

Supplementary Material 1.

Sample Pretreatment for ATP Assay

Tissue samples: Accurately weigh the tissue sample. Add 9 volumes of ice-cold double-distilled water according to the ratio of weight (g) to volume (mL) of 1:9. Prepare the homogenate in an ice-water bath to obtain a 10% homogenate (take an aliquot, centrifuge at 3,500 rpm for 10 minutes, and collect the supernatant for protein concentration determination). Then, place the homogenate in a boiling water bath for 10 minutes, remove, mix thoroughly, and extract for 1 minute. Centrifuge at 3,500 rpm for 10 minutes and collect the supernatant for analysis.

Sample Pretreatment for GSH-Px and SOD Assays

Tissue samples: Accurately weigh the tissue sample. Add 9 volumes of normal saline according to the ratio of weight (g) to volume (mL) of 1:9. Mince the tissue and prepare the homogenate in an ice-water bath. Centrifuge at 3,500 rpm for 10 minutes. Collect the supernatant, which represents the 10% homogenate supernatant, for analysis. Additionally, determine the protein concentration.

Sample Pretreatment for MDA Assay

Tissue samples: Accurately weigh the tissue sample. Add 9 volumes of normal saline according to the ratio of weight (g) to volume (mL) of 1:9. Mince the tissue and prepare the homogenate in an ice-water bath. Centrifuge at 4,000 rpm for 10 minutes. Collect the supernatant, which represents the 10% homogenate supernatant, for analysis. Additionally, determine the protein concentration.

Sample Pretreatment for caspase 9 Assay

Add lysis buffer to the tissue sample at a ratio of 100 μ L of lysis buffer per 10 mg of tissue. Homogenize using a tissue grinder. Transfer the homogenate to a 1.5 mL centrifuge tube and incubate on ice for an additional 5 minutes for lysis. Centrifuge at $16,000 \times g$ for 10 minutes at 4 °C. Transfer the supernatant to a pre-chilled centrifuge tube on ice. Immediately determine the

enzymatic activity of caspase 9. Meanwhile, take a small aliquot of the sample to determine the protein concentration.

Sample Pretreatment for L-Lactate Assay

For tissue samples, add 100 μ L of Lactate Assay Buffer per 10 mg of tissue and homogenize under low-temperature conditions on ice. Centrifuge the homogenate at approximately $12,000 \times g$ for 5 minutes at 4 °C. Collect the supernatant for subsequent analysis. All the above procedures must be performed on ice.

Supplementary Table S1

Comparison of mitochondrial number and morphometric parameters between CeD patients and healthy controls

Parameter	CeD group (n=3)	Healthy control group (n=3)
Mitochondrial number (per field)	43.4 $\pm$ 5.7	65.3 $\pm$ 5.1
Area (μ m ²)	0.0256 $\pm$ 0.0119	0.0184 $\pm$ 0.0068
Length (μ m)	0.1500 $\pm$ 0.0693	0.1070 $\pm$ 0.0054
Width (μ m)	0.0734 $\pm$ 0.0302	0.0538 $\pm$ 0.0030
Circularity	0.0708 $\pm$ 0.0132	0.0734 $\pm$ 0.0030
Aspect ratio	2.19 $\pm$ 0.17	2.11 $\pm$ 0.03

Note: Data are presented as mean $\pm$ SD. No statistical comparisons were performed due to the very small sample size (n=3 per group). These descriptive data are for exploratory purposes only.

Supplementary Table S2

Variable 1	Variable 2	Correlation coefficient (r)	Raw <i>P</i> value	FDR-adjusted <i>P</i> value (P~FDR~)
ATP	SOD	0.853	<0.001	0.006
4-HNE	25(OH)D	0.663	0.009	0.027
caspase 9	EPO	-0.615	0.030	0.045

L-lactate	caspase 9	0.546	0.038	0.045
L-lactate	EPO	-0.588	0.040	0.048
L-lactate	Ferritin	0.566	0.050	0.050

Note: FDR correction was performed using the Benjamini–Hochberg method with a threshold of $q < 0.10$. EPO: erythropoietin; 25(OH)D: 25-hydroxyvitamin D.