 1mm isotropic voxels and provided high fluid-tissue conspicuity. The bimodal intensity distribution was discrete in all cases, and an operator selected the minima between peaks. Prior to analysis, images were re-aligned first in the axial plane so that the cerebellar-interhemispheric fissure was perpendicular to the bottom of the image frame, and then in the sagittal plane so that the fourth ventricle was perpendicular to the bottom of the image frame (44-46).

The anterior-superior vermis sample was measured on seven, 1 mm thick, aligned and extracted sagittal slices—the mid-sagittal and three, 1 mm thick parasagittal slices taken from left and right of the midline. The cerebellar hemisphere sample was measured on five, 1 mm thick slices, which were extracted at the widest diameter of a projection image of the entire brain. The tissue margins were manually identified on aligned and extracted coronal images, guided by the landmarks described in the atlas of Schmahmann *et al.* (47). All scoring was conducted manually and blind to subject identification.

Corpus Callosum—The area of the corpus callosum was identified on the midsagittal slice extracted from SPGR data (94, 2mm thick slices; TR/TE=25/5ms, flip angle=30°, matrix=256×192) with a semi-automated edge identification procedure. Prior to segmentation, the silhouette of the corpus callosum was rotated to a plane parallel to the inferior extremes of the rostrum anteriorly and splenium posteriorly. Following the automated routine, the borders of the corpus callosum were manually edited to remove non-target voxels (48).

Correction of Brain Volumes for Intracranial Volume and Age—MRI volumes were adjusted with a two-step linear regression procedure to correct first for normal variation in intracranial volume (ICV) and then age (cf. 49,50). The resulting values were expressed as standardized Z-scores, with an expected control mean±SD=0±1.0.

Statistical Analysis

Sway path data were subjected to a series of repeated measures analyses of variance (ANOVAs) conducted on summary scores, which served as a means of data reduction, thereby minimizing the number of comparisons conducted. Where appropriate, Geiser-Greenhouse (G-G) correction was applied. Follow-up t-tests identified specific group differences. Correlations between sway path lengths and alcoholism factors or regional brain volumes were tested with Pearson correlations. Multiple regression analysis was used to test for specificity of brain structure-function relationships.

We also performed frequency analyses (fast Fourier transform) on the anterior-posterior and lateral-medial sway velocity (the 2-point differential of the filtered sway path). Following the method of Baloh and colleagues (51,52) to characterize the frequency (Hz) of maximal sway velocity, we derived a frequency quotient, which was the power of the spectral frequencies between 2 and 5 Hz divided by those between 0 and <2 Hz, with the expectation that the alcoholics would have a higher ratio than controls. The power in the 5 to 7 Hz frequency range, which was abnormally high in alcoholic men (20), was also subjected to group analysis. Because prior work had shown that frequency analysis of center of pressure sway path velocity (distance/time) to be more sensitive than amplitude (distance) (51), only velocity was subjected to frequency analysis.

Results

Means±SD for sway path and tremor data, regional MRI volumes appear in Tables S1 and S2 in Supplement 1.

Sway Path Length and Direction: Effect of Vision, Touch, and Stance

An omnibus ANOVA involved two groups (controls and alcoholics), three stabilizing conditions (vision, touch, and stance), and two levels of each condition (stabilizing factor present or absent) (Figure 2). The sway paths of both groups were shorter with than without stabilizing factors ($F(1,84)=136.617$, $p=.0001$), but the difference between groups was modest ($F(1,42)=4.015$, $p=.0516$) as was the 3-way interaction ($F(2,84)=2.490$, $p=.0945$ G-G). Follow-up t-tests revealed that, regardless of stance, alcoholic women demonstrated longer sway paths than control women with eyes open (feet together $t(42)=2.039$, $p=.0478$; feet apart $t(42)=2.036$, $p=.0481$) or with touch (feet together $t(42)=2.052$, $p=.0464$; feet apart $t(42)=2.489$, $p=.0168$). Thus, although both groups benefited from stabilizing factors, the alcoholic group never achieved normal levels.

Potential group differences in preferential sway direction (anterior-posterior vs. medial-lateral) were examined by comparing the mean sway path length of two stance conditions, regardless of presence of vision or touch information (Figure 3). Repeated measures ANOVAs for group and direction yielded group effects (greater sway in alcoholics than controls) for feet apart ($F(1,42)=4.69$, $p=.0361$) and feet together ($F(1,42)=4.932$, $p=.0318$). The group-by-direction interaction was significant for the feet apart condition only ($F(1,42)=4.232$, $p=.0459$), indicating disproportionately greater sway in the anterior-posterior than medial-lateral direction in the alcoholic than control women.

Frequency Analysis of Sway Velocity

Frequency analysis focused on differences in the direction of sway in the vision and stance conditions between the two groups (Figure 4). The power of the sway velocity spectrum was expressed as a frequency quotient (2-5 Hz/0-2 Hz). Repeated measures ANOVAs revealed greater sway prominence in this ratio in the alcoholic women than controls ($F(1,42)=9.339$, $p=.0039$) with feet together. The only consistent findings across the stance analyses were observations of greater sway prominence in the anterior-posterior than medial-lateral direction with feet together ($F(1,42)=51.264$, $p=.0001$) or apart ($F(1,42)=6.484$, $p=.0001$) regardless of diagnostic group.

A similar pair of ANOVAs was conducted on power of peak sway velocity between 5-7 Hz. Both ANOVAs identified significant group effects (feet together $F(1,42)=5.114$, $p=.0290$; feet apart $F(1,42)=51.264$, $p=.0001$) and group-by-direction interactions (feet together $F(1,42)=11.001$, $p=.0019$ G-G; feet apart $F(1,42)=15.533$, $p=.0003$ G-G), indicating disproportionately greater sway prominence in the 5-7 Hz band in the anterior-posterior than medial-lateral direction in the alcoholic than control group in the feet together condition.

Group Differences in Regional Brain Volumes

Taking age and intracranial volume variation into account, the alcoholic group had a .53 SD deficit in vermal volume ($t(41)=1.758$, $p=.086$, two-tailed) and a .61 SD deficit in callosal area ($t(41)=1.887$, $p=.066$, two-tailed), but no evidence for deficits in cerebellar hemisphere volume ($t(41)=.905$, $p=.370$, two-tailed). Despite the absence of a statistically robust group difference in anterior superior vermal volume, 13 of 15 alcoholics had volumes below the control mean.

Correlations with Cerebellar Vermian and Comparison Brain Volumes

In alcoholics, but not controls, smaller vermal volumes correlated with longer sway paths when balancing with feet apart and regardless of presence or absence of vision or touch (Feet Apart composite score correlation with vermis Z-score=-.58, $p=.0233$, Figure 5). By contrast, no correlation between sway path and cerebellar hemisphere or corpus callosum size was

significant. To test selectivity of the vermian correlations with respect to the cerebellum, multiple regression analyses entered volumes of the vermis and the cerebellar hemispheres as simultaneous predictors of sway path length in the feet apart conditions. In no case was cerebellar hemisphere volume a unique predictor of sway path length ($p=.1148$ to $.4745$), whereas vermian volume was a unique predictor of each of the four composite scores: Feet Apart-Eyes Open ($p=.0136$), Feet Apart-Eyes Closed ($p=.0184$), Feet Apart-Touch ($p=.0118$), and Feet Apart-No Touch ($p=.0297$). Similarly, callosal size was not a unique predictor of sway path length ($p=.1147$ to $.2024$), whereas vermian volume was: Feet Apart-Eyes Open ($p=.0161$), Feet Apart-Eyes Closed ($p=.0202$), Feet Apart-Touch ($p=.0262$), and Feet Apart-No Touch ($p=.0178$).

Although none of the 2-5/0-2 Hz frequency ratios correlated significantly with any brain measure, correlations between sway prominence in the 5-7 Hz band and vermian volume were forthcoming, albeit modest, in the Feet Apart-Eyes Closed conditions for both sway directions: anterior-posterior $r=-.52$, $p=.0495$; medial-lateral $r=-.50$, $p=.0567$. Neither cerebellar hemisphere nor corpus callosum size correlated with any velocity measure.

Correlations with Alcoholism Variables

Neither lifetime alcohol consumption nor length of sobriety correlated with either sway path or velocity measures in the alcoholics.

Discussion

Our study of alcoholic women, who had maintained sobriety for a median of 3 months, revealed longer sway path length than control women in attempting to maintain upright static posture. Postural instability in the alcoholic women was more dramatic in the anterior-posterior than medial-lateral directions and in truncal tremor, measured as greater sway prominence, which was disproportionately high in the 5-7 Hz band. Both alcoholics and controls exhibited sway and tremor reduction with the addition of vision or touch information or with change from closed to open stance. These stabilizing conditions aided both groups equally well; thus, the alcoholic group never achieved normal stability levels in either sway or tremor. The selective relations between greater sway and 5-7 Hz tremor and smaller volumes of the anterior superior vermis, although predicted, had not heretofore been described in abstinent alcoholic women as a group.

The pattern of instability and relation with focal anterior vermian volume observed in alcoholic women shared similarities with and also differences from those observed in alcoholic men (20). Like the men, the alcoholic women exhibited significant reduction in sway path length and velocity with sensory and stance stabilizing conditions. Unlike the alcoholic men, however, whose balance showed disproportionately greater improvement over that displayed by control men with such aids, the degree of stabilization provided by sensory and stance information was similar in alcoholic and control women. Despite stabilizing factors, neither sway nor tremor was fully quelled in alcoholic men or women. Of note is the markedly greater abnormality in sway of the alcoholic men than alcoholic women. Without stabilizing factors, the men had a ~ 2 SD deficit in sway which improved to ~ 1 SD deficit with stabilizing factors relative to their sex-matched controls (20), whereas the alcoholic women only ~ 0.6 SD deficits regardless of presence or absence of stabilization conditions. Recently, we demonstrated that, compared with healthy aging women, healthy aging men show greater decline in postural control during quiet standing and show greater sway in the anterior-posterior than medial-lateral direction in challenging conditions (38). The differences between alcoholic men and women observed without stabilizing factors appear to be an exaggerated pattern of that observed in nonalcoholic aging men and women. This possibility comports with another finding that poorer balance scores, even after adjustment for normal age effects, correlated

with older age in alcoholic men (17) indicative of an age-alcoholism interaction (53,54), an effect not observed in alcoholic women (55).

Other sex differences include the observation that self-reported amount of lifetime alcohol consumption was a significant predictor of long sway path length in alcoholic men but not women. Degree of impaired postural control has also been related to the amount of alcohol drunk in the 6 months prior to examination (56,57). As a group, the alcoholic men from our earlier study had drunk 2.5 times that of the alcoholic women reported herein. With regard to recovery of gait and balance with prolonged sobriety (4,58,59), we showed that the extent of the improvement after a year of sobriety was selectively related to shrinkage of the fourth, but not lateral, ventricle (60). Alcohol abstinence of even 4 years, however, was not enough in one group of alcoholic women to have their gait and balance normalize (31,61) and raises the possibilities that the extent of behavioral recovery is sex-linked and also limited by the degree of vermal damage, because in both alcoholic men and women the extent of their stability impairment correlated selectively with vermal volume (cf., 61).

Changing from a narrow- to a broad-based stance invokes a biomechanical change in balance strategy from hip to trunk (62). The alcoholic women showed greater instability in the anterior-posterior than medial-lateral direction, even with a broad-based stance, possibly indicative of poor control of trunk orientation. Lesion studies have shown that truncal control of quiet standing is disrupted by spinocerebellar pathology (63-66), which is consistent with the correlations noted in the present study between exaggerated sway paths with feet apart and vermal volume. Sway in patients with vermal lesions, including detoxified alcoholics, occurs preferentially in the anterior-posterior plane (51,67). Consistent with this sway bias, lifetime alcohol consumption in alcoholics has been related to posturographic measures of anterior-posterior but not medial-lateral static postural instability with or without visual input (56,68).

Chronic tremor with a cerebellar pathogenesis is a recognized disorder in detoxified alcoholics (69). Although alcohol-related cerebellar kinetic or postural tremor typically occurs at 3-5 Hz (2,5), in the current study greater sway prominence in the 5-7 Hz band in the alcoholic women may be indicative of thalamic damage to cerebellar-thalamic relays. Supporting this speculation is a monkey model of parkinsonism demonstrating that a lesion in thalamic nuclei that receive input from the cerebellum (but not thalamic nuclei receiving nigral input) produced postural tremor at 5-7 Hz that was reduced by sensory input (6). Also consistent with the cerebellar circuitry hypothesis are observations of three cases of axial postural tremor, with suspected or autopsy-confirmed cerebellar pathology, who displayed tremor between 3 and 10 Hz (5). A possible neural substrate of the postural instability and associated increased power of the velocity spectrum up to 7 Hz in the alcoholic women studied herein and alcoholic men previously reported (20) was compromise of the anterior superior vermal lobules together with disruption of cerebellar-pontine-thalamic structure (70,71) and circuitry (72) known to occur in uncomplicated alcoholism.

In conclusion, in alcoholic women sway path length was selectively related to volume of the cerebellar vermis and not comparison regions, namely, the lateral cerebellar hemispheres or corpus callosum. Further substantiation for a vermal mechanism of excessive sway derived from spectral frequency analysis, which revealed associations of smaller vermal volume with greater power of the velocity spectrum and a tremor prominence in the 5-7 Hz band, previously observed in abstinent alcoholic men. Use of sensory information and stance stabilizing posture reduced sway paths and presumed truncal tremor of the alcoholics to the level of control women when balancing without such stabilizing factors and in the face of compromised brain structure. Thus, despite enhancement of postural stability with sensory and biomechanical aids, women with a history of alcoholism are at heightened risk of falling, especially under sensorimotor impoverished conditions, and even after months of sobriety.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Examples of sway paths (medial-lateral—x-axis; anterior-posterior—y-axis) for one trial performed by a 53-year old control woman (top) and a 53-year old alcoholic woman (bottom). The left panel of sway paths displays performance without any stabilizing factors (eyes closed/feet together/no touch), and the right panel shows performance when provided all three stabilizing factors (eyes open/feet apart/touch). The sway path length was 73.2mm for the alcoholic woman with all three stabilizing factors and was virtually the same (73.1mm) for the control woman without any aids.

Figure 2.

Means $\pm$ SE sway path lengths for the two stance conditions (feet together and feet apart) for the 29 control and 15 alcoholic women. The eyes open and eyes closed conditions are mean $\pm$ SE sway path lengths irrespective of touch information; the touch and no touch conditions are mean $\pm$ SE sway path lengths irrespective of vision information. * $p < .05$, ** $p < .01$.

Figure 3.

Means $\pm$ SE sway path lengths for the Feet Together and Feet Apart composite scores (collapsed across touch or vision conditions) parsed by sway direction for the 29 control and 15 alcoholic women. In the feet apart condition, alcoholic displayed disproportionately greater sway in the anterior-posterior than medial-lateral direction than the control women. * $p < .05$.

Figure 4.

The grand average spectra from the frequency analysis of center of pressure sway path velocity (distance/time) presented in ~ 0.5 Hz frequency bins for 29 controls (open squares, gray) and 15 alcoholics (filled squares, black). The grand average spectra for the anterior-posterior plane are in the top panel of four figures (eyes closed/feet together; eyes closed/feet apart; eyes open/feet together; eyes open/feet apart). The grand average spectra for the medial-lateral plane are in the bottom panel. Note the peak in power in the 5-7 Hz frequency band in the alcoholic relative to the control women.

Figure 5.

In alcoholics, smaller vermian volumes correlated with longer sway paths and greater sway prominence in the 5-7 Hz frequency band. MR images are mid-sagittal and para-sagittal sections at 1 mm intervals of T1-weighted SPGR (left column of images in each pair) and T2-weighted late-echo FSE (right column of images in each pair) of a 59 year-old alcoholic woman (left column of image pairs) and a 60 year-old control woman (right column of image pairs). Arrows point to the corpus callosum, and circles encompass the anterior superior vermis. Note that the alcoholic woman had approximately 1.25 SD volume deficit (for her intracranial volume [ICV] and age) in the anterior superior vermis and corpus callosum, whereas the sizes of control woman's brain structures were well within normal range. The data of this alcoholic woman are demarcated by arrows in the scatterplots. Despite size deficits in both brain structures, only the vermis significantly and uniquely predicted severity of postural instability in alcoholic women.

Table 1Subject characteristics: Mean($\pm$ SD) or frequency count

	Control Women	Alcoholic Women	t-test p-value
Sample size	29	15	
Age	49.4 (9.0)	49.4 (8.8)	n.s.
Education (years)	16.0 (2.1)	14.7 (2.3)	n.s.
Socioeconomic status^a	23.1 (8.5)	25.2 (8.2)	n.s.
Handedness^b	24.8 (18.4)	22.1 (13.4)	n.s.
Body Mass Index	25.1 (4.5)	22.1 (3.2)	.0298
Lifetime alcohol consumption (kg)	35.3 (34.7)	421.8 (322.0)	.0001
NART IQ	114.4 (5.7)	114.1 (5.3)	n.s.
Dementia Rating Scale^c	141.0 (2.5)	139.5 (2.4)	n.s.
WASI			
Verbal IQ	113.9 (11.7)	109.7 (10.7)	n.s.
Performance IQ	116.8 (10.3)	103.8 (11.2)	.0005
Grip Strength (kg)^d	22.2 (5.6)	19.1 (5.1)	n.s.
Fine Finger Movement			
Unimanual^d	80.0 (10.0)	76.6 (12.6)	n.s.
Bimanual^d	77.2 (9.8)	71.6 (14.1)	n.s.

^a Lower scores indicate higher socioeconomic status^b Right handedness = 14-32; left handedness = 50-70 (Crovitz and Zener, 1982)^c Dementia cut-off < 124; no one scored at or below this cut-off^d Mean of left and right hands