dietetics

Brief Report

Effect of a Two-Week Diet without Meat and Poultry on Serum Coenzyme Q_{10} Levels

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Abstract: Coenzyme Q_{10} (CoQ_{10}) is an essential compound for energy production in the mitochondria and the antioxidation of lipid-soluble substances in cells. As it can be biosynthesized in cells, CoQ_{10} is not an essential nutrient. However, its intake through meals contributes to the maintenance of CoQ_{10} levels in the body. Therefore, understanding the effects of daily diet on serum CoQ_{10} levels is crucial. This study investigated the effect of a two-week diet without meat or poultry, which are rich in CoQ_{10} content, on serum CoQ_{10} levels of 22 young women aged 20–21 years. Upon restricting the intake of meat and poultry, the participants' average daily intake of CoQ_{10} from meals decreased from 2.1 ± 0.6 to 1.1 ± 0.5 mg/day. Simultaneously, the average serum reduced, oxidized, and total CoQ_{10} levels decreased by 14%, 31%, and 16%, respectively, after the two-week dietary intervention, whereas the reduced serum CoQ_{10} ratio increased significantly. These results suggest that meat and poultry are significant sources of CoQ_{10} in the diet. Dietary habits affect serum CoQ_{10} levels; however, further research is required to determine whether people who follow long-term diets with lower serum CoQ_{10} levels, such as a healthy reference diet proposed by the EAT-Lancet Commission in addition to vegetarian and vegan diets, need CoQ_{10} supplementation to maintain health and achieve healthy longevity.

Keywords: CoQ_{10}; dietary intake; meat and poultry restrictions

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1. Introduction

Coenzyme Q_{10} (CoQ_{10}) is a vitamin-like molecule consisting of a quinone moiety and ten isoprene units. It functions as a coenzyme for shuttling electrons between mitochondrial electron transport chains involved in ATP synthesis, acts as a cofactor for multiple mitochondrial enzymes, and its reduced form (also called ubiquinol-10) serves as a lipophilic antioxidant in the mitochondria and extramitochondrial membrane, protecting against oxidative damage [1,2]. CoQ_{10} is synthesized endogenously, involving a minimum of 13 genes in its biosynthesis [3]. Spontaneous mutations in these genes result in primary CoQ_{10} deficiency and impaired ATP synthesis. Certain classes of drugs, such as statins and bisphosphonates (enzyme inhibitors involved in the CoQ_{10} precursor synthesis), may reduce serum CoQ_{10} levels with side reactions such as myalgia and general discomfort [3]. Furthermore, CoQ_{10} biosynthesis in humans decreases after 20 years of age, leading to a decreased CoQ_{10} concentration in the organs [3,4]. Therefore, oral CoQ_{10} supplementation may alleviate symptoms of primary CoQ_{10} deficiency, prevent certain side-effects of the above drug inhibitors, confer health benefits in older people by improving vitality, physical performance, and quality of life, and prevent chronic oxidative stress associated with cardiovascular and neurodegenerative diseases [3,5]

Although CoQ_{10} is not an essential nutrient, up to 40% of plasma/serum CoQ_{10} is reportedly obtained from dietary intake [6,7]. Consequently, the daily diet may affect plasma and serum CoQ_{10} levels. Meat, poultry, and fish are rich in CoQ_{10} [8,9]. The CoQ_{10}

intake from meals in the Danish population is approximately 3–5 mg/day, with two-thirds derived from meat and poultry [9]. Our previous study estimated the daily CoQ_{10} intake in Japan as 3.71 ± 2.74 and 2.98 ± 2.07 mg/day in men and women, respectively, using the food weighing method and the data on the CoQ_{10} contents in food [10]. The significant individual differences in CoQ_{10} intake from meals among the participants were attributed to differences in dietary habits, especially the amount of animal protein intake, including meat and poultry.

Circumstantial evidence exists on the relationship between plasma and serum CoQ_{10} levels and dietary habits. Indians have lower baseline serum CoQ_{10} levels than the Chinese and Caucasians, which may be attributed to vegetarian cereal-based diets consumed by the Indian population [11]. The Japanese in Tokyo have lower plasma CoQ_{10} levels (geometric means 1.18 μmol/L) than Japanese Americans (1.42 μmol/L) and Japanese Brazilians (1.45 μmol/L) [12]. This was reflected in the difference in the annual sum of meat and poultry consumption between Japan, the United States of America, and Brazil (37.21, 95.54, and 78.69 kg/year/capita, respectively, in 2015) [13]. Furthermore, the plasma CoQ_{10} levels in healthy Japanese vegetarians/vegans were 23% lower than those in omnivores [14]. However, changes in food intake habits have not been reported to directly affect serum/plasma CoQ_{10} levels.

In this novel study, I investigated the effects of a two-week meat- and poultry-restricted diet trial on changes in serum CoQ_{10} levels in young Japanese women majoring in nutrition/dietetics. Furthermore, the two-week average daily intake of CoQ_{10} from meals before and during the dietary intervention was estimated using a simplified table for CoQ_{10} intake calculation based on our previous study [10].

2. Materials and Methods

2.1. Study Design

The study was conducted from September 2015 to October 2015 and from September 2016 to October 2016. Twenty-two healthy volunteers (all women and omnivores) majoring in nutrition/dietetics at Wayo Women's University were included, and no exclusion criteria were taken. Participants recorded their meal menu for 2 weeks at baseline and during the meat- and poultry-restricted diet intervention to estimate the average daily amount of CoQ_{10} intake from meals. According to the participants' dietary menu records, they all ate dishes containing meat or poultry at baseline but not during the meat or poultry restriction period. The estimated daily intake of CoQ_{10} was calculated based on a simplified CoQ_{10} intake calculation table [10]. The participants did not weigh the food items in meals; therefore, the calorie and energy-providing nutrient intake estimation at baseline and during the restricted period was not performed using the meal record. Instead, a brief-type self-administered diet history questionnaire (BDHQ) was employed [15]. Participants completed the BDHQ twice, once at baseline and once after restricting their meat and poultry diet. The BDHQ form completed by participants indicated that they did not take any dietary supplements throughout the study. The anthropometric data were determined using a stadiometer (YG-200, Yagami Inc., Nagoya, Japan) and a body scale (HBF-375; Omron Corporation, Kyoto, Japan) at baseline, when blood samples were collected for biochemical analyses, including serum CoQ_{10} levels. Subsequently, the participants were restricted from eating meat and poultry for 2 weeks.

To reanalyze the data in this study, I adopted an opt-out recruitment approach targeting the participants. Instead of obtaining informed consent, I gave participants the research information and a chance to decline study participation by disclosing it on Dr. Suzuki's laboratory websites "https://wayonutrsuzukilab.wixsite.com/biochem (accessed on 28 December 2023)" from April to December 2023.

2.2. Ethics Approval

The original intervention study was conducted following the Declaration of Helsinki guidelines and approved by the Wayo Women's University Human Research Ethics Committee (No. 1513). However, the ethical review approval period ended in March 2017. Therefore, in April 2023, the Wayo Women's University Human Research Ethics Committee issued new ethics approval No. 2275 based on the author's application. The study was registered in the University Medical Information Network Clinical Trials Registry with the title "Changes in blood Coenzyme Q_{10} (CoQ_{10}) levels by diet and CoQ_{10}-fortified foods" (UMIN 000050936).

2.3. Blood Collection and Biochemical Analysis Measurements of CoQ_{10}

Blood samples were drawn from a vein and collected in separating agent- and sodium fluoride-containing tubes in the morning (8:00–9:30 a.m.) after fasting overnight for more than 10 h at baseline and after 2 weeks of restricting meat and poultry from meals. Plasma and serum samples were isolated by centrifuging the sodium fluoride and separating agent-containing tubes after clotting. Plasma glucose (Glc) (hexokinase UV method), serum triglycerides (TG) (enzymatic method), serum total cholesterol (TC) (cholesterol oxidase method), serum high-density lipoprotein cholesterol (HDL-C) (direct method), serum low-density lipoprotein cholesterol (LDL-C) (direct method), serum dihomo-γ-linolenic acid (DHLA) (gas chromatography), serum arachidonic acid (AA) (gas chromatography), serum eicosapentaenoic acid (EPA) (gas chromatography), docosahexaenoic acid (DHA) (gas chromatography), serum iron (2-nitroso-5-[*N*-n-propyl-*N*-(3-sulfopropyl)amino]phenol method), serum alanine transaminase (ALT) (the Japan Society of Clinical Chemistry [JSCC] reference method), serum aspartate transaminase (AST) (JSCC reference method), and serum γ-glutamyltransferase (γ-GTP) (JSCC reference method) levels were determined at SRL, Inc. (Tokyo, Japan).

2.4. Measurements of CoQ_{10}

Immediately after serum isolation, 100 µL aliquots were mixed with 700 µL of 2-propanol and stored at –80 °C until analysis. The quantitative analysis of serum CoQ_{10} levels was analyzed by the Kaneka Techno Research Corporation (Osaka, Japan) using a liquid chromatography with a tandem mass spectrometry system (QTRAP 5500; AB SCIEX, Framingham, MA, USA), as described previously [16].

2.5. Data Analyses

Microsoft Excel for Microsoft 365 (Version 2405, Microsoft Corporation, Redmond, WA, USA) was used for statistical analysis. The results are expressed as means ± standard deviation. A paired t-test was performed to assess the significance of the differences between the levels at baseline (BL) and 2 weeks after the meat- and poultry-restricted diet intervention (MR). The level of significance was set at $p < 0.05$. Furthermore, the post hoc power analysis was performed using a web app, Power and Sample Size "https://vbiostatps.app.vumc.org/ps/ (accessed on 28 April 2024)", to evaluate the statistical power.

3. Results

The baseline characteristics of the anthropometric measurement of the participants are presented in Table 1. All participants were young women aged 20–21 years. Three of the 22 participants were underweight (body mass index [BMI] < 18.5 kg/m^2), two were overweight/obese (BMI ≥ 25 kg/m^2), and the remaining had a normal weight (BMI ≥ 18.5 < 25 kg/m^2).

Table 2 presents the estimated daily energy, energy-providing nutrient, meat, poultry, and fish intake calculated using the BDHQ analysis [15] and the estimated CoQ_{10} intake using a simplified CoQ_{10} intake calculation table [10]. The estimated daily energy, carbohydrate, and fat intake did not differ between the BL and MR. However, the estimated protein intake decreased with the MR, with >70% attributed to animal protein. Meat and poultry intake decreased in MR compared to BL, while fish intake increased. The estimated CoQ_{10} intake decreased by 48% with the MR.

Table 1. Baseline characteristics of participants.

Parameter	Participants
Age (years)	20.7 ± 0.4
Women/men (n/n)	22/0
Height (m)	1.58 ± 0.07
Weight (kg)	52.0 ± 7.4
BMI (kg/m^2)	20.7 ± 2.4

Data are expressed as means ± standard deviations except for sex ratio.

Table 2. Estimated energy, energy-providing nutrients, meat, poultry, fish, and the coenzyme Q_{10} (CoQ_{10}) intake of the participants at baseline (BL) and during the two-week meat and poultry restriction (MR).

	BL	MR	*p*-Value
Energy (kJ)	6831 ± 1942	6366 ± 1501	0.104
Carbohydrate (g)	228 ± 65	212 ± 55	0.223
Protein (g)	64.5 ± 23.0	53.4 ± 13.1	0.0040
Animal protein (g)	37.7 ± 17.3	29.6 ± 10.7	0.0076
Vegetable protein (g)	26.8 ± 7.7	23.8 ± 5.8	0.054
Fat (g)	47.3 ± 17.9	45.4 ± 13.7	0.441
Animal fat (g)	22.7 ± 9.5	20.3 ± 6.8	0.095
Vegetable fat (g)	24.6 ± 9.9	25.1 ± 9.0	0.722
Meat (g)	39.9 ± 25.9	16.4 ± 18.1	2.0×10^{-4}
Poultry (g)	35.1 ± 31.1	8.2 ± 7.3	7.9×10^{-4}
Fish (g)	51.2 ± 30.2	117.6 ± 73.2	5.4×10^{-4}
CoQ_{10} (mg)	2.1 ± 0.6	1.1 ± 0.5	8.7×10^{-9}

A brief-type self-administrated diet history questionnaire [15] was used to collect information on energy, carbohydrate, protein, and fat intake. For CoQ_{10}, a simplified CoQ_{10} calculation table [10] was used. Data are expressed as means ± standard deviations. Paired *t*-tests were performed for statistical analysis.

Table 3 presents a comparison of the plasma and serum levels of Glc, lipids (TG, TC, HDL-C, LDL-C), four polyunsaturated fatty acids (DHLA, AA, EPA, DHA) iron, and liver function marker enzymes (ALT, AST, and γ-GTP) between the BL and MR after overnight fasting. Glc, lipids, and iron levels did not vary before (BL) or after (MR) meat and poultry restriction. However, DHLA and AA, which are n-6 polyunsaturated fatty acids, decreased, whereas EPA and DHA, which are n-3 polyunsaturated fatty acids, increased with the MR, coinciding with an increased fish intake instead of meat and poultry. The levels of liver-function-marker enzymes were within the reference values, although ALT and AST levels significantly differed between the BL and MR.

Figure 1 depicts the changes in serum-reduced (ubiquinol-10), oxidized (ubiquinone-10), and total CoQ_{10} (sum of ubiquinol-10 and ubiquinone-10) levels, reduced/total CoQ_{10} ratio, and total CoQ_{10}/TC ratios. A two-week restriction of meat and poultry consumption decreased the reduced, oxidized, total CoQ_{10}, and total CoQ_{10}/TC ratios by 14%, 31%, 16%, and 15%, respectively. The rate of decrease was higher for the oxidized form than for the reduced form. Consequently, the reduced/total CoQ_{10} ratio increased by 1.5%. These results revealed that a restricted diet of meat and poultry decreased serum CoQ_{10} levels and increased the reduced/total ratio. It is noted that the statistical power values of the reduced, oxidized, total CoQ_{10}, total CoQ_{10}/TC, and reduced/total CoQ_{10} ratio calculated by the post hoc power analysis were 0.68, 0.85, 0.83, 0.94, and 0.62, respectively, suggesting that the sample size of this study was not too small to conclude.

Table 3. Levels of plasma glucose, serum lipids, serum fatty acids, serum iron, and serum hepatic enzyme activity in the participants before (BL) and after meat and poultry re-striction for two weeks (MR).

	BL	MR	*p*-Value
Glc (mmol/L)	4.82 ± 0.28	4.94 ± 0.31	0.061
TG (mmol/L)	0.58 ± 0.16	0.63 ± 0.26	0.161
TC (mmol/L)	4.84 ± 0.70	4.74 ± 0.63	0.269
HDL-C (mmol/L)	1.75 ± 0.33	1.72 ± 0.35	0.193
LDL-C (mmol/L)	2.86 ± 0.80	2.71 ± 0.77	0.076
DHLA (mg/L)	26.3 ± 6.6	22.9 ± 5.5	0.0083
AA (mg/L)	167.8 ± 31.4	149.2 ± 27.5	0.000017
EPA (mg/L)	36.0 ± 21.5	59.8 ± 32.3	0.0025
DHA (mg/L)	93.7 ± 25.8	109.4 ± 31.6	0.0071
EPA/ALA	0.22 ± 0.13	0.41 ± 0.22	0.00035
Iron (Fe) (μmol/L)	18.9 ± 7.1	16.3 ± 5.4	0.189
ALT (U/L)	14.3 ± 3.6	11.5 ± 3.7	0.0029
AST (U/L)	13.6 ± 3.7	16.0 ± 3.0	0.0023
γ-GTP (U/L)	13.7 ± 4.8	13.3 ± 4.2	0.268

Glc, glucose; TG, triglycerides; TC, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; DHLA, dihomo-γ-linoleic acid; AA, arachidonic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; ALT, alanine transaminase; AST, aspartate transaminase; γ-GTP, γ-glutamyltransferase. Data are expressed as means ± standard deviations. Paired *t*-tests were performed for statistical analysis.

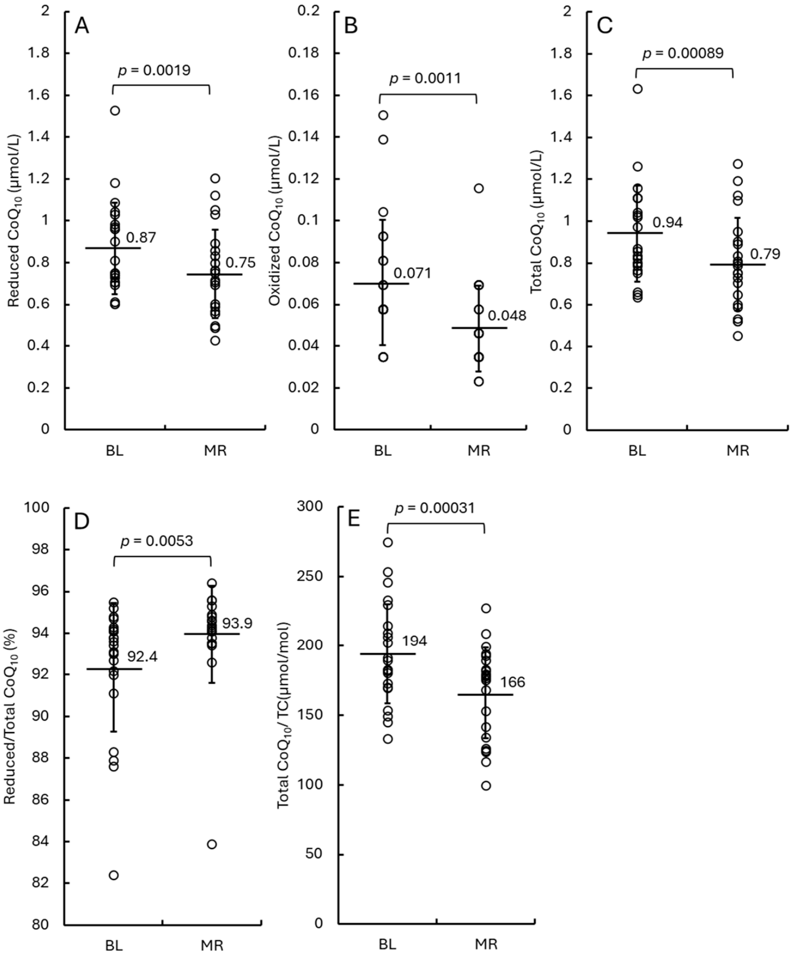

Figure 1. Serum levels of (**A**) reduced coenzyme Q_{10} (CoQ_{10}), (**B**) oxidized CoQ_{10}, (**C**) total CoQ_{10}, (**D**) reduced/total CoQ_{10} ratio, and (**E**) total CoQ_{10}/total cholesterol (TC) ratio. BL, baseline; MR, after ingesting a meat- and poultry-restricted diet for 2 weeks. Data are shown as dot plots with means ± standard deviations. The *p*-values of the paired t-test between BL and MR are indicated on the top square brackets.

4. Discussion

To the best of our knowledge, our study showed, for the first time, that changes in eating habits affect both the dietary intake and blood levels of CoQ_{10}. The estimated average daily intake of CoQ_{10} during meat and poultry restriction was 45% lower than that at baseline in our study. During the restriction period, most participants had a pescatarian diet; meat and poultry were partially replaced by fish. This increased the serum levels of EPA and DHA and the EPA/AA ratio and decreased the serum levels of DHLA and AA. These results are similar to those of a previous observational study in which the amount of fish intake was positively related to plasma levels of EPA and the EPA/AA ratio [17] and an interventional study that showed that an increase in fish intake frequency led to increased plasma levels of EPA and DHA and the EPA/AA ratio and reduced plasma DHLA and AA levels [18]. CoQ_{10} is abundant in meat and poultry, especially organ meats such as the heart and liver [8]. Although CoQ_{10} is also plenteous in fish, its content varies between fish varieties; blue-backed fish, such as herring, horse mackerel, mackerel, and sardine, are rich in CoQ_{10}, whereas white-fleshed fish and shellfish contain lesser amounts of CoQ_{10} [8]. Previous studies estimate the ratios of CoQ_{10} intake from meat and poultry in Danes, Finns, and Japanese to be 64%, 55%, and 44%, respectively [9,19,20]. Therefore, meat is the primary source of dietary CoQ_{10} in omnivores.

The reduced and oxidized forms of CoQ_{10} decreased after a two-week meat and poultry restriction. The rate of decrease was higher for the oxidized form (31%) than for the reduced form (14%). Consequently, the reduced/total CoQ_{10} ratio increased. This increase is consistent with the report by Yamaguchi et al., who found that the reduced/total CoQ_{10} ratio was higher in vegetarians/vegans than in omnivores [14]. The reduced and oxidized forms of CoQ_{10} exist in food [19]. However, during or after absorption in the intestine, most of the oxidized CoQ_{10} is converted to its reduced form [21]. Therefore, most of the CoQ_{10} circulates in its reduced form in the blood, regardless of its initial dietary form [22]. However, a high intake of meat and meat products promotes the formation of reactive oxygen species in the stomach, which are absorbed by the intestine [23]. Therefore, meat and poultry may increase oxidative compounds in the blood in addition to CoQ_{10}. The total antioxidant capacity levels are lower, whereas the total oxidant capacity levels and the oxidative stress index are higher in children receiving an omnivorous diet than in those consuming a lacto-ovo-vegetarian diet [24]. Additionally, the rate of reduction in total CoQ_{10} levels in the blood due to changes in food intake habits in our study (16%) was lower than that reported in a cross-sectional study by Yamaguchi et al. (23%) [14]. The difference between the two studies may be attributed to the difference in fish consumption. This suggests that fish are a valuable source of dietary CoQ_{10}, in addition to meat and poultry.

This study has some limitations. First, I estimated the daily amounts of CoQ_{10} intake using a simplified CoQ_{10} intake calculation table with standard serving sizes of foods for Japanese and did not directly weigh foods containing CoQ_{10}. Therefore, it is less accurate than calculating the sum of each food containing CoQ_{10}. Second, BDHQ was used to estimate daily energy and nutrient intake using standard serving sizes of foods. Because the participants responded to the questionnaire by recalling their diets for 1 month per the instructions, the average meat and poultry intake was not estimated as 0 g during the two-week MR period. Therefore, I could not compare the daily meat, poultry, and fish intake between BL and MR. Participants would be asked to keep photo records of each meal for two weeks of BL and MR periods to estimate the nutrients containing CoQ_{10} and food intake more accurately when further similar analyses are performed. Then, the average daily food and nutrient intake should be calculated using photo records and proper nutrition management software.

The EAT-Lancet Commission recently proposed a healthy reference diet with environmental sustainability to promote human health in the global population [25,26]. The average intake of meat, poultry, and fish in the proposed healthy diet decreased by 85%, 31%, and 69%, respectively, compared to the average intake in Japanese adults in 2018 after adjusting for energy intake [25]. If we modify our food intake habits to the proposed healthy diet, the CoQ_{10} intake from meals can be decreased by approximately 2 mg/day, as estimated using a simplified CoQ_{10} intake calculation table [10], leading to decreased blood CoQ_{10} levels. In addition to food intake habits, excessive physical training and being aged > 60 years contribute to decreased blood CoQ_{10} levels [27,28]. Suppose the EAT-Lancet Commission's healthy reference diet is adhered to, and food intake habits are modified to vegetarian and vegan diets; it is unclear whether CoQ_{10} supplementation to prevent a decrease in blood levels will help maintain health, especially for people who perform strenuous exercise or work and achieve healthy longevity.

5. Conclusions

Meat and poultry are the primary sources of CoQ_{10} from daily food intake. When meat and poultry consumption was restricted for two weeks, the estimated daily average intake of CoQ_{10} decreased by 48%, accompanied by a decrease in serum total CoQ_{10} levels by 16% in young omnivorous Japanese women. These results are consistent with those of previous cross-sectional studies that revealed a relationship between food intake habits and blood CoQ_{10} levels. Although CoQ_{10} is not considered an essential nutrient, further research is required to determine the appropriate amount of CoQ_{10} in the diet to maintain health and achieve healthy human longevity.

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Institutional Review Board Statement: This study was conducted following the Declaration of Helsinki guidelines and approved by Wayo Women's University Human Research Ethics Committee (No. 1513 and 2275).

Informed Consent Statement: Informed consent was obtained from all participants in study No. 1513. We adopted an opt-out recruitment approach targeting the participants when obtaining a new ethical approval as No. 2275. Instead of obtaining informed consent, we gave participants the research information and a chance to decline study participation by disclosing it on Dr. Suzuki's laboratory websites "https://wayonutrsuzukilab.wixsite.com/biochem (accessed on 28 December 2023)" from April to December 2023.

Data Availability Statement: Data supporting the findings of this study are available from the corresponding author, T. S., upon reasonable request.

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Conflicts of Interest: T. S. has no personal or financial conflicts of interest with Kaneka Co. Kaneka did not commit to the design, execution, and interpretation of the data, writing of the manuscript, or the decision to publish the results.

References

1. Guerra, R.M.; Pagliarini, D.J. Coenzyme Q biochemistry and biosynthesis. *Trends Biochem. Sci.* **2023**, *48*, 463–476. [CrossRef] [PubMed]
2. Stefely, J.A.; Pagliarini, D.J. Biochemistry of Mitochondrial Coenzyme Q Biosynthesis. *Trends Biochem. Sci.* **2017**, *42*, 824–843. [CrossRef] [PubMed]
3. Aaseth, J.; Alexander, J.; Alehagen, U. Coenzyme Q_{10} supplementation—In ageing and disease. *Mech. Ageing Dev.* **2021**, *197*, 111521. [CrossRef] [PubMed]
4. Kalen, A.; Appelkvist, E.L.; Dallner, G. Age-related changes in the lipid compositions of rat and human tissues. *Lipids* **1989**, *24*, 579–584. [CrossRef]
5. Hernandez-Camacho, J.D.; Bernier, M.; Lopez-Lluch, G.; Navas, P. Coenzyme Q_{10} Supplementation in Aging and Disease. *Front. Physiol.* **2018**, *9*, 44. [CrossRef] [PubMed]
6. Cupp, M.J.; Tracy, T.S. (Eds.) Coenzyme Q_{10} (Ubiquinone, Ubidecarenone). In *Dietary Supplements: Toxicology and Clinical Pharmacology*; Humana Press: Totowa, NJ, USA, 2003; pp. 53–85.

7. Okamoto, T.; Fukui, K.; Nakamoto, M.; Kishi, T.; Kanamori, N.; Kataoka, K.; Nishii, S.; Kishi, H.; Hiraoka, E.; Okada, A. Serum Levels of Coenzyme Q_{10} and Lipids in Patients during Total Parenteral Nutrition. *J. Nutr. Sci. Vitaminol.* **1986**, *32*, 1–12. [CrossRef] [PubMed]
8. Pravst, I.; Zmitek, K.; Zmitek, J. Coenzyme Q_{10} contents in foods and fortification strategies. *Crit. Rev. Food Sci. Nutr.* **2010**, *50*, 269–280. [CrossRef] [PubMed]
9. Weber, C.; Bysted, A.; Hllmer, G. The coenzyme Q_{10} content of the average Danish diet. *Int. J. Vitam. Nutr. Res.* **1997**, *67*, 123–129. [PubMed]
10. Kawai, K.; Otani, M.; Udagawa, K.; Takahashi, M.; Suzuki, T. Study of nutritional guidance methods concerning coenzyme Q_{10} intake. *New Diet Ther.* **2016**, *32*, 3–13.
11. Singh, R.B.; Niaz, M.A.; Kumar, A.; Sindberg, C.D.; Moesgaard, S.; Littarru, G.P. Effect on absorption and oxidative stress of different oral Coenzyme Q_{10} dosages and intake strategy in healthy men. *Biofactors* **2005**, *25*, 219–224. [CrossRef]
12. Iwasaki, M.; Franke, A.A.; Hamada, G.S.; Miyajima, N.T.; Sharma, S.; Ishihara, J.; Takachi, R.; Tsugane, S.; Le Marchand, L. Comparison of plasma levels of nutrient-related biomarkers among Japanese populations in Tokyo, Japan, Sao Paulo, Brazil, and Hawaii, USA. *Eur. J. Cancer Prev.* **2015**, *24*, 155–161. [CrossRef] [PubMed]
13. OECD Meat Consumption. Available online: https://data.oecd.org/agroutput/meat-consumption.htm (accessed on 18 January 2024).
14. Yamaguchi, T.; Hosoe, K.; Funahashi, I. Lower plasma coenzyme Q_{10} concentrations in healthy vegetarians and vegans compared with omnivores. *Nutrafoods* **2022**, *1*, 379–386. [CrossRef]
15. Kobayashi, S.; Honda, S.; Murakami, K.; Sasaki, S.; Okubo, H.; Hirota, N.; Notsu, A.; Fukui, M.; Date, C. Both Comprehensive and Brief Self-Administered Diet History Questionnaires Satisfactorily Rank Nutrient Intakes in Japanese Adults. *J. Epidemiol.* **2012**, *22*, 151–159. [CrossRef]
16. Takahashi, M.; Nagata, M.; Kaneko, T.; Suzuki, T. Miso Soup Consumption Enhances the Bioavailability of the Reduced Form of Supplemental Coenzyme Q_{10}. *J. Nutr. Metab.* **2020**, *2020*, 5349086. [CrossRef]
17. Hirai, A. An epidemiological study on the dietary ingestion of eicosapentaenoic acid (EPA) and platelet function in Japanese. *J. Jpn. Soc. Intern. Med.* **1985**, *74*, 13–20. [CrossRef] [PubMed]
18. Ogawa, T.; Kimoto, S.; Hozumi, R. Effects of fish intake frequency on plasma laboratory test. *Bull. Minamikyushu Univ.* **2018**, *48A*, 1–8.
19. Kubo, H.; Fujii, K.; Kawabe, T.; Matsumoto, S.; Kishida, H.; Hosoe, K. Food content of ubiquinol-10 and ubiquinone-10 in the Japanese diet. *J. Food Compos. Anal.* **2008**, *21*, 199–210. [CrossRef]
20. Mattila, P.; Kumpulainen, J. Coenzymes $Q_9$and Q_{10}: Contents in Foods and Dietary Intake. *J. Food Composit. Anal.* **2001**, *14*, 409–417. [CrossRef]
21. Bhagavan, H.N.; Chopra, R.K.; Craft, N.E.; Chitchumroonchokchai, C.; Failla, M.L. Assessment of coenzyme Q_{10} absorption using an in vitro digestion-Caco-2 cell model. *Int. J. Pharm.* **2007**, *333*, 112–117. [CrossRef] [PubMed]
22. Mohr, D.; Bowry, V.W.; Stocker, R. Dietary supplementation with coenzyme Q_{10} results in increased levels of ubiquinol-10 within circulating lipoproteins and increased resistance of human low-density lipoprotein to the initiation of lipid peroxidation. *Biochim. Biophys. Acta* **1992**, *1126*, 247–254. [CrossRef]
23. Macho-Gonzalez, A.; Garcimartin, A.; Lopez-Oliva, M.E.; Bastida, S.; Benedi, J.; Ros, G.; Nieto, G.; Sanchez-Muniz, F.J. Can Meat and Meat-Products Induce Oxidative Stress? *Antioxidants* **2020**, *9*, 638. [CrossRef] [PubMed]
24. Rowicka, G.; Klemarczyk, W.; Ambroszkiewicz, J.; Strucinska, M.; Kawiak-Jawor, E.; Weker, H.; Chelchowska, M. Assessment of Oxidant and Antioxidant Status in Prepubertal Children following Vegetarian and Omnivorous Diets. *Antioxidants* **2023**, *12*, 682. [CrossRef] [PubMed]
25. Hayashi, F. International research trends that focus on sustainable diet beyond healthy diet. *J. Food Syst. Res.* **2020**, *27*, 93–101. [CrossRef] [PubMed]
26. Willett, W.; Rockstrom, J.; Loken, B.; Springmann, M.; Lang, T.; Vermeulen, S.; Garnett, T.; Tilman, D.; DeClerck, F.; Wood, A.; et al. Food in the Anthropocene: The EAT-Lancet Commission on healthy diets from sustainable food systems. *Lancet* **2019**, *393*, 447–492. [CrossRef] [PubMed]
27. Niklowitz, P.; Onur, S.; Fischer, A.; Laudes, M.; Palussen, M.; Menke, T.; Doring, F. Coenzyme Q_{10} serum concentration and redox status in European adults: Influence of age, sex, and lipoprotein concentration. *J. Clin. Biochem. Nutr.* **2016**, *58*, 240–245. [CrossRef]
28. Siebrecht, S.; Chan, D.Y.L.; Rosenfeldt, F.; Lin, K.W. Coenzyme Q_{10} and ubiquinol for physical performance. In *Coenzyme Q10: From Fact to Fiction*; Hargreaves, I.P., Ed.; Nova Science Pub Inc.: London, UK, 2015; pp. 293–321.