

METHODS FOR THE DIAGNOSIS, RISK ASSESSMENT, AND MONITORING OF AUTISM SPECTRUM DISORDERS

FIELD OF THE INVENTION

The present invention relates to the diagnosis, risk assessment, and monitoring of Autism Spectrum Disorder (ASD). More specifically the present invention relates to the measurement of small molecules or metabolites that are found to have different abundances between persons with a clinical manifestation of ASD and subjects not expressing symptoms of ASD. Further, this invention relates to the monitoring of putative therapeutic strategies designed to ameliorate the biochemical abnormalities associated with ASD.

BACKGROUND

Autism is a lifelong disorder of unknown origin. The disorder is characterized by behavioural, developmental, neuropathological, and sensory abnormalities (American Psychiatric Association 1994) and is usually diagnosed between the ages of 3 and 10 with peak prevalence rates observed in children aged 5-8 (Yeargin-Allsopp, Rice et al. 2003). At this time, decreased cerebellar Purkinje cell density (Courchesne 1997; Palmen, van Engeland et al. 2004), increased oxidative stress (Yorbik, Sayal et al. 2002; Sogut, Zoroglu et al. 2003; Chauhan, Chauhan et al. 2004; James, Cutler et al. 2004; Zoroglu, Armutcu et al. 2004; Chauhan and Chauhan 2006), and abnormal methionine/homocysteine metabolism (James, Cutler et al. 2004) are the only robust biological characteristics of autism.

Although there is debate as to whether autism has a pre- (Courchesne, Redcay et al. 2004) or post-natal origin (Kern and Jones 2006), it is generally accepted that the symptoms and pathology persist throughout the life of the subject (Bauman and Kemper 2005). These findings suggest that there is an underlying and ongoing biochemical abnormality in autism, regardless of its origin. However, no such underlying biochemical abnormalities have been reported that correlate with the etiology or symptomology of ASD. As such, there is no biochemical test for autism.

Accordingly there is a need for methods that can diagnose ASD in subjects suspected of having ASD or methods that can identify subjects that are at risk of

ASD and furthermore there is a need for methods that can assist in the monitoring of therapeutic strategies for the treatment of ASD.

SUMMARY

It has been determined that subjects with clinically diagnosed ASD have different abundances of small molecules or metabolites in their blood plasma relative to non-ASD subjects. It has further been determined that some high risk subjects (i.e. family history) with little or no ASD symptoms exhibit a biochemical phenotype analogous to that of subjects with a full clinical ASD phenotype. As such, methods for diagnosing ASD and for diagnosing elevated risk of ASD are provided.

It has been determined that subjects clinically diagnosed with ASD can be biochemically characterized as having a phenotype generally described by either:

- a) elevated levels of saturated or monounsaturated very long chain fatty acid (VLCFA) containing phospholipids;
- b) elevated levels of docosahexaenoic acid (22:6, DHA) containing phospholipids;
- c) elevated levels of polyunsaturated VLCFA containing phospholipids; or
- d) combinations thereof.

It has further been determined that an experimental ASD therapeutic (Acetyl-Carnitine) can modify the above biochemical ASD phenotype such that some ASD biochemical markers return to non-ASD levels and that some ASD biochemical markers remain unchanged. It has further been determined that ASD subjects taking acetyl-carnitine exhibit biochemical changes that differentiate them from both ASD subjects not taking carnitine as well as non-ASD subjects not taking acetyl-carnitine. As such, methods for the monitoring of experimental ASD therapeutics in general and for the specific monitoring of acetyl-carnitine therapy are provided.

A method for the differential biochemical characterization of subjects presenting with ASD is provided. This differential biochemical characterizing has ramifications on the treatment and management of subjects presenting ASD symptoms. Firstly, it has

been determined that ASD subjects with similar clinical phenotypes have dramatically different biochemical phenotypes. These findings indicate that different therapeutic strategies may need to be developed for different ASD subjects depending on the subject's biochemical phenotype. More importantly, the present findings indicate that the monitoring of the dose and therapeutic effectiveness of an ASD therapeutic in a subject diagnosed with ASD is preferably personalized to that particular subject's biochemical profile. For example, in subjects exhibiting high saturated VLCFA levels, the monitoring of saturated VLCFA levels may represent the most sensitive determiner of effective therapy or dosage, but such measurements may be of little or no value to an ASD subject exhibiting high polyunsaturated VLCFA levels and normal saturated VLCFA levels.

In one illustrative embodiment, the present invention provides for a method for diagnosing a human subject's health state or change in health state for Autism Spectrum Disorder (ASD) or identifying a human subject's risk of ASD, the method comprising the steps of:

- a) analyzing a sample obtained from a patient to obtain quantifying data for one or more accurate masses;
- b) comparing the quantifying data for said one or more accurate masses to corresponding data obtained from one or more reference samples; and
- c) using said comparison to diagnose the human subject's health state or change in health state for ASD based on the differences between the quantifying data and the corresponding data of the one or more accurate masses;

wherein the one or more accurate masses is listed in any one of Tables 2 to 10.

In another illustrative embodiment, the present invention provides for a method for diagnosing a human subject's health state or change in health state for Autism Spectrum Disorder (ASD) or identifying a human subject's risk of ASD, the method comprising the steps of:

- a) analyzing a sample obtained from a patient to obtain quantifying data for one or more of the following:

- saturated or monounsaturated very long chain fatty acid (VLCFA) containing phospholipids;

docosahexaenoic acid (22:6, DHA) containing phospholipids;
DHA precursors (24:5, 24:6);
catabolic products of DHA beta-oxidation (20:6);
polyunsaturated VLCFA containing phospholipids; and
combinations thereof;

b) comparing the quantifying data to corresponding data obtained from one or more reference samples; and

c) using said comparison to diagnose the human subject's health state or change in health state for ASD based on having one of the following characterizations when compared to the corresponding data obtained from one or more reference samples:

elevated levels of saturated or monounsaturated very long chain fatty acid (VLCFA) containing phospholipids;

elevated levels of docosahexaenoic acid (22:6, DHA) containing phospholipids;

elevated levels of DHA precursors (24:5, 24:6);

elevated levels of catabolic products of DHA beta-oxidation (20:6);

elevated levels of polyunsaturated VLCFA containing phospholipids; or
combinations thereof.

In another illustrative embodiment, the present invention provides for a method for diagnosing a human subject's health state or change in health state for Autism Spectrum Disorder (ASD) or identifying a human subject's risk of ASD, the method comprising the steps of:

a) analyzing a sample obtained from a patient to obtain quantifying data for one or more metabolites;

b) comparing the quantifying data for said one or more metabolites to corresponding data obtained from one or more reference samples; and

c) using said comparison to diagnose the human subject's health state or change in health state for ASD based on the differences between the quantifying data and the corresponding data of the one or more metabolites

wherein the one or more metabolites is listed in any one of Tables 3 to 10.

In another illustrative embodiment, the present invention provides for a method for diagnosing a human subject's health state or change in health state for Autism Spectrum Disorder (ASD) or identifying a human subject's risk of ASD, the method comprising: comparing quantifying data comprising one or more accurate masses listed in any one of Tables 2 to 10 of a sample from the human subject to corresponding data obtained from one or more reference samples; wherein the human subject's health state or change in health state for Autism Spectrum Disorder (ASD) or risk of ASD is based on a difference in intensity of the one or more accurate masses between the sample from the human subject and one or more reference samples.

In another illustrative embodiment, the present invention provides for a method for diagnosing a human subject's health state or change in health state for Autism Spectrum Disorder (ASD) or identifying a human subject's risk of ASD, the method comprising: comparing quantifying data comprising one or more metabolites listed in any one of Tables 3 to 10 of a sample from the human subject to corresponding data obtained from one or more reference samples; wherein the human subject's health state or change in health state for Autism Spectrum Disorder (ASD) or risk of ASD is based on a difference in intensity of the one or more metabolites between the sample from the human subject and one or more reference samples.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the invention will become more apparent from the following description in which reference is made to the appended drawings wherein:

Figure 1 is a summary of PtdEtn (phosphatidylethanolamine) changes in plasma of autistic subjects;

Figure 2 is a graph illustrating levels of key DHA and arachidonic acid (AA) containing PlsEtn (plasmenylethanolamine) and PtdEtn in longitudinal samples collected over the course of one year from individual subjects diagnosed with autism versus controls. Values are control-normalized and expressed as mean +/- SEM of the ratio to PtdEtn 16:0/18:0, n=3 for each child, n=30 for controls, *, p<0.05 vs. control;

Figure 3 is a graph illustrating levels of key VLCFA containing PtdEtn in longitudinal samples collected over the course of one year from individual subjects diagnosed with autism versus controls. Values are control-normalized and expressed as mean $\pm$ SEM of the ratio to PtdEtn 16:0/18:0, n=3 for each child, n=30 for controls, *, p<0.05 vs. control;

Figure 4 is a graph illustrating levels of carnitine and O-acetylcarnitine in longitudinal samples collected over the course of one year from individual subjects diagnosed with autism versus controls. Values are control normalized and expressed as mean $\pm$ SEM, n=3 for each child, n=30 for controls, *, p<0.05 vs. control;

Figure 5 is a graph illustrating levels of key DHA and AA containing PlsEtn and VLCFA containing PtdEtn in longitudinal samples collected over the course of one year from autistic subjects taking carnitine supplements [n=12 (4x3)] vs. subjects not taking carnitine supplements [n=33 (11x3)] and vs. controls [n=30 (10x3)]. Values control-normalized and expressed as mean $\pm$ SEM of the ratio to PtdEtn 16:0/18:0, *, p<0.05 vs. control, #, p<0.05 vs. autism, no carnitine; and

Figure 6 is a graph illustrating a within family comparison of key DHA containing PlsEtn and PtdEtn and AA containing PlsEtn in longitudinal samples collected over the course of one year from autistic subjects and their asymptomatic siblings. Values are control-normalized and expressed as mean $\pm$ SEM of the ratio to PtdEtn 16:0/18:0, *, p<0.05 vs. control.

DETAILED DESCRIPTION

Small molecules or metabolites that are found to have different abundances between clinically diagnosed ASD, and normal patients expressing no symptoms of ASD have been identified. Based on these differences, a subject's health state or change in health state with respect to ASD may be determined. Methods for diagnosing a subject's health state, for example for diagnosing the presence or absence of ASD are provided, and methods for diagnosing a change in health state, for example for monitoring an ASD therapy, are provided.

Illustrative methods for diagnosing a subject's health state or change in health state with regard to ASD of the present invention comprise the steps of:

- a) analyzing a sample(s) obtained from a human subject to obtain quantifying data for one or more than one metabolite marker or accurate mass;
- b) comparing the quantifying data for said one or more than one metabolite marker or accurate mass to corresponding data obtained from one or more than one reference sample; and
- c) using said comparison to arrive at a determination of the subject's health state or change in health state.

The illustrative methods may further include the preliminary step of obtaining one or more than one sample from the human subject for analysis.

By the term "metabolite", it is meant specific small molecules, the levels or intensities of which are measured in a sample, and that may be used as markers to diagnose a disease state. These small molecules may also be referred to herein as "metabolite marker", "metabolite component", "biomarker", or "biochemical marker".

In one illustrative embodiment there is provided a method for diagnosing the biochemical ASD phenotype of a subject, comprising the steps of: introducing one or more than one sample from one or more than one patient with probable ASD into a high resolution mass spectrometer (for example, and without wishing to be limiting, a Fourier Transform Ion Cyclotron Resonance Mass Spectrometer (FTMS)); obtaining quantifying data for one or more than one metabolite marker; optionally creating a database of said quantifying data; comparing the quantifying data from the sample with corresponding reference data collected from non-ASD subjects; and using said comparison to determine the biochemical ASD phenotype of the subject. The biochemical ASD phenotype of the subject may be determined based on the differences identified when comparing the quantifying data from the sample with the corresponding reference data. The differences between ASD and non-ASD subjects are described in any one of Tables 2, 11-18.

In another illustrative embodiment there is provided a method for identifying subjects at risk of ASD, comprising the steps of: introducing one or more than one sample from one or more than one subject of unknown ASD status into a high resolution mass spectrometer (for example, and without wishing to be limiting, a Fourier

Transform Ion Cyclotron Resonance Mass Spectrometer (FTMS)); obtaining quantifying data for one or more than one of the parent masses listed in any one of tables 2-10; optionally creating a database of said quantifying data; comparing the quantifying data from the sample with corresponding reference data collected from non-ASD subjects; and using said comparison to determine whether the subject has elevated risk of ASD.

In another illustrative embodiment there is provided a method for monitoring an ASD therapy, comprising the steps of: introducing a plurality of samples from one or more than one ASD subject into a high resolution mass spectrometer (for example, and without wishing to be limiting, a Fourier Transform Ion Cyclotron Resonance Mass Spectrometer (FTMS)); obtaining quantifying data for one or more than one of the parent masses listed in any one of tables 2-10; optionally creating a database of said quantifying data; comparing the quantifying data from the plurality of samples with each other and with corresponding reference data collected from non-ASD subjects and/or with previous collected quantifying data from a pre-therapy stage or an earlier-therapy stage of the subject(s) and using said comparison to determine whether the therapeutic strategy had a positive, negative, or no effect on the subject's underlying biochemical phenotype.

In another illustrative embodiment there is provided a method for diagnosing the biochemical ASD phenotype of a subject, comprising the steps of: introducing one or more than one sample from one or more than one patient with clinically diagnosed ASD into a multi-stage mass spectrometer (for example, and without wishing to be limiting, a triple quadrupole mass spectrometer (TQ)); obtaining quantifying data for one or more than one of the metabolites listed in any one of Tables 3-10; optionally creating a database of said quantifying data; comparing the quantifying data from the sample with corresponding reference data collected from non-ASD subjects; and using said comparison to determine whether the subject has ASD.

In another illustrative embodiment there is provided a method for identifying subjects at risk of ASD, comprising the steps of: introducing one or more than one sample from one or more than one subject of unknown ASD status into a multi-stage mass spectrometer (for example, and without wishing to be limiting, a triple quadrupole mass spectrometer (TQ)); obtaining quantifying data for one or more than one of the

metabolites listed in any one of Tables 3-10; optionally creating a database of said quantifying data; comparing the quantifying data from the sample with corresponding reference data collected from non-ASD subjects; and using said comparison to determine whether the subject has elevated risk of ASD.

In another illustrative embodiment there is provided a method for monitoring an ASD therapy, comprising the steps of: introducing a plurality of samples from one or more than one ASD subject into a multi-stage mass spectrometer (for example, and without wishing to be limiting, a triple quadrupole mass spectrometer (TQ)); obtaining quantifying data for one or more than one of the metabolites listed in any one of Tables 3-10; optionally creating a database of said quantifying data; comparing the quantifying data from the plurality of samples with each other and/or with corresponding reference data collected from non-ASD subjects and/or with previously collected quantifying data from a pre-therapy stage or an earlier-therapy stage of the subject(s) and using said comparison to determine whether the therapeutic strategy had a positive, negative, or no effect on the subject's underlying biochemical phenotype.

In another illustrative embodiment there is provided a method for diagnosing the biochemical ASD phenotype of a subject, comprising the steps of: obtaining quantifying data for one or more than one of the metabolites listed in any one of Tables 2-10 from one or more than one ASD subject; optionally creating a database of said quantifying data; comparing the quantifying data from the sample with corresponding reference data collected from non-ASD subjects; and using said comparison to determine whether the subject has ASD.

In another illustrative embodiment there is provided a method for identifying subjects at risk of ASD, comprising the steps of: obtaining quantifying data for one or more than one of the metabolites listed in any one of Tables 2-10 from one or more than one subject of unknown ASD status; optionally creating a database of said quantifying data; comparing the quantifying data from the sample with corresponding reference data collected from non-ASD subjects; and using said comparison to determine whether the subject has elevated risk of ASD.

In another illustrative embodiment there is provided a method for monitoring an ASD therapy, comprising the steps of: obtaining quantifying data for one or more than one of the metabolites listed in any one of Tables 2-10 from a plurality of samples collected from one or more than one ASD subject; optionally creating a database of said quantifying data; comparing the quantifying data from the plurality of samples with each other and/or with corresponding reference data collected from non-ASD subjects and/or with previously collected quantifying data from a pre-therapy stage or an earlier-therapy stage of the subject(s); and using said comparison to determine whether the therapeutic strategy had a positive, negative, or no effect on the subject's underlying biochemical phenotype.

As would be obvious to anyone skilled in the art, other analytical technologies other than those illustrated above may be used to quantify the metabolites listed in Tables 2-10 including colorimetric chemical assays (UV, or other wavelength), antibody-based enzyme-linked immunosorbant assays (ELISAs), chip-based and polymerase-chain reaction for nucleic acid detection assays, bead-based nucleic-acid detection methods, dipstick chemical assays or other chemical reaction, image analysis such as magnetic resonance imaging (MRI), positron emission tomography (PET) scan, computerized tomography (CT) scan, nuclear magnetic resonance (NMR), and various mass spectrometry-based systems.

As outlined above, illustrative methods for diagnosing a subject's health state or change in health state with regard to ASD of the present invention comprise the steps of:

- a) analyzing a sample(s) obtained from a human subject to obtain quantifying data for one or more than one metabolite marker;
- b) comparing the quantifying data for said one or more than one metabolite marker to corresponding data obtained from one or more than one reference sample; and
- c) using said comparison to arrive at a determination of the subject's health state or change in health state.

The illustrative methods may further include the preliminary step of obtaining one or more than one sample from the human subject for analysis.

The step of analyzing the sample (step a) may comprise analyzing the sample using a mass spectrometer (MS). For example, and without wishing to be limiting, such mass spectrometer may be of the FTMS, orbitrap, time of flight (TOF), magnetic sector, linear ion trap (LIT) or quadrupole types. Alternatively, the mass spectrometer may be equipped with an additional pre-detector mass filter. For example, and without wishing to be limiting, such instruments are commonly referred to as quadrupole-FTMS (Q-FTMS), quadrupole –TOF (Q-TOF) or triple quadrupole (TQ or QQQ). In addition, the mass spectrometer may be operated in either the parent ion detection mode (MS) or in MS_n mode, where $n \geq 2$. MS_n refers to the situation where the parent ion is fragmented by collision induced dissociation (CID) or other fragmentation procedures to create fragment ions, and then one or more than one of said fragments are detected by the mass spectrometer. Such fragments may then be further fragmented to create further fragments. Alternatively, the sample may be introduced into the mass spectrometer using a liquid or gas chromatographic system or by direct injection.

By the term “differential diagnosis” or “differentially diagnosing”, it is meant that various aspects of a disease state may be distinguished from one another. In particular, the methods disclosed herein allow for differential diagnosis of various biochemical phenotypes of ASD; for example and without wishing to be limiting, the methods disclosed herein may provide the diagnosis of subjects with or at risk of ASD with the biochemical phenotype of:

- a) elevated levels of saturated or monounsaturated very long chain fatty acid (VLCFA) containing phospholipids;
- b) elevated levels of docosahexaenoic acid (22:6, DHA) containing phospholipids;
- c) elevated levels of polyunsaturated VLCFA containing phospholipids; or
- d) combinations thereof,

In accordance with the methods disclosed herein, any type of biological sample that originates from anywhere within the body, for example but not limited to, blood (serum/plasma), CSF, urine, stool, breath, saliva, or biopsy of any solid tissue including tumor, adjacent normal, smooth and skeletal muscle, adipose tissue, liver,

skin, hair, brain, kidney, pancreas, lung, colon, stomach, or other may be used. Of particular interest are samples that are plasma. While the term "plasma" is used herein, those skilled in the art will recognize that serum or whole blood or a sub-fraction of whole blood may also be used. CSF may be obtained by a lumbar puncture requiring a local anesthetic.

In a non-limiting example, when a blood sample is drawn from a patient there are several ways in which the sample may be processed. The range of processing can be as little as none (i.e. frozen whole blood) or as complex as the isolation of a particular cell type. The most common and routine procedures involve the preparation of either serum or plasma from whole blood. All blood sample processing methods, including spotting of blood samples onto solid-phase supports, such as filter paper or other immobile materials, are within the scope of the methods described herein.

Without wishing to be limiting, the processed blood or plasma sample described above may then be further processed to make it compatible with the methodical analysis technique to be employed in the detection and measurement of the metabolites contained within the processed blood sample. The types of processing can range from as little as no further processing to as complex as differential extraction and chemical derivatization. Extraction methods may include sonication, soxhlet extraction, microwave assisted extraction (MAE), supercritical fluid extraction (SFE), accelerated solvent extraction (ASE), pressurized liquid extraction (PLE), pressurized hot water extraction (PHWE) and/or surfactant assisted extraction (PHWE) in common solvents such as methanol, ethanol, mixtures of alcohols and water, or organic solvents such as ethyl acetate or hexane. A method of particular interest for extracting metabolites for FTMS non-targeted analysis and for flow injection LC-MS/MS analysis is to perform a liquid/liquid extraction whereby non-polar metabolites dissolve in an organic solvent and polar metabolites dissolve in an aqueous solvent.

The extracted samples may be analyzed using any suitable method including those known in the art. For example, and without wishing to be limiting, extracts of biological samples are amenable to analysis on essentially any mass spectrometry platform, either by direct injection or following chromatographic separation. Typical

mass spectrometers are comprised of a source that ionizes molecules within the sample, and a detector for detecting the ionized molecules or fragments of molecules. Non-limiting examples of common sources include electron impact, electrospray ionization (ESI), atmospheric pressure chemical ionization (APCI), atmospheric pressure photo ionization (APPI), matrix assisted laser desorption ionization (MALDI), surface enhanced laser desorption ionization (SELDI), and derivations thereof. Common mass separation and detection systems can include quadrupole, quadrupole ion trap, linear ion trap, time-of-flight (TOF), magnetic sector, ion cyclotron (FTMS), Orbitrap, and derivations and combinations thereof. The advantage of FTMS over other MS-based platforms is its high resolving capability that allows for the separation of metabolites differing by only hundredths of a Dalton, many of which would be missed by lower resolution instruments.

The metabolites are generally characterized by their accurate mass, as measured by mass spectrometry technique. The accurate mass may also be referred to as “accurate neutral mass” or “neutral mass”. The accurate mass of a metabolite is given herein in Daltons (Da), or a mass substantially equivalent thereto. By “substantially equivalent thereto”, it is meant that a ± 5 ppm difference in the accurate mass would indicate the same metabolite. The accurate mass is given as the mass of the neutral metabolite. During the ionization of the metabolites, which occurs during analysis of the sample, the metabolite will cause either a loss or gain of one or more hydrogen atoms and a loss or gain of an electron. This changes the accurate mass to the “ionized mass”, which differs from the accurate mass by the mass of hydrogen atoms and electrons lost or gained during ionization. Unless otherwise specified, the accurate neutral mass will be referred to herein.

Similarly, when a metabolite is described by its molecular formula, the molecular formula of the neutral metabolite will be given. Naturally, the molecular formula of the ionized metabolite will differ from the neutral molecular formula by the number of hydrogen atoms lost or gained during ionization or due to the addition of a non-hydrogen adduct ion.

Data is collected during analysis and quantifying data for one or more than one metabolite is obtained. “Quantifying data” is obtained by measuring the levels or intensities of specific metabolites present in a sample.

The quantifying data is compared to corresponding data from one or more than one reference sample. The "reference sample" is any suitable reference sample for the particular disease state. For example, and without wishing to be limiting in any manner, the reference sample may be a sample from a control individual, i.e., a person not suffering from ASD with or without a family history of ASD (also referred to herein as a " 'normal' counterpart"); the reference sample may also be a sample obtained from a patient clinically diagnosed with ASD. As would be understood by a person of skill in the art, more than one reference sample may be used for comparison to the quantifying data. For example and without wishing to be limiting, the one or more than one reference sample may be a first reference sample obtained from a non-ASD control individual. The one or more than one reference sample may further include a second reference sample obtained from a patient with clinically diagnosed ASD of the peroxisomal type, a third reference sample obtained from a patient with clinically diagnosed ASD of the mitochondrial type, a fourth reference sample obtained from a patient suffering from clinically diagnosed ASD of an unknown type, or any combination thereof. In the case of monitoring a subjects change in disease state, the reference sample may include a sample obtained an earlier time period either pre-therapy or during therapy to compare the change in disease state as a result of therapy.

Methods within the scope of the present invention will be further illustrated in the following non-limiting examples.

Example 1: Identification of ASD Subjects using Accurate Mass Biomarkers

Sample Collection. Three plasma samples were collected from 15 clinically diagnosed ASD subjects and 12 non-ASD controls over a 12 month period (six month interval between samplings).

Sample extraction. Plasma samples were stored at -80°C until thawed for analysis. All extractions were performed on ice. Metabolites were extracted using 1% ammonium hydroxide and ethyl acetate (EtOAc) in the ratio of 1:1:5, respectively, three times followed by two more extractions with 0.33 % formic acid and EtOAc in the ratio of 1:1:5. Samples were centrifuged between extractions at 4°C for 10 min

at 3500 rpm, and the organic layers combined. The organic and aqueous extracts were then stored at -80°C until analysis.

Mass Spectrometric Analysis. Plasma extracts were analyzed by direct injection into a FTMS and ionization by either ESI or atmospheric pressure chemical ionization (APCI) in both positive and negative modes. Sample extracts were diluted either three or six-fold in methanol:0.1%(v/v) ammonium hydroxide (50:50, v/v) for negative ionization modes, or in methanol:0.1% (v/v) formic acid (50:50, v/v) for positive ionization modes. For APCI, sample extracts were directly injected without diluting. All analyses were performed on a Bruker Daltonics APEX III Fourier transform ion cyclotron resonance mass spectrometer equipped with a 7.0 T actively shielded superconducting magnet (Bruker Daltonics, Billerica, MA). Samples were directly injected using electrospray ionization (ESI) and/or APCI at a flow rate of 1200 μ L per hour. Ion transfer/detection parameters were optimized using a standard mix of serine, tetra-alanine, reserpine, Hewlett-Packard tuning mix and the adrenocorticotrophic hormone fragment 4-10. In addition, the instrument conditions were tuned to optimize ion intensity and broad-band accumulation over the mass range of 100–1000 amu according to the instrument manufacturer's recommendations. A mixture of the above mentioned standards was used to internally calibrate each sample spectrum for mass accuracy over the acquisition range of 100–1000 amu.

In total, six separate analyses comprising combinations of extracts and ionization modes were obtained for each sample:

Aqueous Extract

1. Positive ESI (analysis mode 1101)
2. Negative ESI (analysis mode 1102)

Organic Extract

3. Positive ESI (analysis mode 1201)
4. Negative ESI (analysis mode 1202)

5. Positive APCI (analysis mode 1203)

6. Negative APCI (analysis mode 1204)

Mass Spectrometry Data Processing. Using a linear least-squares regression line, mass axis values were calibrated such that each internal standard mass peak had a mass error of <1 p.p.m. compared with its theoretical mass. Using XMASS software from Bruker Daltonics Inc., data file sizes of 1 megaword were acquired and zero-filled to 2 megawords. A sinm data transformation was performed prior to Fourier transform and magnitude calculations. The mass spectra from each analysis were integrated, creating a peak list that contained the accurate mass and absolute intensity of each peak. Compounds in the range of 100–2000 m/z were analyzed. In order to compare and summarize data across different ionization modes and polarities, all detected mass peaks were converted to their corresponding neutral masses assuming hydrogen adduct formation. A self-generated two-dimensional (mass vs. sample intensity) array was then created using DISCOVAmetrics™ software (Phenomenome Discoveries Inc., Saskatoon, SK, Canada). The data from multiple files were integrated and this combined file was then processed to determine the unique masses. The average of each unique mass was determined, representing the y-axis. This value represents the average of all of the detected accurate masses that were statistically determined to be equivalent. Considering that the mass accuracy of the instrument for the calibration standards is approximately 1 ppm, a person skilled in the art will recognize that these average masses may include individual masses that fall within +/- 5 ppm of this average mass. A column was created for each file that was originally selected to be analyzed, representing the x-axis. The intensity for each mass found in each of the files selected was then filled into its representative x,y coordinate. Coordinates that did not contain an intensity value were left blank. Once in the array, the data were further processed, visualized and interpreted, and putative chemical identities were assigned. Each of the spectra were then peak picked to obtain the mass and intensity of all metabolites detected. These data from all of the modes were then merged to create one data file per sample. The data from all samples was then merged and aligned to create a two-dimensional metabolite array in which each sample was represented by a column and each unique metabolite was represented

by a single row. In the cell corresponding to a given metabolite sample combination, the intensity of the metabolite in that sample was displayed. When the data is represented in this format, metabolites showing differences between groups of samples can be determined. Using this method, accurate mass features that differed between ASD subjects not taking carnitine supplements and non-ASD subjects. By using all or a subset of accurate masses described in Table 2, the methods disclosed herein allow for the diagnosis of ASD.

Example 2: The Diagnosis and Individual Characterization of ASD subjects using LC-MS/MS and the Evaluation of a ASD Therapeutic

Sample Collection. Three plasma samples were collected from 15 clinically diagnosed ASD subjects and 12 non-ASD controls over a 12 month period (six month interval between samplings). Four subjects were treated with carnitine (A09, A11, A13, A15). Table 1 outlines the clinical characteristics of the subjects studied. Social cognition scores were determined using methods known in the art. Although 12 non-autistic control subjects were enrolled, two siblings (C08 and C29) excluded from the control population for overall comparisons due to the fact that their plasma levels of PlsEtn 18:1/22:6 were significantly higher than the rest of the controls ($p=5.6e-6$ and $4.0e-4$, respectively, Figure 6).

Sample extraction was as described in Example 1.

LC-MS/MS flow injection analyses. Analyses were performed using a linear ion trap mass spectrometer (4000 Q TRAP, Applied Biosystems) coupled with an Agilent 1100 LC system. Sample was prepared by adding 15 μ L of internal standard (5 μ g/mL of (24-¹³C)-Cholic Acid (Cambridge Isotope Laboratories, Andover, MA) in methanol) to 120 μ L ethyl acetate fraction of each sample. 100 μ L of sample was injected by flow injection analysis (FIA), and monitored under negative APCI mode. The method was based on multiple reaction monitoring (MRM) of one parent/fragment transition for each metabolite and (24-¹³C)-Cholic Acid. Each transition was scanned for 70 ms. 10% EtOAc in MeOH at a flow rate of 360 μ L/min was used as the mobile phase. The source parameters were set as follows: CUR: 10.0, CAD: 8, NC: -4.0, TEM: 400, GS1: 30, GS2: 50, interface heater on. The compound parameters were set as follows: DP: -120.0, EP: -10, NC: -4.0, CE: -40,

CXP: -15. Tables 3-10 lists the metabolites and the MS/MS transition that was used for each metabolite. A standard curve was generated for all analytes to verify instrument linearity by serial dilution of a healthy normal serum extract with constant concentration of (24-¹³C)-Cholic Acid. All samples were analyzed in a randomized blinded manner and were bracketed by known serum standard dilutions. All standard curves had r^2 values > 0.98.

Plasma PtdEtn, PlsEtn, and Autism

In total, plasma levels of 136 PtdEtn and 15 PlsEtn species were measured. The results of these analyses are summarized in Tables 11-18 and in Figure 1. The key observations for autistic subjects not taking carnitine were:

1. Levels of virtually all saturated VLCFA (SVLCFA) were significantly elevated;
2. Levels of 18:1 were decreased but levels of monounsaturated VLCFA (MUVLCFA) were elevated;
3. Levels of LCFA and VLCFA containing three double bonds were significantly decreased;
4. Levels of DHA (22:6), DHA precursors (24:5, 24:6), and catabolic products of DHA beta-oxidation (20:6) were all elevated;
5. Levels of PlsEtn containing DHA were elevated.

Plasma levels of 26:0 containing PtdEtn were not observed to be increased relative to 22:0 containing PtdEtn. These results are contrary to those observed from subjects suffering from peroxisomal disorders, where 26:0 is elevated to a much greater extent than 22:0 (Moser and Moser 1996). Therefore the methods described in this application provide a means to differentiate ASD from peroxisomal disorders.

These results indicate that all children with ASD exhibit a universal metabolic phenotype. The uncontrolled nature of the collection protocol was such that these findings represent a true sub-sampling of ASD subjects. Each subject was sampled at three different times over the course of one year and no dietary restrictions were imposed. Under these settings, 11/11 untreated ASD children exhibited the same

biochemical phenotype, that is, statistically elevated levels of VLCFA and/or DHA containing phospholipids (Figures 2-3). In addition, in 8/8 families in which a non-ASD sibling was available for comparative analysis the ASD child had a more pronounced biochemical phenotype than the non-ASD sibling (Figure 6). These metabolic abnormalities best fit a model of impaired mitochondrial fatty acid beta oxidation resulting in excessive extra-mitochondrial processing of palmitate.

Example 3: Individual Subject Analyses

Since longitudinal samples were collected on all participants, it was possible to evaluate each participant separately. This analysis revealed dramatic subject-to-subject variability but relatively modest within subject variability, considering that the three samples were collected over the course of an entire year. As described above, all ASD subjects exhibit the same underlying metabolic abnormality – the excessive extramitochondrial processing of palmitate. However, the actual biochemical manifestation and diagnosis of this abnormality was observed to have various subject-to-subject variability. To illustrate this phenomenon, Tables 2 and 3 display the individual profiles of eight prototypical biomarkers representative of the 5 metabolite changes described in Example 2 (note that the last 4 subjects were taking acetyl-carnitine and are not part of this discussion). Table 2 focuses on DHA and AA containing PlsEtn and PtdEtn. As can be observed, only subjects A22 and A05 did not show a significantly elevated level of DHA containing PlsEtn or PtdEtn. However by looking at Figure 3 it is observed that these 2 subjects have elevated levels of polyunsaturated VLCFA 26:3.

All of the autistic children not taking carnitine supplementation (11/11) were observed to have significantly higher levels ($p < 0.05$) of either DHA-PlsEtn or VLCFA-PtdEtn (Figures 2 and 3).

Example 4: Monitoring the biochemical efficacy of an experimental ASD therapy

It has been suggested that mitochondrial defects are associated with ASD (Lombard 1998; Clark-Taylor and Clark-Taylor 2004). Since acetyl-carnitine is known to have mitochondrial enhancing qualities (Pettegrew, Levine et al. 2000) it has been suggested as a possible therapeutic for ASD. Acetyl-carnitine is not approved nor has it been proven to be effective in ASD. To illustrate the utility of a method of

monitoring ASD therapy as disclosed herein, the diagnostic ASD biomarkers described above were quantified in subjects taking acetyl-carnitine supplements. Figure 4 illustrates the carnitine and acetyl carnitine levels in all of the subjects. None of the ASD subjects not taking carnitine exhibited either a deficiency or an elevation in either carnitine or acetyl-carnitine. All of the subjects taking acetyl-carnitine had elevated levels of both carnitine and acetyl-carnitine.

Comparison of the plasma levels of the eight most descriptive metabolites between the carnitine +/- autistic subjects and controls, determined that the effect of carnitine on the autism biomarkers was striking (Figure 5). Complete normalization of DHA-PlsEtn, DHA-PtdEtn, the DHA precursor (24:6) and saturated VLCFA (28:0) was observed. Carnitine supplementation had no significant effect on 28:1 and 26:3 PdtEtn, suggesting that carnitine is only effective at modulating palmitate-derived elongation products. However, subjects taking carnitine had significantly elevated levels of AA-PtdEtn (20:4). These data suggest that carnitine is effective in preventing VLCFA, DHA, and DHA-PlsEtn accumulation by restoring palmitate oxidation in the mitochondria. However, the rate of elongation and desaturation of mono- and di-unsaturated fatty acid precursors appear to be unaffected and a compensatory elevation in AA appears to occur.

Example 5: Identifying subjects with elevated risk of ASD

For eight of the autistic children enrolled (excluding those taking carnitine), asymptomatic or mildly symptomatic siblings were followed simultaneously (Table 1). These subjects are considered high risk due to the increased prevalence of ASD in siblings (Newschaffer, Fallin et al. 2002). When the PlsEtn metabolites of Figure 2 were plotted by family (Figure 6), invariably, the affected sibling had higher levels of one of these metabolites than the non-affected sibling. This difference was statistically significant ($p < 0.05$) in 5 of the 8 subjects. In two of the three situations in which the affected sibling was not observed to have significantly higher levels versus the non-affected sibling, the non-affected sibling had significantly elevated levels relative to controls. These subjects would be biochemically diagnosed as at risk of ASD. When these two control children (C29 and C08) were more closely evaluated for ASD symptoms using the social cognition test (Skuse 2000), it was observed that the male subject (C29) showed a social cognition deficit, whereas the female (C08)

was completely asymptomatic (Table 1). The lack of effect in the female subject is not unexpected as females are thought to have a social cognition reserve. Based upon these findings the methods described in this application can effectively identify subjects at risk of ASD.

Table 1: Clinical information summary.

Controls			Family	Social
Subject ID	Sex	Age	History	Cognition
F1, C29	M	5	Y (A10)	11
F2, C08	F	7	Y (A12)	0
F3, C20	F	17	Y (A16)	3
F4, C17	M	9	Y (A26)	6
F5, C19	M	6	Y (A23, A21)	
F6, C03	M	7	Y (A07)	2
F7, C02	M	15	Y (A11, A15)	1
F7, C28	M	7	Y (A11, A15)	6
F8, C01	F	4	Y (A22)	
C, C04	M	11	N	0
C, C14	M	8	N	2
C, C27	M	8	N	4
Autistic			Family	Social
Subject ID	Sex	Age	History	Cognition
F1, A10	M	7		18
F2, A12	M	9		16
F3, A16	M	10		23
F4, A26	M	5		9
F5, A23	M	5	Y (A21)	
F5, A21	M	8	Y (A23)	21
F6, A07	M	10		18
F7, A11 (Carnitine)	M	13	Y (A15)	23
F7, A15 (Carnitine)	M	8	Y (A11)	23
F8, A22	M	6		
A, A05	M	13		
A, A24	M	7		16
A, A25	M	8		16
A, A09 (Carnitine)	M	2	Y (A13)	14
A, A13 (Carnitine)	M	8	Y (A09)	19

Table 2: Accurate mass features differing between autistic subjects versus controls.

Parent Mass	Analysis Mode	Control		Autism		Ratio	ttest
		Average	SEM	Average	SEM		
820.5267	1204	3.03	0.14	6.07	0.58	2.01	6.9E-06
834.5398	1204	3.11	0.18	5.68	0.47	1.83	1.8E-05
328.2402	1202	6.52	0.52	16.31	2.31	2.50	6.0E-05
879.5992	1102	4.25	0.22	8.40	0.96	1.98	6.0E-05
806.5089	1204	6.43	0.43	11.97	1.28	1.86	9.7E-05
851.5694	1102	8.65	0.63	18.31	2.34	2.12	1.1E-04
807.5133	1204	4.10	0.28	7.52	0.79	1.83	1.3E-04
858.6834	1202	6.98	0.31	9.20	0.45	1.32	1.4E-04
792.4940	1204	5.24	0.29	9.54	1.05	1.82	1.6E-04
852.5719	1102	4.58	0.29	9.13	1.16	1.99	1.9E-04
878.7575	1204	7.87	0.64	4.71	0.46	0.60	3.3E-04
613.3380	1202	3.14	0.23	6.65	0.90	2.12	4.0E-04
622.4949	1203	3.36	0.18	5.46	0.52	1.63	4.1E-04
747.5203	1202	2.56	0.12	4.54	0.53	1.78	6.7E-04
837.5888	1202	4.48	0.18	6.18	0.46	1.38	7.3E-04
851.5681	1202	7.31	0.70	14.50	1.98	1.98	7.6E-04
858.6842	1102	14.36	0.59	18.20	0.99	1.27	1.2E-03
596.5017	1204	6.66	0.62	10.30	0.91	1.55	1.4E-03
852.5713	1202	4.10	0.35	7.40	0.97	1.80	1.5E-03
841.5387	1102	2.62	0.14	4.49	0.55	1.71	2.6E-03
550.4964	1203	40.21	4.56	23.19	2.97	0.58	3.2E-03
819.5794	1204	2.97	0.21	5.07	0.52	1.70	3.6E-03
859.6879	1102	7.29	0.30	8.96	0.47	1.23	3.7E-03
551.4998	1203	15.62	1.78	9.08	1.16	0.58	3.7E-03
828.5476	1201	7.13	0.46	11.30	1.37	1.59	3.8E-03
893.7762	1204	17.14	1.38	11.80	1.06	0.69	4.0E-03
750.5406	1204	4.76	0.44	7.83	0.98	1.64	4.8E-03
793.4944	1204	3.60	0.27	5.96	0.64	1.66	5.3E-03
791.5471	1204	6.06	0.69	11.08	1.59	1.83	5.4E-03
827.5440	1201	13.69	0.87	21.48	2.71	1.57	6.0E-03
879.5982	1202	3.25	0.26	5.12	0.58	1.57	6.4E-03
904.7514	1203	7.48	0.47	9.88	0.72	1.32	6.6E-03
906.7790	1204	10.73	0.81	7.85	0.64	0.73	7.7E-03
905.7564	1203	4.94	0.24	6.28	0.43	1.27	7.9E-03
865.7508	1204	12.49	1.14	7.96	1.14	0.64	8.4E-03
753.5273	1201	3.95	0.28	2.99	0.19	0.76	8.5E-03
594.4849	1204	5.68	0.47	8.14	0.82	1.43	9.8E-03
218.2034	1203	2.97	0.11	3.43	0.13	1.16	9.8E-03
894.7838	1204	7.10	0.68	4.83	0.42	0.68	1.1E-02
558.4652	1204	2.46	0.15	3.28	0.26	1.34	1.2E-02
779.4864	1204	2.87	0.26	4.55	0.50	1.58	1.4E-02
595.4887	1204	2.86	0.24	3.94	0.33	1.38	1.4E-02
246.2345	1203	2.82	0.09	3.23	0.14	1.14	1.5E-02
596.5018	1202	5.30	0.55	7.62	0.74	1.44	1.5E-02
724.5244	1204	4.03	0.31	5.66	0.60	1.40	1.6E-02

775.5516	1204	5.24	0.48	8.69	1.21	1.66	1.7E-02
549.4840	1203	15.46	1.39	10.90	1.23	0.71	1.8E-02
866.7550	1204	7.92	0.67	5.48	0.71	0.69	1.9E-02
548.4807	1203	41.47	3.64	30.01	3.13	0.72	2.1E-02
258.2346	1203	3.56	0.13	3.99	0.13	1.12	2.3E-02
766.4787	1204	2.51	0.18	7.25	1.31	2.89	2.3E-02
329.2436	1202	2.74	0.18	5.09	0.65	1.86	2.3E-02
256.2189	1203	4.45	0.15	5.05	0.21	1.13	2.4E-02
760.5813	1201	13.23	0.47	11.72	0.44	0.89	2.4E-02
174.1408	1203	3.49	0.13	3.98	0.17	1.14	2.5E-02
594.4858	1202	4.25	0.40	5.82	0.56	1.37	2.6E-02
962.7618	1204	2.66	0.13	4.16	0.46	1.56	2.7E-02
826.5555	1102	2.14	0.17	5.70	1.87	2.67	2.8E-02
876.7233	1203	3.47	0.25	4.96	0.61	1.43	2.8E-02
302.2219	1201	13.90	1.45	18.90	1.71	1.36	2.9E-02
604.5431	1203	36.62	3.98	25.17	3.15	0.69	3.0E-02
792.5522	1204	4.37	0.58	7.20	0.93	1.65	3.1E-02
777.5689	1204	4.49	0.25	5.68	0.48	1.27	3.2E-02
946.8169	1204	6.59	0.70	4.49	0.63	0.68	3.2E-02
597.5053	1204	3.54	0.30	4.54	0.34	1.28	3.2E-02
766.5359	1204	2.92	0.15	4.77	1.06	1.63	3.2E-02
892.7708	1204	39.04	2.67	30.96	2.51	0.79	3.3E-02
605.5462	1203	14.99	1.68	10.28	1.31	0.69	3.3E-02
860.7753	1203	6.00	0.48	4.59	0.42	0.76	3.4E-02
592.4705	1204	2.70	0.15	3.46	0.30	1.28	3.4E-02
863.7358	1204	12.95	1.01	9.54	1.21	0.74	3.4E-02
920.8001	1204	10.52	1.02	7.72	0.77	0.73	3.6E-02
249.8832	1102	6.12	0.13	6.60	0.18	1.08	3.6E-02
805.5608	1101	4.42	0.21	5.14	0.27	1.16	3.7E-02
759.5781	1201	28.60	1.02	25.52	1.03	0.89	3.8E-02
242.2033	1203	5.30	0.18	5.94	0.25	1.12	3.9E-02
749.5371	1204	9.02	1.01	13.85	2.07	1.54	3.9E-02
856.6691	1102	8.16	0.26	9.16	0.41	1.12	4.0E-02
919.7934	1204	22.85	1.99	17.18	1.79	0.75	4.0E-02
728.5573	1204	3.12	0.24	3.92	0.29	1.26	4.0E-02
826.5563	1202	2.25	0.19	5.37	1.71	2.38	4.1E-02
562.4959	1203	5.62	0.48	4.22	0.45	0.75	4.2E-02
782.5645	1201	33.97	1.03	30.81	1.13	0.91	4.3E-02
776.5559	1204	3.15	0.19	4.92	0.66	1.56	4.3E-02
576.5117	1203	208.21	13.70	167.71	13.99	0.81	4.4E-02
362.0842	1201	1.95	0.01	2.11	0.06	1.08	4.4E-02
950.7566	1204	4.70	0.28	5.88	0.51	1.25	4.4E-02
876.7429	1204	7.66	0.61	5.93	0.57	0.77	4.6E-02
577.5154	1203	84.74	5.75	68.18	5.88	0.80	4.9E-02

Table 3: Molecular formula, accurate mass, and LC-MS/MS parameters for phosphatidylethanolamine (PtdEtn) metabolites with saturated fatty acids at the sn-2 position.

Metabolite Name	Molecular Formula	Parent Mass	M-H Mass	Diagnostic Fragment Mass	MS/MS Transition
PtdEtn 16:0/18:0	C39H78N1O8P1	719.5465	718.5	R1 (C16H31O2) - 255	718.5 / 255.2
PtdEtn 16:0/20:0	C41H82N1O8P1	747.5778	746.6	R1 (C16H31O2) - 255	746.6 / 255.2
PtdEtn 16:0/22:0	C43H86N1O8P1	775.6091	774.6	R1 (C16H31O2) - 255	774.6 / 255.2
PtdEtn 16:0/24:0	C45H90N1O8P1	803.6404	802.6	R1 (C16H31O2) - 255	802.6 / 255.2
PtdEtn 16:0/26:0	C47H94N1O8P1	831.6717	830.7	R1 (C16H31O2) - 255	830.7 / 255.2
PtdEtn 16:0/28:0	C49H98N1O8P1	859.7030	858.7	R1 (C16H31O2) - 255	858.7 / 255.2
PtdEtn 16:0/30:0	C51H102N1O8P1	887.7343	886.7	R1 (C16H31O2) - 255	886.7 / 255.2
PtdEtn 16:0/32:0	C53H106N1O8P1	915.7656	914.8	R1 (C16H31O2) - 255	914.8 / 255.2
PtdEtn 16:0/34:0	C55H110N1O8P1	943.7969	942.8	R1 (C16H31O2) - 255	942.8 / 255.2
PtdEtn 16:0/36:0	C57H114N1O8P1	971.8282	970.8	R1 (C16H31O2) - 255	970.8 / 255.2
PtdEtn 16:0/38:0	C59H118N1O8P1	999.8595	998.9	R1 (C16H31O2) - 255	998.9 / 255.2
PtdEtn 16:0/40:0	C61H122N1O8P1	1027.8908	1026.9	R1 (C16H31O2) - 255	1026.9 / 255.2
PtdEtn 18:0/18:0	C41H82N1O8P1	747.5778	746.6	R1 (C18H35O2) - 283	746.6 / 283.2
PtdEtn 18:0/20:0	C43H86N1O8P1	775.6091	774.6	R1 (C18H35O2) - 283	774.6 / 283.2
PtdEtn 18:0/22:0	C45H90N1O8P1	803.6404	802.6	R1 (C18H35O2) - 283	802.6 / 283.2
PtdEtn 18:0/24:0	C47H94N1O8P1	831.6717	830.7	R1 (C18H35O2) - 283	830.7 / 283.2
PtdEtn 18:0/26:0	C49H98N1O8P1	859.7030	858.7	R1 (C18H35O2) - 283	858.7 / 283.2
PtdEtn 18:0/28:0	C51H102N1O8P1	887.7343	886.7	R1 (C18H35O2) - 283	886.7 / 283.2
PtdEtn 18:0/30:0	C53H106N1O8P1	915.7656	914.8	R1 (C18H35O2) - 283	914.8 / 283.2
PtdEtn 18:0/32:0	C55H110N1O8P1	943.7969	942.8	R1 (C18H35O2) - 283	942.8 / 283.2
PtdEtn 18:0/34:0	C57H114N1O8P1	971.8282	970.8	R1 (C18H35O2) - 283	970.8 / 283.2
PtdEtn 18:0/36:0	C59H118N1O8P1	999.8595	998.9	R1 (C18H35O2) - 283	998.9 / 283.2
PtdEtn 18:0/38:0	C61H122N1O8P1	1027.8908	1026.9	R1 (C18H35O2) - 283	1026.9 / 283.2
PtdEtn 18:0/40:0	C63H126N1O8P1	1055.9221	1054.9	R1 (C18H35O2) - 283	1054.9 / 283.2

Table 4: Molecular formula, accurate mass, and LC-MS/MS parameters for phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing one unsaturation.

Metabolite Name	Molecular Formula	Parent Mass	M-H Mass	Diagnostic Fragment Mass	MS/MS Transition
PtdEtn 16:0/18:1	C39H76N1O8P1	717.5308	716.5	R1 (C16H31O2) - 255	716.5 / 255.2
PtdEtn 16:0/20:1	C41H80N1O8P1	745.5621	744.6	R1 (C16H31O2) - 255	744.6 / 255.2
PtdEtn 16:0/22:1	C43H84N1O8P1	773.5934	772.6	R1 (C16H31O2) - 255	772.6 / 255.2
PtdEtn 16:0/24:1	C45H88N1O8P1	801.6247	800.6	R1 (C16H31O2) - 255	800.6 / 255.2
PtdEtn 16:0/26:1	C47H92N1O8P1	829.6560	828.6	R1 (C16H31O2) - 255	828.6 / 255.2
PtdEtn 16:0/28:1	C49H96N1O8P1	857.6873	856.7	R1 (C16H31O2) - 255	856.7 / 255.2
PtdEtn 16:0/30:1	C51H100N1O8P1	885.7186	884.7	R1 (C16H31O2) - 255	884.7 / 255.2
PtdEtn 16:0/32:1	C53H104N1O8P1	913.7499	912.7	R1 (C16H31O2) - 255	912.7 / 255.2
PtdEtn 16:0/34:1	C55H108N1O8P1	941.7812	940.8	R1 (C16H31O2) - 255	940.8 / 255.2
PtdEtn 16:0/36:1	C57H112N1O8P1	969.8125	968.8	R1 (C16H31O2) - 255	968.8 / 255.2
PtdEtn 16:0/38:1	C59H116N1O8P1	997.8438	996.8	R1 (C16H31O2) - 255	996.8 / 255.2
PtdEtn 16:0/40:1	C61H120N1O8P1	1025.8751	1024.9	R1 (C16H31O2) - 255	1024.9 / 255.2
PtdEtn 18:0/18:1	C41H80N1O8P1	1053.9064	1052.9	R1 (C18H35O2) - 283	744.6 / 283.2
PtdEtn 18:0/20:1	C43H84N1O8P1	773.5934	772.6	R1 (C18H35O2) - 283	772.6 / 283.2
PtdEtn 18:0/22:1	C45H88N1O8P1	801.6247	800.6	R1 (C18H35O2) - 283	800.6 / 283.2
PtdEtn 18:0/24:1	C47H92N1O8P1	829.6560	828.6	R1 (C18H35O2) - 283	828.6 / 283.2
PtdEtn 18:0/26:1	C49H96N1O8P1	857.6873	856.7	R1 (C18H35O2) - 283	856.7 / 283.2
PtdEtn 18:0/28:1	C51H100N1O8P1	885.7186	884.7	R1 (C18H35O2) - 283	884.7 / 283.2
PtdEtn 18:0/30:1	C53H104N1O8P1	913.7499	912.7	R1 (C18H35O2) - 283	912.7 / 283.2
PtdEtn 18:0/32:1	C55H108N1O8P1	941.7812	940.8	R1 (C18H35O2) - 283	940.8 / 283.2
PtdEtn 18:0/34:1	C57H112N1O8P1	969.8125	968.8	R1 (C18H35O2) - 283	968.8 / 283.2
PtdEtn 18:0/36:1	C59H116N1O8P1	997.8438	996.8	R1 (C18H35O2) - 283	996.8 / 283.2
PtdEtn 18:0/38:1	C61H120N1O8P1	1025.8751	1024.9	R1 (C18H35O2) - 283	1024.9 / 283.2
PtdEtn 18:0/40:1	C63H124N1O8P1	1053.9064	1052.9	R1 (C18H35O2) - 283	1052.9 / 283.2

Table 5: Molecular formula, accurate mass, and LC-MS/MS parameters for phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing two unsaturations.

Metabolite Name	Molecular Formula	Parent Mass	M-H Mass	Diagnostic Fragment Mass	MS/MS Transition
PtdEtn 16:0/18:2	C39H74N1O8P1	715.5152	714.5	R1 (C16H31O2) - 255	714.5 / 255.2
PtdEtn 16:0/20:2	C41H78N1O8P1	743.5465	742.5	R1 (C16H31O2) - 255	742.5 / 255.2
PtdEtn 16:0/22:2	C43H82N1O8P1	771.5778	770.6	R1 (C16H31O2) - 255	770.6 / 255.2
PtdEtn 16:0/24:2	C45H86N1O8P1	799.6091	798.6	R1 (C16H31O2) - 255	798.6 / 255.2
PtdEtn 16:0/26:2	C47H90N1O8P1	827.6404	826.6	R1 (C16H31O2) - 255	826.6 / 255.2
PtdEtn 16:0/28:2	C49H94N1O8P1	855.6717	854.7	R1 (C16H31O2) - 255	854.7 / 255.2
PtdEtn 16:0/30:2	C51H98N1O8P1	883.7030	882.7	R1 (C16H31O2) - 255	882.7 / 255.2
PtdEtn 16:0/32:2	C53H102N1O8P1	911.7343	910.7	R1 (C16H31O2) - 255	910.7 / 255.2
PtdEtn 16:0/34:2	C55H106N1O8P1	939.7656	938.8	R1 (C16H31O2) - 255	938.8 / 255.2
PtdEtn 16:0/36:2	C57H110N1O8P1	967.7969	966.8	R1 (C16H31O2) - 255	966.8 / 255.2
PtdEtn 16:0/38:2	C59H114N1O8P1	995.8282	994.8	R1 (C16H31O2) - 255	994.8 / 255.2
PtdEtn 16:0/40:2	C61H118N1O8P1	1023.8595	1022.9	R1 (C16H31O2) - 255	1022.9 / 255.2
PtdEtn 18:0/18:2	C41H78N1O8P1	743.5465	742.5	R1 (C18H35O2) - 283	742.5 / 283.2
PtdEtn 18:0/20:2	C43H82N1O8P1	771.5778	770.6	R1 (C18H35O2) - 283	770.6 / 283.2
PtdEtn 18:0/22:2	C45H86N1O8P1	799.6091	798.6	R1 (C18H35O2) - 283	798.6 / 283.2
PtdEtn 18:0/24:2	C47H90N1O8P1	827.6404	826.6	R1 (C18H35O2) - 283	826.6 / 283.2
PtdEtn 18:0/26:2	C49H94N1O8P1	855.6717	854.7	R1 (C18H35O2) - 283	854.7 / 283.2
PtdEtn 18:0/28:2	C51H98N1O8P1	883.7030	882.7	R1 (C18H35O2) - 283	882.7 / 283.2
PtdEtn 18:0/30:2	C53H102N1O8P1	911.7343	910.7	R1 (C18H35O2) - 283	910.7 / 283.2
PtdEtn 18:0/32:2	C55H106N1O8P1	939.7656	938.8	R1 (C18H35O2) - 283	938.8 / 283.2
PtdEtn 18:0/34:2	C57H110N1O8P1	967.7969	966.8	R1 (C18H35O2) - 283	966.8 / 283.2
PtdEtn 18:0/36:2	C59H114N1O8P1	995.8282	994.8	R1 (C18H35O2) - 283	994.8 / 283.2
PtdEtn 18:0/38:2	C61H118N1O8P1	1023.8595	1022.9	R1 (C18H35O2) - 283	1022.9 / 283.2
PtdEtn 18:0/40:2	C63H122N1O8P1	1051.8908	1050.9	R1 (C18H35O2) - 283	1050.9 / 283.2

Table 6: Molecular formula, accurate mass, and LC-MS/MS parameters for phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing three unsaturations.

Metabolite Name	Molecular Formula	Parent Mass	M-H Mass	Diagnostic Fragment Mass	MS/MS Transition
PtdEtn 16:0/18:3	C39H72N1O8P1	713.4995	712.5	R1 (C16H31O2) - 255	712.5 / 255.2
PtdEtn 16:0/20:3	C41H76N1O8P1	741.5308	740.5	R1 (C16H31O2) - 255	740.5 / 255.2
PtdEtn 16:0/22:3	C43H80N1O8P1	769.5621	768.6	R1 (C16H31O2) - 255	768.6 / 255.2
PtdEtn 16:0/24:3	C45H84N1O8P1	797.5934	796.6	R1 (C16H31O2) - 255	796.6 / 255.2
PtdEtn 16:0/26:3	C47H88N1O8P1	825.6247	824.6	R1 (C16H31O2) - 255	824.6 / 255.2
PtdEtn 16:0/28:3	C49H92N1O8P1	853.6560	852.6	R1 (C16H31O2) - 255	852.6 / 255.2
PtdEtn 16:0/30:3	C51H96N1O8P1	881.6873	880.7	R1 (C16H31O2) - 255	880.7 / 255.2
PtdEtn 16:0/32:3	C53H100N1O8P1	909.7186	908.7	R1 (C16H31O2) - 255	908.7 / 255.2
PtdEtn 16:0/34:3	C55H104N1O8P1	937.7499	936.7	R1 (C16H31O2) - 255	936.7 / 255.2
PtdEtn 16:0/36:3	C57H108N1O8P1	965.7812	964.8	R1 (C16H31O2) - 255	964.8 / 255.2
PtdEtn 16:0/38:3	C59H112N1O8P1	993.8125	992.8	R1 (C16H31O2) - 255	992.8 / 255.2
PtdEtn 16:0/40:3	C61H116N1O8P1	1021.8438	1020.8	R1 (C16H31O2) - 255	1020.8 / 255.2
PtdEtn 18:0/18:3	C41H76N1O8P1	741.5308	740.5	R1 (C18H35O2) - 283	740.5 / 283.2
PtdEtn 18:0/20:3	C43H80N1O8P1	769.5621	768.6	R1 (C18H35O2) - 283	768.6 / 283.2
PtdEtn 18:0/22:3	C45H84N1O8P1	797.5934	796.6	R1 (C18H35O2) - 283	796.6 / 283.2
PtdEtn 18:0/24:3	C47H88N1O8P1	825.6247	824.6	R1 (C18H35O2) - 283	824.6 / 283.2
PtdEtn 18:0/26:3	C49H92N1O8P1	853.6560	852.6	R1 (C18H35O2) - 283	852.6 / 283.2
PtdEtn 18:0/28:3	C51H96N1O8P1	881.6873	880.7	R1 (C18H35O2) - 283	880.7 / 283.2
PtdEtn 18:0/30:3	C53H100N1O8P1	909.7186	908.7	R1 (C18H35O2) - 283	908.7 / 283.2
PtdEtn 18:0/32:3	C55H104N1O8P1	937.7499	936.7	R1 (C18H35O2) - 283	936.7 / 283.2
PtdEtn 18:0/34:3	C57H108N1O8P1	965.7812	964.8	R1 (C18H35O2) - 283	964.8 / 283.2
PtdEtn 18:0/36:3	C59H112N1O8P1	993.8125	992.8	R1 (C18H35O2) - 283	992.8 / 283.2
PtdEtn 18:0/38:3	C61H116N1O8P1	1021.8438	1020.8	R1 (C18H35O2) - 283	1020.8 / 283.2
PtdEtn 18:0/40:3	C63H120N1O8P1	1049.8751	1048.9	R1 (C18H35O2) - 283	1048.9 / 283.2

Table 7: Molecular formula, accurate mass, and LC-MS/MS parameters for phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing four unsaturations.

Metabolite Name	Molecular Formula	Parent Mass	M-H Mass	Diagnostic Fragment Mass	MS/MS Transition
PtdEtn 16:0/20:4	C41H74N1O8P1	739.5152	738.5	R1 (C16H31O2) - 255	738.5 / 255.2
PtdEtn 16:0/22:4	C43H78N1O8P1	767.5465	766.5	R1 (C16H31O2) - 255	766.5 / 255.2
PtdEtn 16:0/24:4	C45H82N1O8P1	795.5778	794.6	R1 (C16H31O2) - 255	794.6 / 255.2
PtdEtn 16:0/26:4	C47H86N1O8P1	823.6091	822.6	R1 (C16H31O2) - 255	822.6 / 255.2
PtdEtn 16:0/28:4	C49H90N1O8P1	851.6404	850.6	R1 (C16H31O2) - 255	850.6 / 255.2
PtdEtn 16:0/30:4	C51H94N1O8P1	879.6717	878.7	R1 (C16H31O2) - 255	878.7 / 255.2
PtdEtn 16:0/32:4	C53H98N1O8P1	907.7030	906.7	R1 (C16H31O2) - 255	906.7 / 255.2
PtdEtn 16:0/34:4	C55H102N1O8P1	935.7343	934.7	R1 (C16H31O2) - 255	934.7 / 255.2
PtdEtn 16:0/36:4	C57H106N1O8P1	963.7656	962.8	R1 (C16H31O2) - 255	962.8 / 255.2
PtdEtn 16:0/38:4	C59H110N1O8P1	991.7969	990.8	R1 (C16H31O2) - 255	990.8 / 255.2
PtdEtn 16:0/40:4	C61H114N1O8P1	1019.8282	1018.8	R1 (C16H31O2) - 255	1018.8 / 255.2
PtdEtn 18:0/20:4	C43H78N1O8P1	767.5465	766.5	R1 (C18H35O2) - 283	766.5 / 283.2
PtdEtn 18:0/22:4	C45H82N1O8P1	795.5778	794.6	R1 (C18H35O2) - 283	794.6 / 283.2
PtdEtn 18:0/24:4	C47H86N1O8P1	823.6091	822.6	R1 (C18H35O2) - 283	822.6 / 283.2
PtdEtn 18:0/26:4	C49H90N1O8P1	851.6404	850.6	R1 (C18H35O2) - 283	850.6 / 283.2
PtdEtn 18:0/28:4	C51H94N1O8P1	879.6717	878.7	R1 (C18H35O2) - 283	878.7 / 283.2
PtdEtn 18:0/30:4	C53H98N1O8P1	907.7030	906.7	R1 (C18H35O2) - 283	906.7 / 283.2
PtdEtn 18:0/32:4	C55H102N1O8P1	935.7343	934.7	R1 (C18H35O2) - 283	934.7 / 283.2
PtdEtn 18:0/34:4	C57H106N1O8P1	963.7656	962.8	R1 (C18H35O2) - 283	962.8 / 283.2
PtdEtn 18:0/36:4	C59H110N1O8P1	991.7969	990.8	R1 (C18H35O2) - 283	990.8 / 283.2
PtdEtn 18:0/38:4	C61H114N1O8P1	1019.8282	1018.8	R1 (C18H35O2) - 283	1018.8 / 283.2
PtdEtn 18:0/40:4	C63H118N1O8P1	1047.8595	1046.9	R1 (C18H35O2) - 283	1046.9 / 283.2

Table 8: Molecular formula, accurate mass, and LC-MS/MS parameters for phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing five unsaturations.

Metabolite Name	Molecular Formula	Parent Mass	M-H Mass	Diagnostic Fragment Mass	MS/MS Transition
PtdEtn 16:0/20:5	C41H72N1O8P1	737.4995	736.5	R1 (C16H31O2) - 255	736.5 / 255.2
PtdEtn 16:0/22:5	C43H76N1O8P1	765.5308	764.5	R1 (C16H31O2) - 255	764.5 / 255.2
PtdEtn 16:0/24:5	C45H80N1O8P1	793.5621	792.6	R1 (C16H31O2) - 255	792.6 / 255.2
PtdEtn 16:0/26:5	C47H84N1O8P1	821.5934	820.6	R1 (C16H31O2) - 255	820.6 / 255.2
PtdEtn 16:0/28:5	C49H88N1O8P1	849.6247	848.6	R1 (C16H31O2) - 255	848.6 / 255.2
PtdEtn 16:0/30:5	C51H92N1O8P1	877.6560	876.6	R1 (C16H31O2) - 255	876.6 / 255.2
PtdEtn 16:0/32:5	C53H96N1O8P1	905.6873	904.7	R1 (C16H31O2) - 255	904.7 / 255.2
PtdEtn 16:0/34:5	C55H100N1O8P1	933.7186	932.7	R1 (C16H31O2) - 255	932.7 / 255.2
PtdEtn 16:0/36:5	C57H104N1O8P1	961.7499	960.7	R1 (C16H31O2) - 255	960.7 / 255.2
PtdEtn 16:0/38:5	C59H108N1O8P1	989.7812	988.8	R1 (C16H31O2) - 255	988.8 / 255.2
PtdEtn 16:0/40:5	C61H112N1O8P1	1017.8125	1016.8	R1 (C16H31O2) - 255	1016.8 / 255.2
PtdEtn 18:0/20:5	C43H76N1O8P1	765.5308	764.5	R1 (C18H35O2) - 283	764.5 / 283.2
PtdEtn 18:0/22:5	C45H80N1O8P1	793.5621	792.6	R1 (C18H35O2) - 283	792.6 / 283.2
PtdEtn 18:0/24:5	C47H84N1O8P1	821.5934	820.6	R1 (C18H35O2) - 283	820.6 / 283.2
PtdEtn 18:0/26:5	C49H88N1O8P1	849.6247	848.6	R1 (C18H35O2) - 283	848.6 / 283.2
PtdEtn 18:0/28:5	C51H92N1O8P1	877.6560	876.6	R1 (C18H35O2) - 283	876.6 / 283.2
PtdEtn 18:0/30:5	C53H96N1O8P1	905.6873	904.7	R1 (C18H35O2) - 283	904.7 / 283.2
PtdEtn 18:0/32:5	C55H100N1O8P1	933.7186	932.7	R1 (C18H35O2) - 283	932.7 / 283.2
PtdEtn 18:0/34:5	C57H104N1O8P1	961.7499	960.7	R1 (C18H35O2) - 283	960.7 / 283.2
PtdEtn 18:0/36:5	C59H108N1O8P1	989.7812	988.8	R1 (C18H35O2) - 283	988.8 / 283.2
PtdEtn 18:0/38:5	C61H112N1O8P1	1017.8125	1016.8	R1 (C18H35O2) - 283	1016.8 / 283.2
PtdEtn 18:0/40:5	C63H116N1O8P1	1045.8438	1044.8	R1 (C18H35O2) - 283	1044.8 / 283.2

Table 9: Molecular formula, accurate mass, and LC-MS/MS parameters for phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing six unsaturations.

Metabolite Name	Molecular Formula	Parent Mass	M-H Mass	Diagnostic Fragment Mass	MS/MS Transition
PtdEtn 16:0/20:6	C41H70N1O8P1	735.4839	734.5	R1 (C16H31O2) - 255	734.5 / 255.2
PtdEtn 16:0/22:6	C43H74N1O8P1	763.5152	762.5	R1 (C16H31O2) - 255	762.5 / 255.2
PtdEtn 16:0/24:6	C45H78N1O8P1	791.5465	790.5	R1 (C16H31O2) - 255	790.5 / 255.2
PtdEtn 16:0/26:6	C47H82N1O8P1	819.5778	818.6	R1 (C16H31O2) - 255	818.6 / 255.2
PtdEtn 16:0/28:6	C49H86N1O8P1	847.6091	846.6	R1 (C16H31O2) - 255	846.6 / 255.2
PtdEtn 16:0/30:6	C51H90N1O8P1	875.6404	874.6	R1 (C16H31O2) - 255	874.6 / 255.2
PtdEtn 16:0/32:6	C53H94N1O8P1	903.6717	902.7	R1 (C16H31O2) - 255	902.7 / 255.2
PtdEtn 16:0/34:6	C55H98N1O8P1	931.7030	930.7	R1 (C16H31O2) - 255	930.7 / 255.2
PtdEtn 16:0/36:6	C57H102N1O8P1	959.7343	958.7	R1 (C16H31O2) - 255	958.7 / 255.2
PtdEtn 16:0/38:6	C59H106N1O8P1	987.7656	986.8	R1 (C16H31O2) - 255	986.8 / 255.2
PtdEtn 16:0/40:6	C61H110N1O8P1	1015.7969	1014.8	R1 (C16H31O2) - 255	1014.8 / 255.2
PtdEtn 18:0/20:6	C43H74N1O8P1	763.5152	762.5	R1 (C18H35O2) - 283	762.5 / 283.2
PtdEtn 18:0/22:6	C45H78N1O8P1	791.5465	790.5	R1 (C18H35O2) - 283	790.5 / 283.2
PtdEtn 18:0/24:6	C47H82N1O8P1	819.5778	818.6	R1 (C18H35O2) - 283	818.6 / 283.2
PtdEtn 18:0/26:6	C49H86N1O8P1	847.6091	846.6	R1 (C18H35O2) - 283	846.6 / 283.2
PtdEtn 18:0/28:6	C51H90N1O8P1	875.6404	874.6	R1 (C18H35O2) - 283	874.6 / 283.2
PtdEtn 18:0/30:6	C53H94N1O8P1	903.6717	902.7	R1 (C18H35O2) - 283	902.7 / 283.2
PtdEtn 18:0/32:6	C55H98N1O8P1	931.7030	930.7	R1 (C18H35O2) - 283	930.7 / 283.2
PtdEtn 18:0/34:6	C57H102N1O8P1	959.7343	958.7	R1 (C18H35O2) - 283	958.7 / 283.2
PtdEtn 18:0/36:6	C59H106N1O8P1	987.7656	986.8	R1 (C18H35O2) - 283	986.8 / 283.2
PtdEtn 18:0/38:6	C61H110N1O8P1	1015.7969	1014.8	R1 (C18H35O2) - 283	1014.8 / 283.2
PtdEtn 18:0/40:6	C63H114N1O8P1	1043.8282	1042.8	R1 (C18H35O2) - 283	1042.8 / 283.2

Table 10: Molecular formula, accurate mass, and LC-MS/MS parameters for ethanolamine plasmalogens (PlsEtn) metabolites with selected sn-2 position fatty acids.

Metabolite Name	Molecular Formula	Parent Mass	M-H Mass	Diagnostic Fragment Mass	MS/MS Transition
PlsEtn 16:0/18:1	C39H76N1O7P1	701.5359	700.5	R2 (C18H33O2) - 281	700.5 / 281.2
PlsEtn 16:0/18:2	C39H74N1O7P1	699.5203	698.5	R2 (C18H31O2) - 279	698.5 / 279.2
PlsEtn 16:0/18:3	C39H72N1O7P1	697.5046	696.5	R2 (C18H29O2) - 277	696.5 / 277.2
PlsEtn 16:0/20:4	C41H74N1O7P1	723.5203	722.5	R2 (C20H31O2) - 303	722.5 / 303.2
PlsEtn 16:0/22:6	C43H74N1O7P1	747.5203	746.5	R2 (C22H31O2) - 327	746.5 / 327.2
PlsEtn 18:0/18:1	C41H80N1O7P1	729.5672	728.5	R2 (C18H33O2) - 281	728.5 / 281.2
PlsEtn 18:0/18:2	C41H78N1O7P1	727.5516	726.5	R2 (C18H31O2) - 279	726.5 / 279.2
PlsEtn 18:0/18:3	C41H76N1O7P1	725.5359	724.5	R2 (C18H29O2) - 277	724.5 / 277.2
PlsEtn 18:0/20:4	C43H78N1O7P1	751.5516	750.5	R2 (C20H31O2) - 303	750.5 / 303.2
PlsEtn 18:0/22:6	C45H78N1O7P1	775.5516	774.5	R2 (C22H31O2) - 327	774.5 / 327.2
PlsEtn 18:1/18:1	C41H78N1O7P1	727.5516	726.5	R2 (C18H33O2) - 281	726.5 / 281.2
PlsEtn 18:1/18:2	C41H76N1O7P1	725.5359	724.5	R2 (C18H31O2) - 279	724.5 / 279.2
PlsEtn 18:1/18:3	C41H74N1O7P1	723.5203	722.5	R2 (C18H29O2) - 277	722.5 / 277.2
PlsEtn 18:1/20:4	C43H76N1O7P1	749.5359	748.5	R2 (C20H31O2) - 303	748.5 / 303.2
PlsEtn 18:1/22:6	C45H76N1O7P1	773.5359	772.5	R2 (C22H31O2) - 327	772.5 / 327.2

Table 11: Plasma levels of phosphatidylethanolamine (PtdEtn) metabolites with saturated fatty acids at the sn-2 position in non-autistic children, autistic children not taking carnitine supplements, and autistic children taking carnitine supplements (All values are expressed as the ratio to PtdEtn 16:0/18:0).

Metabolite Name	MS/MS Transition	Autism				Autism vs. Control					
		Control		- Carnitine		+ Carnitine		- Carnitine		+ Carnitine	
		Avg	SEM	Avg	SEM	Avg	SEM	Ratio	p	Ratio	p
PtdEtn 16:0/18:0	718.5 / 255.2	1.000	0.000	1.000	0.000	1.000	0.000	1.00	1.0E+00	1.00	1.0E+00
PtdEtn 16:0/20:0	746.6 / 255.2	0.694	0.019	0.703	0.013	0.734	0.036	1.01	6.9E-01	1.06	2.8E-01
PtdEtn 16:0/22:0	774.6 / 255.2	0.030	0.001	0.036	0.002	0.032	0.002	1.19	6.2E-03	1.05	5.3E-01
PtdEtn 16:0/24:0	802.6 / 255.2	0.033	0.001	0.041	0.001	0.034	0.001	1.27	9.8E-06	1.04	5.3E-01
PtdEtn 16:0/26:0	830.7 / 255.2	0.044	0.003	0.053	0.003	0.050	0.005	1.21	5.2E-02	1.13	3.6E-01
PtdEtn 16:0/28:0	858.7 / 255.2	0.054	0.003	0.092	0.008	0.056	0.005	1.70	3.8E-05	1.03	7.9E-01
PtdEtn 16:0/30:0	886.7 / 255.2	0.009	0.000	0.009	0.000	0.011	0.001	1.08	2.8E-01	1.27	1.7E-02
PtdEtn 16:0/32:0	914.8 / 255.2	0.004	0.000	0.005	0.000	0.006	0.000	1.20	8.2E-02	1.27	4.7E-02
PtdEtn 16:0/34:0	942.8 / 255.2	0.004	0.000	0.005	0.000	0.005	0.001	1.24	9.7E-03	1.42	8.3E-03
PtdEtn 16:0/36:0	970.8 / 255.2	0.004	0.000	0.004	0.000	0.005	0.000	1.23	2.9E-02	1.33	1.3E-02
PtdEtn 16:0/38:0	998.9 / 255.2	0.004	0.000	0.005	0.000	0.005	0.000	1.28	2.3E-02	1.31	1.2E-02
PtdEtn 16:0/40:0	1026.9 / 255.2	0.005	0.000	0.005	0.000	0.006	0.001	1.11	1.7E-01	1.28	3.0E-02
PtdEtn 18:0/18:0	746.6 / 283.2	0.525	0.012	0.581	0.023	0.588	0.034	1.11	4.0E-02	1.12	2.9E-02
PtdEtn 18:0/20:0	774.6 / 283.2	0.427	0.017	0.578	0.033	0.491	0.041	1.35	2.3E-04	1.15	9.0E-02
PtdEtn 18:0/22:0	802.6 / 283.2	0.044	0.002	0.076	0.006	0.048	0.003	1.73	5.2E-06	1.09	3.2E-01
PtdEtn 18:0/24:0	830.7 / 283.2	0.026	0.001	0.038	0.002	0.028	0.002	1.48	1.0E-05	1.09	3.2E-01
PtdEtn 18:0/26:0	858.7 / 283.2	0.034	0.004	0.061	0.006	0.039	0.005	1.80	4.5E-04	1.13	5.4E-01
PtdEtn 18:0/28:0	886.7 / 283.2	0.031	0.002	0.056	0.005	0.036	0.004	1.83	2.4E-05	1.16	1.8E-01
PtdEtn 18:0/30:0	914.8 / 283.2	0.003	0.000	0.004	0.000	0.005	0.001	1.34	1.3E-02	1.49	5.2E-03
PtdEtn 18:0/32:0	942.8 / 283.2	0.002	0.000	0.002	0.000	0.002	0.000	1.10	4.9E-01	1.14	4.1E-01
PtdEtn 18:0/34:0	970.8 / 283.2	0.002	0.000	0.002	0.000	0.003	0.000	1.35	6.1E-02	1.72	3.6E-03
PtdEtn 18:0/36:0	998.9 / 283.2	0.002	0.000	0.002	0.000	0.003	0.000	1.22	1.3E-01	1.33	8.1E-02
PtdEtn 18:0/38:0	1026.9 / 283.2	0.002	0.000	0.003	0.000	0.003	0.000	1.63	2.0E-03	1.25	1.1E-01
PtdEtn 18:0/40:0	1054.9 / 283.2	0.003	0.000	0.003	0.000	0.003	0.001	1.32	6.3E-03	1.26	1.3E-01
										0.95	7.3E-01

Table 12: Plasma levels of phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing one unsaturation in non-autistic children, autistic children not taking carnitine supplements, and autistic children taking carnitine supplements (All values are expressed as the ratio to PtdEtn 16:0/18:0).

Metabolite Name	MS/MS Transition	Autism						Autism vs. Control					
		Control		- Carnitine		+ Carnitine		- Carnitine		+ Carnitine		+ Carn vs. - Carn	
		Avg	SEM	Avg	SEM	Avg	SEM	Ratio	p	Ratio	p	Ratio	p
PtdEtn 16:0/18:1	716.5 / 255.2	0.633	0.026	0.497	0.022	0.860	0.093	0.79	1.9E-04	1.36	2.6E-03	1.73	2.0E-06
PtdEtn 16:0/20:1	744.6 / 255.2	6.423	0.178	6.316	0.136	6.882	0.322	0.98	6.3E-01	1.07	1.9E-01	1.09	6.3E-02
PtdEtn 16:0/22:1	772.6 / 255.2	0.080	0.002	0.087	0.002	0.083	0.003	1.08	4.3E-02	1.04	4.4E-01	0.96	4.1E-01
PtdEtn 16:0/24:1	800.6 / 255.2	0.042	0.001	0.045	0.001	0.046	0.002	1.05	1.3E-01	1.09	6.9E-02	1.03	5.1E-01
PtdEtn 16:0/26:1	828.6 / 255.2	0.024	0.001	0.024	0.001	0.026	0.001	1.01	8.2E-01	1.08	1.9E-01	1.07	2.1E-01
PtdEtn 16:0/28:1	856.7 / 255.2	0.015	0.001	0.017	0.001	0.021	0.003	1.09	3.0E-01	1.41	7.8E-03	1.30	4.0E-02
PtdEtn 16:0/30:1	884.7 / 255.2	0.004	0.000	0.004	0.000	0.005	0.000	0.93	4.4E-01	1.12	3.8E-01	1.21	9.4E-02
PtdEtn 16:0/32:1	912.7 / 255.2	0.003	0.000	0.004	0.000	0.004	0.000	1.15	9.0E-02	1.14	2.7E-01	0.99	9.6E-01
PtdEtn 16:0/34:1	940.8 / 255.2	0.005	0.000	0.005	0.000	0.006	0.000	0.92	1.4E-01	1.09	2.1E-01	1.19	2.4E-02
PtdEtn 16:0/36:1	968.8 / 255.2	0.005	0.000	0.005	0.000	0.007	0.001	0.91	1.7E-01	1.26	9.2E-03	1.38	4.1E-04
PtdEtn 16:0/38:1	996.8 / 255.2	0.003	0.000	0.003	0.000	0.004	0.000	0.94	5.5E-01	1.17	2.8E-01	1.25	1.1E-01
PtdEtn 16:0/40:1	1024.9 / 255.2	0.005	0.000	0.006	0.000	0.007	0.001	1.09	2.5E-01	1.29	4.5E-02	1.19	1.5E-01
PtdEtn 18:0/18:1	744.6 / 283.2	0.359	0.031	0.284	0.024	0.645	0.145	0.79	6.0E-02	1.80	8.1E-03	2.28	4.2E-04
PtdEtn 18:0/20:1	772.6 / 283.2	2.026	0.070	2.118	0.047	2.445	0.212	1.05	2.7E-01	1.21	1.9E-02	1.15	3.2E-02
PtdEtn 18:0/22:1	800.6 / 283.2	0.044	0.002	0.056	0.003	0.051	0.003	1.29	1.9E-04	1.17	3.5E-02	0.90	2.5E-01
PtdEtn 18:0/24:1	828.6 / 283.2	0.023	0.001	0.028	0.001	0.026	0.002	1.24	4.8E-04	1.16	4.1E-02	0.93	4.1E-01
PtdEtn 18:0/26:1	856.7 / 283.2	0.015	0.001	0.020	0.001	0.017	0.001	1.34	1.9E-04	1.14	6.4E-02	0.85	1.3E-01
PtdEtn 18:0/28:1	884.7 / 283.2	0.008	0.000	0.011	0.001	0.010	0.001	1.45	1.6E-05	1.27	5.7E-02	0.87	3.1E-01
PtdEtn 18:0/30:1	912.7 / 283.2	0.002	0.000	0.003	0.000	0.002	0.000	1.32	2.8E-02	1.26	1.8E-01	0.95	7.6E-01
PtdEtn 18:0/32:1	940.8 / 283.2	0.003	0.000	0.003	0.000	0.003	0.000	1.02	8.6E-01	1.26	8.6E-02	1.24	8.6E-02
PtdEtn 18:0/34:1	968.8 / 283.2	0.002	0.000	0.002	0.000	0.002	0.000	1.02	8.7E-01	1.06	7.2E-01	1.04	7.7E-01
PtdEtn 18:0/36:1	996.8 / 283.2	0.002	0.000	0.003	0.000	0.003	0.000	1.04	7.0E-01	1.11	4.9E-01	1.07	6.4E-01
PtdEtn 18:0/38:1	1024.9 / 283.2	0.002	0.000	0.002	0.000	0.003	0.000	1.20	2.5E-01	1.31	1.9E-01	1.10	6.3E-01
PtdEtn 18:0/40:1	1052.9 / 283.2	0.002	0.000	0.003	0.000	0.003	0.000	1.22	8.3E-02	1.40	2.1E-02	1.15	3.5E-01

Table 13: Plasma levels of phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing two unsaturations in non-autistic children, autistic children not taking carnitine supplements, and autistic children taking carnitine supplements (All values are expressed as the ratio to PtdEtn 16:0/18:0).

Metabolite Name	MS/MS Transition	Autism						Autism vs. Control					
		Control		- Carnitine		+ Carnitine		- Carnitine		+ Carnitine		+ Carn vs. - Carn	
		Avg	SEM	Avg	SEM	Avg	SEM	Ratio	p	Ratio	p	Ratio	p
PtdEtn 16:0/18:2	714.5 / 255.2	0.612	0.041	0.523	0.042	0.913	0.145	0.85	1.4E-01	1.49	9.9E-03	1.75	1.1E-03
PtdEtn 16:0/20:2	742.5 / 255.2	10.816	0.270	10.963	0.487	10.679	0.654	1.01	8.0E-01	0.99	8.2E-01	0.97	7.5E-01
PtdEtn 16:0/22:2	770.6 / 255.2	0.355	0.013	0.324	0.015	0.398	0.028	0.91	1.2E-01	1.12	1.1E-01	1.23	1.7E-02
PtdEtn 16:0/24:2	798.6 / 255.2	0.022	0.001	0.022	0.001	0.026	0.002	1.00	9.7E-01	1.22	9.1E-03	1.22	9.1E-03
PtdEtn 16:0/26:2	826.6 / 255.2	0.041	0.002	0.040	0.002	0.041	0.002	0.98	7.3E-01	0.98	8.5E-01	1.01	9.5E-01
PtdEtn 16:0/28:2	854.7 / 255.2	0.015	0.001	0.015	0.001	0.019	0.002	1.02	8.0E-01	1.25	2.6E-02	1.23	6.3E-02
PtdEtn 16:0/30:2	882.7 / 255.2	0.003	0.000	0.003	0.000	0.004	0.000	0.93	4.8E-01	1.37	3.1E-03	1.47	2.8E-03
PtdEtn 16:0/32:2	910.7 / 255.2	0.003	0.000	0.003	0.000	0.004	0.001	1.07	5.5E-01	1.32	8.9E-02	1.24	1.6E-01
PtdEtn 16:0/34:2	938.8 / 255.2	0.005	0.000	0.004	0.000	0.006	0.000	0.97	6.0E-01	1.24	1.6E-02	1.28	9.8E-03
PtdEtn 16:0/36:2	966.8 / 255.2	0.005	0.000	0.005	0.000	0.006	0.000	1.10	2.1E-01	1.23	5.7E-02	1.12	2.2E-01
PtdEtn 16:0/38:2	994.8 / 255.2	0.003	0.000	0.003	0.000	0.004	0.001	0.89	2.8E-01	1.27	9.2E-02	1.42	2.7E-02
PtdEtn 16:0/40:2	1022.9 / 255.2	0.004	0.000	0.006	0.000	0.005	0.001	1.24	8.1E-03	1.19	7.0E-02	0.96	7.3E-01
PtdEtn 18:0/18:2	742.5 / 283.2	1.216	0.092	1.092	0.098	1.977	0.430	0.90	3.6E-01	1.62	1.7E-02	1.81	5.4E-03
PtdEtn 18:0/20:2	770.6 / 283.2	6.861	0.210	7.107	0.257	7.237	0.609	1.04	4.7E-01	1.05	4.6E-01	1.02	8.2E-01
PtdEtn 18:0/22:2	798.6 / 283.2	0.203	0.008	0.193	0.009	0.267	0.028	0.95	3.8E-01	1.31	4.8E-03	1.39	1.7E-03
PtdEtn 18:0/24:2	826.6 / 283.2	0.012	0.001	0.013	0.001	0.016	0.002	1.04	6.3E-01	1.30	1.7E-02	1.26	1.9E-02
PtdEtn 18:0/26:2	854.7 / 283.2	0.021	0.001	0.023	0.001	0.023	0.002	1.08	2.4E-01	1.10	3.4E-01	1.01	8.9E-01
PtdEtn 18:0/28:2	882.7 / 283.2	0.006	0.000	0.008	0.000	0.008	0.001	1.21	9.5E-03	1.27	3.7E-02	1.05	6.6E-01
PtdEtn 18:0/30:2	910.7 / 283.2	0.002	0.000	0.003	0.000	0.003	0.000	1.42	3.2E-03	1.50	2.1E-02	1.05	7.4E-01
PtdEtn 18:0/32:2	938.8 / 283.2	0.002	0.000	0.002	0.000	0.002	0.000	1.24	1.5E-01	1.07	7.4E-01	0.87	4.2E-01
PtdEtn 18:0/34:2	966.8 / 283.2	0.002	0.000	0.002	0.000	0.003	0.000	1.13	3.0E-01	1.45	2.6E-02	1.28	1.3E-01
PtdEtn 18:0/36:2	994.8 / 283.2	0.002	0.000	0.002	0.000	0.002	0.000	1.17	2.3E-01	1.19	3.4E-01	1.02	9.1E-01
PtdEtn 18:0/38:2	1022.9 / 283.2	0.001	0.000	0.002	0.000	0.003	0.000	1.17	2.1E-01	1.72	2.3E-03	1.47	2.4E-02
PtdEtn 18:0/40:2	1050.9 / 283.2	0.001	0.000	0.002	0.000	0.002	0.001	1.30	3.6E-01	1.42	3.7E-01	1.09	8.1E-01

Table 14: Plasma levels of phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing three unsaturations in non-autistic children, autistic children not taking carnitine supplements, and autistic children taking carnitine supplements (All values are expressed as the ratio to PtdEtn 16:0/18:0).

Metabolite Name	MS/MS Transition	Autism						Autism vs. Control					
		Control		- Carnitine		+ Carnitine		- Carnitine		+ Carnitine		+ Carn vs. - Carn	
		Avg	SEM	Avg	SEM	Avg	SEM	Ratio	p	Ratio	p	Ratio	p
PtdEtn 16:0/18:3	712.5 / 255.2	0.339	0.015	0.290	0.015	0.348	0.024	0.86	2.6E-02	1.03	7.4E-01	1.20	5.1E-02
PtdEtn 16:0/20:3	740.5 / 255.2	0.309	0.015	0.251	0.010	0.339	0.039	0.81	2.1E-03	1.10	3.7E-01	1.35	3.5E-03
PtdEtn 16:0/22:3	768.6 / 255.2	2.327	0.099	1.986	0.101	2.506	0.166	0.85	1.9E-02	1.08	3.5E-01	1.26	1.1E-02
PtdEtn 16:0/24:3	796.6 / 255.2	0.050	0.002	0.043	0.002	0.064	0.003	0.85	1.6E-02	1.28	1.4E-03	1.51	5.0E-06
PtdEtn 16:0/26:3	824.6 / 255.2	0.023	0.001	0.030	0.004	0.031	0.005	1.33	1.1E-01	1.37	2.7E-02	1.03	9.1E-01
PtdEtn 16:0/28:3	852.6 / 255.2	0.009	0.000	0.009	0.001	0.013	0.002	1.05	6.3E-01	1.39	9.5E-03	1.33	4.4E-02
PtdEtn 16:0/30:3	880.7 / 255.2	0.009	0.000	0.010	0.001	0.013	0.002	1.14	3.5E-01	1.41	1.4E-02	1.24	3.0E-01
PtdEtn 16:0/32:3	908.7 / 255.2	0.004	0.000	0.004	0.000	0.005	0.001	1.18	5.3E-02	1.41	5.5E-03	1.19	1.5E-01
PtdEtn 16:0/34:3	936.7 / 255.2	0.003	0.000	0.004	0.000	0.005	0.000	1.14	2.0E-01	1.38	7.5E-03	1.21	1.4E-01
PtdEtn 16:0/36:3	964.8 / 255.2	0.006	0.000	0.006	0.000	0.006	0.000	1.13	7.9E-02	1.16	1.4E-01	1.03	7.3E-01
PtdEtn 16:0/38:3	992.8 / 255.2	0.005	0.000	0.005	0.000	0.006	0.001	0.89	1.6E-01	1.15	2.1E-01	1.29	1.1E-02
PtdEtn 16:0/40:3	1020.8 / 255.2	0.005	0.000	0.005	0.000	0.005	0.001	1.21	4.0E-02	1.19	2.3E-01	0.99	9.4E-01
PtdEtn 18:0/18:3	740.5 / 283.2	0.185	0.008	0.169	0.009	0.218	0.019	0.91	1.6E-01	1.17	7.0E-02	1.29	1.2E-02
PtdEtn 18:0/20:3	768.6 / 283.2	0.348	0.020	0.298	0.018	0.435	0.065	0.86	6.4E-02	1.25	9.6E-02	1.46	7.7E-03
PtdEtn 18:0/22:3	796.6 / 283.2	1.574	0.071	1.461	0.074	1.854	0.129	0.93	2.8E-01	1.18	5.1E-02	1.27	1.0E-02
PtdEtn 18:0/24:3	824.6 / 283.2	0.029	0.002	0.026	0.001	0.042	0.003	0.87	7.2E-02	1.44	2.3E-04	1.65	6.9E-07
PtdEtn 18:0/26:3	852.6 / 283.2	0.012	0.001	0.014	0.003	0.013	0.002	1.20	4.9E-01	1.10	5.7E-01	0.92	8.3E-01
PtdEtn 18:0/28:3	880.7 / 283.2	0.006	0.000	0.006	0.000	0.006	0.001	1.01	9.6E-01	1.10	3.9E-01	1.10	4.7E-01
PtdEtn 18:0/30:3	908.7 / 283.2	0.004	0.000	0.005	0.000	0.006	0.001	1.15	2.2E-01	1.43	1.4E-02	1.24	1.8E-01
PtdEtn 18:0/32:3	936.7 / 283.2	0.002	0.000	0.002	0.000	0.001	0.000	1.12	3.3E-01	0.77	1.3E-01	0.69	3.8E-02
PtdEtn 18:0/34:3	964.8 / 283.2	0.002	0.000	0.002	0.000	0.003	0.001	1.13	5.5E-01	1.61	1.1E-01	1.43	1.7E-01
PtdEtn 18:0/36:3	992.8 / 283.2	0.003	0.000	0.003	0.000	0.004	0.001	0.95	7.0E-01	1.32	2.1E-01	1.38	9.4E-02
PtdEtn 18:0/38:3	1020.8 / 283.2	0.002	0.000	0.002	0.000	0.002	0.000	1.10	5.2E-01	1.30	1.4E-01	1.18	3.1E-01
PtdEtn 18:0/40:3	1048.9 / 283.2	0.002	0.000	0.002	0.000	0.004	0.001	1.08	5.9E-01	1.80	2.3E-02	1.67	3.0E-02

Table 15: Plasma levels of phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing four unsaturations in non-autistic children, autistic children not taking carnitine supplements, and autistic children taking carnitine supplements (All values are expressed as the ratio to PtdEtn 16:0/18:0).

Metabolite Name	MS/MS Transition	Autism				Autism vs. Control							
		Control		- Carnitine		+ Carnitine		- Carnitine		+ Carnitine		+ Carn vs. - Carn	
		Avg	SEM	Avg	SEM	Avg	SEM	Ratio	p	Ratio	p	Ratio	p
PtdEtn 16:0/20:4	738.5 / 255.2	0.541	0.036	0.479	0.032	0.900	0.099	0.88	2.0E-01	1.66	1.2E-04	1.88	4.1E-06
PtdEtn 16:0/22:4	766.5 / 255.2	4.431	0.197	4.206	0.187	4.811	0.268	0.95	4.1E-01	1.09	2.9E-01	1.14	9.2E-02
PtdEtn 16:0/24:4	794.6 / 255.2	0.309	0.013	0.285	0.016	0.389	0.024	0.92	2.5E-01	1.26	4.0E-03	1.36	1.5E-03
PtdEtn 16:0/26:4	822.6 / 255.2	0.012	0.001	0.013	0.000	0.014	0.001	1.09	1.4E-01	1.21	4.1E-02	1.11	1.5E-01
PtdEtn 16:0/28:4	850.6 / 255.2	0.015	0.001	0.014	0.001	0.018	0.002	0.94	3.8E-01	1.19	6.6E-02	1.26	1.0E-02
PtdEtn 16:0/30:4	878.7 / 255.2	0.017	0.001	0.017	0.001	0.019	0.001	1.00	9.7E-01	1.13	1.0E-01	1.13	2.2E-01
PtdEtn 16:0/32:4	906.7 / 255.2	0.010	0.000	0.011	0.000	0.012	0.001	1.10	6.7E-02	1.28	1.3E-03	1.16	6.1E-02
PtdEtn 16:0/34:4	934.7 / 255.2	0.003	0.000	0.003	0.000	0.004	0.000	1.19	1.4E-01	1.52	2.9E-03	1.28	6.4E-02
PtdEtn 16:0/36:4	962.8 / 255.2	0.005	0.000	0.005	0.000	0.005	0.000	1.07	3.4E-01	1.03	7.8E-01	0.96	6.8E-01
PtdEtn 16:0/38:4	990.8 / 255.2	0.006	0.000	0.006	0.000	0.007	0.001	1.06	3.5E-01	1.20	1.5E-02	1.13	1.8E-01
PtdEtn 16:0/40:4	1018.8 / 255.2	0.002	0.000	0.003	0.000	0.003	0.000	1.07	5.1E-01	1.40	1.7E-02	1.31	6.0E-02
PtdEtn 18:0/20:4	766.5 / 283.2	1.420	0.095	1.419	0.106	2.433	0.273	1.00	1.0E+00	1.71	6.6E-05	1.71	1.2E-04
PtdEtn 18:0/22:4	794.6 / 283.2	3.068	0.137	3.231	0.185	3.686	0.261	1.05	4.9E-01	1.20	2.8E-02	1.14	1.9E-01
PtdEtn 18:0/24:4	822.6 / 283.2	0.141	0.006	0.134	0.006	0.203	0.014	0.95	5.1E-01	1.44	2.9E-05	1.51	7.4E-05
PtdEtn 18:0/26:4	850.6 / 283.2	0.007	0.000	0.008	0.000	0.010	0.001	1.06	4.1E-01	1.36	8.4E-04	1.29	1.3E-03
PtdEtn 18:0/28:4	878.7 / 283.2	0.012	0.001	0.012	0.001	0.017	0.001	1.01	9.2E-01	1.40	4.0E-04	1.38	3.7E-03
PtdEtn 18:0/30:4	906.7 / 283.2	0.008	0.000	0.009	0.000	0.010	0.001	1.15	5.3E-02	1.23	1.6E-02	1.07	4.9E-01
PtdEtn 18:0/32:4	934.7 / 283.2	0.002	0.000	0.002	0.000	0.003	0.000	0.99	9.6E-01	1.30	1.1E-01	1.31	6.9E-02
PtdEtn 18:0/34:4	962.8 / 283.2	0.003	0.000	0.003	0.000	0.003	0.000	1.04	7.4E-01	1.22	1.9E-01	1.17	2.4E-01
PtdEtn 18:0/36:4	990.8 / 283.2	0.002	0.000	0.002	0.000	0.003	0.000	0.96	8.6E-01	1.53	5.8E-02	1.59	6.0E-02
PtdEtn 18:0/38:4	1018.8 / 283.2	0.002	0.000	0.002	0.000	0.003	0.000	1.08	4.5E-01	1.32	4.2E-02	1.22	1.8E-01
PtdEtn 18:0/40:4	1046.9 / 283.2	0.002	0.000	0.002	0.000	0.003	0.001	1.25	1.1E-01	1.43	6.6E-02	1.14	5.0E-01

Table 16: Plasma levels of phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing five unsaturations in non-autistic children, autistic children not taking carnitine supplements, and autistic children taking carnitine supplements (All values are expressed as the ratio to PtdEtn 16:0/18:0).

Metabolite Name	MS/MS Transition	Autism						Autism vs. Control					
		Control		- Carnitine		+ Carnitine		- Carnitine		+ Carnitine		+ Carn vs. - Carn	
		Avg	SEM	Avg	SEM	Avg	SEM	Ratio	p	Ratio	p	Ratio	p
PtdEtn 16:0/20:5	736.5 / 255.2	0.118	0.005	0.131	0.010	0.137	0.010	1.11	3.0E-01	1.15	9.8E-02	1.04	7.6E-01
PtdEtn 16:0/22:5	764.5 / 255.2	0.450	0.030	0.616	0.118	0.505	0.049	1.37	1.9E-01	1.12	3.3E-01	0.82	5.8E-01
PtdEtn 16:0/24:5	792.6 / 255.2	0.774	0.031	0.907	0.048	0.825	0.079	1.17	2.6E-02	1.07	4.6E-01	0.91	3.8E-01
PtdEtn 16:0/26:5	820.6 / 255.2	0.028	0.001	0.030	0.001	0.032	0.003	1.08	9.8E-02	1.14	1.3E-01	1.05	5.1E-01
PtdEtn 16:0/28:5	848.6 / 255.2	0.015	0.001	0.016	0.001	0.018	0.001	1.04	6.1E-01	1.20	9.0E-02	1.15	1.0E-01
PtdEtn 16:0/30:5	876.6 / 255.2	0.009	0.000	0.009	0.000	0.012	0.001	1.06	4.1E-01	1.35	1.0E-02	1.27	1.3E-02
PtdEtn 16:0/32:5	904.7 / 255.2	0.014	0.001	0.015	0.001	0.018	0.001	1.04	6.2E-01	1.31	1.4E-02	1.26	2.3E-02
PtdEtn 16:0/34:5	932.7 / 255.2	0.010	0.001	0.009	0.000	0.011	0.001	0.96	5.6E-01	1.18	1.1E-01	1.23	1.7E-02
PtdEtn 16:0/36:5	960.7 / 255.2	0.002	0.000	0.003	0.000	0.002	0.000	1.07	5.7E-01	1.06	7.7E-01	0.98	9.2E-01
PtdEtn 16:0/38:5	988.8 / 255.2	0.005	0.000	0.005	0.000	0.005	0.000	1.07	4.3E-01	1.02	8.4E-01	0.96	6.9E-01
PtdEtn 16:0/40:5	1016.8 / 255.2	0.003	0.000	0.003	0.000	0.004	0.000	1.10	2.9E-01	1.19	1.7E-01	1.08	4.2E-01
PtdEtn 18:0/20:5	764.5 / 283.2	0.098	0.007	0.136	0.024	0.140	0.018	1.39	1.4E-01	1.43	1.1E-02	1.03	9.3E-01
PtdEtn 18:0/22:5	792.6 / 283.2	0.356	0.023	0.555	0.101	0.437	0.043	1.56	7.1E-02	1.23	7.9E-02	0.79	4.9E-01
PtdEtn 18:0/24:5	820.6 / 283.2	0.304	0.012	0.390	0.025	0.384	0.032	1.28	3.5E-03	1.26	5.8E-03	0.98	8.9E-01
PtdEtn 18:0/26:5	848.6 / 283.2	0.018	0.001	0.019	0.001	0.022	0.002	1.07	1.9E-01	1.21	9.4E-03	1.13	1.2E-01
PtdEtn 18:0/28:5	876.6 / 283.2	0.008	0.001	0.008	0.001	0.009	0.001	0.99	9.3E-01	1.12	5.0E-01	1.13	4.8E-01
PtdEtn 18:0/30:5	904.7 / 283.2	0.005	0.000	0.005	0.000	0.006	0.001	1.10	3.1E-01	1.41	3.4E-02	1.28	6.5E-02
PtdEtn 18:0/32:5	932.7 / 283.2	0.008	0.001	0.008	0.000	0.010	0.001	1.01	9.2E-01	1.35	3.1E-02	1.34	1.6E-02
PtdEtn 18:0/34:5	960.7 / 283.2	0.004	0.000	0.004	0.000	0.005	0.001	1.03	7.0E-01	1.34	2.4E-02	1.29	2.1E-02
PtdEtn 18:0/36:5	988.8 / 283.2	0.001	0.000	0.002	0.000	0.002	0.000	1.17	2.3E-01	1.28	1.7E-01	1.10	6.2E-01
PtdEtn 18:0/38:5	1016.8 / 283.2	0.002	0.000	0.003	0.000	0.003	0.000	1.26	6.2E-02	1.24	1.1E-01	0.99	9.3E-01
PtdEtn 18:0/40:5	1044.8 / 283.2	0.002	0.000	0.002	0.000	0.002	0.000	1.12	2.8E-01	1.40	1.7E-02	1.25	5.9E-02

Table 17: Plasma levels of phosphatidylethanolamine (PtdEtn) metabolites with sn-2 position fatty acids containing six unsaturations in non-autistic children, autistic children not taking carnitine supplements, and autistic children taking carnitine supplements (All values are expressed as the ratio to PtdEtn 16:0/18:0).

Metabolite Name	MS/MS Transition	Autism						Autism vs. Control					
		Control		- Carnitine		+ Carnitine		- Carnitine		+ Carnitine		+ Carn vs. - Carn	
		Avg	SEM	Avg	SEM	Avg	SEM	Ratio	p	Ratio	p	Ratio	p
PtdEtn 16:0/20:6	734.5 / 255.2	0.151	0.009	0.276	0.026	0.132	0.010	1.83	4.5E-05	0.87	2.1E-01	0.48	1.9E-03
PtdEtn 16:0/22:6	762.5 / 255.2	0.351	0.033	0.532	0.052	0.363	0.034	1.52	5.7E-03	1.04	8.3E-01	0.68	6.6E-02
PtdEtn 16:0/24:6	790.5 / 255.2	0.836	0.050	1.678	0.169	0.707	0.078	2.01	2.4E-05	0.85	1.8E-01	0.42	1.5E-03
PtdEtn 16:0/26:6	818.6 / 255.2	0.029	0.001	0.030	0.002	0.031	0.003	1.03	7.3E-01	1.09	4.1E-01	1.06	6.0E-01
PtdEtn 16:0/28:6	846.6 / 255.2	0.009	0.000	0.010	0.000	0.011	0.001	1.12	1.1E-01	1.22	2.8E-02	1.09	3.1E-01
PtdEtn 16:0/30:6	874.6 / 255.2	0.010	0.001	0.012	0.001	0.010	0.001	1.21	5.8E-02	1.05	7.7E-01	0.86	2.0E-01
PtdEtn 16:0/32:6	902.7 / 255.2	0.014	0.002	0.016	0.001	0.017	0.001	1.09	4.3E-01	1.21	2.7E-01	1.10	2.9E-01
PtdEtn 16:0/34:6	930.7 / 255.2	0.007	0.000	0.008	0.000	0.010	0.000	1.11	1.6E-01	1.30	6.8E-03	1.17	6.1E-02
PtdEtn 16:0/36:6	958.7 / 255.2	0.003	0.000	0.003	0.000	0.004	0.000	0.95	6.2E-01	1.20	1.6E-01	1.27	1.0E-01
PtdEtn 16:0/38:6	986.8 / 255.2	0.004	0.000	0.005	0.000	0.005	0.001	1.15	9.1E-02	1.22	1.1E-01	1.06	5.8E-01
PtdEtn 16:0/40:6	1014.8 / 255.2	0.003	0.000	0.003	0.000	0.004	0.000	1.01	9.1E-01	1.10	3.5E-01	1.09	4.2E-01
PtdEtn 18:0/20:6	762.5 / 283.2	0.124	0.009	0.216	0.021	0.128	0.008	1.75	2.3E-04	1.03	7.9E-01	0.59	1.6E-02
PtdEtn 18:0/22:6	790.5 / 283.2	0.392	0.030	0.728	0.079	0.410	0.036	1.86	3.3E-04	1.05	7.3E-01	0.56	2.3E-02
PtdEtn 18:0/24:6	818.6 / 283.2	0.456	0.026	0.957	0.105	0.470	0.045	2.10	3.8E-05	1.03	7.9E-01	0.49	8.6E-03
PtdEtn 18:0/26:6	846.6 / 283.2	0.011	0.000	0.013	0.001	0.014	0.001	1.19	2.3E-02	1.25	5.7E-03	1.05	6.4E-01
PtdEtn 18:0/28:6	874.6 / 283.2	0.005	0.000	0.007	0.000	0.006	0.001	1.28	9.0E-03	1.17	1.7E-01	0.91	4.5E-01
PtdEtn 18:0/30:6	902.7 / 283.2	0.007	0.001	0.009	0.001	0.008	0.001	1.26	7.7E-02	1.17	3.8E-01	0.94	6.2E-01
PtdEtn 18:0/32:6	930.7 / 283.2	0.006	0.001	0.007	0.000	0.009	0.001	1.18	9.8E-02	1.38	2.9E-02	1.16	1.6E-01
PtdEtn 18:0/34:6	958.7 / 283.2	0.003	0.000	0.004	0.000	0.005	0.000	1.22	3.1E-02	1.42	4.4E-03	1.17	1.4E-01
PtdEtn 18:0/36:6	986.8 / 283.2	0.002	0.000	0.003	0.000	0.003	0.000	1.28	7.1E-02	1.62	2.5E-03	1.26	1.3E-01
PtdEtn 18:0/38:6	1014.8 / 283.2	0.002	0.000	0.003	0.000	0.002	0.000	1.07	5.7E-01	0.98	9.0E-01	0.92	5.8E-01
PtdEtn 18:0/40:6	1042.8 / 283.2	0.001	0.000	0.002	0.000	0.003	0.001	1.20	3.4E-01	1.79	2.7E-02	1.49	1.0E-01

Table 18: Plasma levels of ethanolamine plasmalogens (PlsEtn) metabolites with selected sn-2 position fatty acids in non-autistic children, autistic children not taking carnitine supplements, and autistic children taking carnitine supplements (All values are expressed as the ratio to PtdEtn 16:0/18:0).

Metabolite Name	MS/MS Transition	Autism						Autism vs. Control					
		Control		- Carnitine		+ Carnitine		- Carnitine		+ Carnitine		+ Carn vs. - Carn	
		Avg	SEM	Avg	SEM	Avg	SEM	Ratio	p	Ratio	p	Ratio	p
PlsEtn 16:0/18:1	700.5 / 281.2	0.626	0.027	0.669	0.025	0.727	0.067	1.07	2.5E-01	1.16	9.7E-02	1.09	3.3E-01
PlsEtn 16:0/18:2	698.5 / 279.2	1.987	0.096	2.206	0.109	2.333	0.309	1.11	1.4E-01	1.17	1.6E-01	1.06	6.2E-01
PlsEtn 16:0/18:3	696.5 / 277.2	0.033	0.002	0.032	0.002	0.039	0.005	0.98	7.9E-01	1.19	2.1E-01	1.21	1.1E-01
PlsEtn 16:0/20:4	722.5 / 303.2	3.289	0.218	4.096	0.306	3.969	0.622	1.25	3.9E-02	1.21	2.0E-01	0.97	8.4E-01
PlsEtn 16:0/22:6	746.5 / 327.2	0.495	0.031	1.021	0.096	0.446	0.049	2.06	5.2E-06	0.90	4.0E-01	0.44	1.0E-03
PlsEtn 18:0/18:1	728.5 / 281.2	0.782	0.034	0.925	0.047	0.902	0.078	1.18	1.8E-02	1.15	1.0E-01	0.98	8.1E-01
PlsEtn 18:0/18:2	726.5 / 279.2	3.010	0.167	3.284	0.172	3.058	0.340	1.09	2.6E-01	1.02	8.9E-01	0.93	5.2E-01
PlsEtn 18:0/18:3	724.5 / 277.2	0.046	0.003	0.047	0.003	0.052	0.008	1.02	8.2E-01	1.13	4.1E-01	1.11	4.3E-01
PlsEtn 18:0/20:4	750.5 / 303.2	6.899	0.412	8.803	0.721	8.025	1.056	1.28	2.9E-02	1.16	2.3E-01	0.91	5.7E-01
PlsEtn 18:0/22:6	774.5 / 327.2	0.669	0.039	1.406	0.141	0.628	0.062	2.10	1.0E-05	0.94	5.8E-01	0.45	2.2E-03
PlsEtn 18:1/18:1	726.5 / 281.2	0.520	0.031	0.629	0.029	0.628	0.065	1.21	1.2E-02	1.21	1.0E-01	1.00	9.8E-01
PlsEtn 18:1/18:2	724.5 / 279.2	1.402	0.100	1.573	0.085	1.664	0.280	1.12	1.9E-01	1.19	2.7E-01	1.06	6.8E-01
PlsEtn 18:1/18:3	722.5 / 277.2	0.023	0.002	0.025	0.001	0.030	0.004	1.06	5.9E-01	1.27	1.8E-01	1.19	1.6E-01
PlsEtn 18:1/20:4	748.5 / 303.2	3.425	0.230	4.177	0.292	4.083	0.489	1.22	5.0E-02	1.19	1.7E-01	0.98	8.7E-01
PlsEtn 18:1/22:6	772.5 / 327.2	0.411	0.024	0.875	0.082	0.408	0.044	2.13	2.7E-06	0.99	9.3E-01	0.47	1.8E-03

All references identified herein are incorporated herein by reference.

The present invention has been described with regard to a plurality of illustrative embodiments. However, it will be apparent to persons skilled in the art that a

number of variations and modifications can be made without departing from the scope of the invention as defined in the claims.

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CLAIMS

- 1. A method for diagnosing a human subject's Autism Spectrum Disorder (ASD) health state or change in ASD health state or identifying a human subject's risk of ASD, the method comprising: comparing quantifying data comprising one or more accurate masses listed in Table 2 of a sample from the human subject to corresponding data obtained from one or more reference samples;**

wherein the human subject's ASD health state or change in ASD health state for or risk of ASD is based on a difference in intensity of the one or more accurate masses between the sample from the human subject and one or more reference samples.
- 2. A method for diagnosing a human subject's ASD health state or change in ASD health state or identifying a human subject's risk of ASD, the method comprising the steps of:**

 - a) analyzing a sample obtained from a patient to obtain quantifying data for one or more accurate masses;**
 - b) comparing the quantifying data for said one or more accurate masses to corresponding data obtained from one or more reference samples; and**
 - c) using said comparison to diagnose the human subject's ASD health state or change in ASD health state based on the differences between the quantifying data and the corresponding data of the one or more accurate masses;**

wherein the one or more accurate masses is listed in Table 2.
- 3. A method for diagnosing a human subject's ASD health state or change in ASD health state or identifying a human subject's risk of ASD, the method comprising the steps of:**

 - a) analyzing a sample obtained from a patient to obtain quantifying data for one or more ethanolamine phospholipids;**
 - b) comparing the quantifying data for said one or more ethanolamine phospholipids to corresponding data obtained from one or more reference samples; and**

c) using said comparison to diagnose the human subject's ASD health state or change in ASD health state

4. The method of claim 3, wherein the one or more ethanolamine phospholipids is listed in any one of Tables 3 to 10.

5. The method of claim 1, 2 or 3, wherein the determination of the ASD health state or change in ASD health state comprises the determination of: the presence or absence of ASD, the biochemical ASD phenotype of the subject, an elevated risk of ASD, or a positive, negative, or nil effect of an ASD therapeutic strategy on the subject's underlying biochemical ASD phenotype.

6. The method of claim 5, wherein the biochemical ASD phenotype is characterized as any one of:

a) elevated levels of saturated or monounsaturated very long chain fatty acid (VLCFA)-containing ethanolamine phospholipids;

b) elevated levels of docosahexaenoic acid (22:6, DHA)-containing ethanolamine phospholipids;

c) elevated levels of polyunsaturated VLCFA-containing ethanolamine phospholipids;

d) decreased levels of 18:3, 20:3, 22:3, or 24:3- containing ethanolamine phospholipids and

e) combinations thereof.

7. The method of claim 1, 2 or 3, wherein the sample is whole blood, plasma, serum, or a subfraction of whole blood.

8. The method of claim 2, wherein step a) comprises the extraction of the accurate masses into an organic solvent.

9. The method of claim 2, wherein step a) comprises the extraction of the accurate masses into an aqueous solvent.
10. The method of claim 2, wherein step a) comprises analyzing the sample by mass spectrometry.
11. The method of claim 10, wherein the mass spectrometer is selected from the group consisting of: a Fourier transform ion cyclotron resonance, time of flight, orbitrap, quadrupole and triple quadrupole mass spectrometer.
12. The method of claim 11, wherein the mass spectrometer is a triple quadrupole mass spectrometer.
13. The method of claim 1, 2 or 3, wherein the reference sample is taken from a non-ASD subject.
14. The method of claim 1, 2 or 3, wherein the reference sample is taken from one or more ASD subjects not on a therapeutic regimen.
15. The method of claim 1, 2 or 3, wherein the reference sample is one or more samples taken from the human at a pre-therapy stage or at an earlier-therapy stage.
16. The method of claim 1 or 2, wherein the human subject is diagnosed with ASD based on having either: elevated levels of ethanolamine phospholipids containing saturated or monounsaturated very long chain fatty acids (VLCFA); docosahexaenoic acid (22:6, DHA); VLCFA DHA precursor (24:5, 24:6); catabolic products of DHA beta-oxidation (20:6), polyunsaturated VLCFA; decreased levels of ethanolamine phospholipids containing 18:3, 20:3, 22:3, 24:3 fatty acids or combinations thereof.
17. The method of claim 16, wherein the human subject is diagnosed with ASD based on having a metabolic abnormality described by one or more metabolite listed in

any one of tables 11-18 having a statistically significant ($p < 0.05$) change relative to the corresponding data of the reference sample from a non-ASD subject.

18. A method for diagnosing a human subject's ASD health state or change in ASD health state or identifying a human subject's risk of ASD, the method comprising the steps of:

a) analyzing a sample obtained from a patient to obtain quantifying data for one or more of the following:

saturated or monounsaturated very long chain fatty acid (VLCFA)-containing ethanolamine phospholipids;
docosahexaenoic acid (22:6, DHA)-containing phospholipids;
DHA precursor (24:5, 24:6)-containing phospholipids;
catabolic products of DHA beta-oxidation (20:6)-containing phospholipids;
polyunsaturated VLCFA-containing phospholipids; and
combinations thereof;

b) comparing the quantifying data to corresponding data obtained from one or more reference samples; and

c) using said comparison to diagnose the human subject's ASD health state or change in ASD health state based on having one of the following characterizations when compared to the corresponding data obtained from one or more reference samples:

elevated levels of saturated or monounsaturated very long chain fatty acid (VLCFA)-containing ethanolamine phospholipids;

elevated levels of docosahexaenoic acid (22:6, DHA)-containing ethanolamine phospholipids;

elevated levels of DHA precursor (24:5, 24:6)-containing ethanolamine phospholipids;

elevated levels of ethanolamine phospholipids containing catabolic products of DHA beta-oxidation (20:6);

elevated levels of polyunsaturated VLCFA-containing ethanolamine phospholipids;

decreased levels of ethanolamine phospholipids containing LCFA
containing three double bonds (18:3, 20:3, 22:3, 24:3)
or combinations thereof.

19. The method of claim 2, wherein the method is for monitoring an ASD therapy,
wherein step b) comprises:

comparing the quantifying data for the one or more accurate masses to
corresponding data obtained from one or more reference samples collected from non-
ASD subjects and/or with previous collected quantifying data from a pre-therapy stage
or an earlier therapy stage of the patient;

and step c) comprises:

c) using said comparison to determine the biochemical effect of the therapy on
the human subject;

wherein the one or more accurate masses is listed in Table 2.

20. The method of claim 19, wherein the therapy is a carnitine therapy.