Vegetarian Diets along with Regular Exercise: Impact on High-Density Lipoprotein Cholesterol Levels among Taiwanese Adults

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Received: 3 January 2020; Accepted: 10 February 2020; Published: 13 February 2020

Abstract: Background and objectives: High-density lipoprotein cholesterol (HDL-C) is important for improving risk estimates of atherosclerotic cardiovascular disease. We investigated the effect of omnivore and diverse vegetarian diets in connection with exercise on HDL-C. Materials and Methods: Historical data of 9588 biobank participants (4025 exercisers and 5563 non-exercisers) aged 30–70 years were categorized as omnivores (n = 8589), former vegetarians (n = 544), lacto-ovo vegetarians (n = 417), and strict vegetarians (n = 38). We used multiple linear regression for analyses. Results: HDL-C levels were higher in exercisers compared to non-exercisers. Compared with omnivores, strict vegetarians had decreased levels of HDL-C (β = −5.705; p = 0.001) followed by lacto-ovo vegetarians (β = −3.900; p < 0.001) and former vegetarians (β = −0.329; p = 0.475). The test for trend was significant (p < 0.001). After categorization by exercise modalities, the β-value was −13.984 for strict vegetarians, −4.419 for lacto-ovo vegetarians, and −1.864 for former vegetarians, respectively (p < 0.05). There was an interaction between diet and exercise (p = 0.009). Omnivores who exercised regularly had significantly higher HDL-C, whereas strict vegetarians who exercised regularly had significantly lower HDL-C. Conclusions: In summary, strict vegetarian diets in conjunction with regular exercise might not serve as healthful behaviors to be implemented in everyday life considering the negative impact on HDL-C.

Keywords: HDL-C; physical exercise; cardiovascular disease

1. Introduction

Dyslipidemia (defined as high total cholesterol, high low-density lipoprotein (LDL) cholesterol, or low high-density lipoprotein (HDL) cholesterol) is one of the modifiable risk factors linked to cardiovascular disease (CVD) [1]. It is predominantly characterized by low concentrations of HDL cholesterol in Asia and the Middle East [2]. Low HDL cholesterol is a lipid fraction that serves as a marker for poor metabolic health [3] and may occur in the presence or absence (i.e., isolated HDL-C) of other lipoprotein abnormalities [4,5]. A 1 mg/dL HDL reduction has been associated with a 3–4% increase in the prevalence of coronary artery disease [6,7].
Physical exercise and a healthful diet have been independently associated with lower rates of cardiovascular disease morbidity and mortality [8]. Regular exercise is one of the ways to increase HDL cholesterol levels [9]. According to a study previously conducted in Japan, an exercise of at least three to four times per week for at least 20 min would help increase HDL levels [10]. In that study, the authors found that each additional 10 min increase in exercise duration yielded an additional 1.4 mg/dL of HDL. HDL Cholesterol levels have been found to be more sensitive to aerobic exercise than other lipid fractions [11]. The impact on HDL cholesterol may also differ by exercise type [12].

Besides exercise, diets have been associated with cholesterolemic profile [13,14]. Associations have been found between dietary interventions and lipid profile in children and adolescents [15]. Significant associations have been found between low-carbohydrate plant-based diets and other lipid fractions but not HDL cholesterol [16]. A review of 30 observational and 19 clinical studies found a 3.6 mg/dL and 3.4 mg/dL reduction in HDL cholesterol following a plant-based vegetarian diet [17]. A short-term very low carbohydrate diet has also been associated with increased HDL cholesterol in normal weight, normolipidemic women [18]. Based on our review of past literature, exercise would increase HDL-C levels while vegetarian diets would decrease it [19].

HDL-C has antioxidative, anti-inflammatory, and anti-thrombotic properties [20]. It has been demonstrated to be a protector factor for atherosclerosis although medical treatments that increase its concentration have failed, in randomized clinical trials, to show cardiovascular benefits. Therefore, increasing HDL by “conventional methods” such as exercise, non-smoking, and healthy diets are the only ways that might have an impact on cardiovascular health. A vegetarian diet is assumed to be healthier but there is scarce evidence on its actual effect on cardiovascular disease. To our knowledge, previous studies have not focused on the combined effect of diet and exercise. In this light, we assessed the impact of vegetarian diets and exercise on HDL cholesterol levels among an adult Taiwanese population.

2. Material and Methods

2.1. Data Source

Clinical and lifestyle data between 2008 and 2015 were obtained from Taiwan Biobank, a national resource with genetic information of Taiwanese adults aged 30–70 years. Recruitment into the biobank started in 2008 and is ongoing. Prior to recruitment in the biobank, all participants gave informed consent. The biobank data are separated into categories including questionnaires, physical examination, blood and urine tests, biological samples, and experimental data. The investigation conformed to the principles outlined in the Declaration of Helsinki. The Institutional Review Board of Chung Shan Medical University approved this study (approval number CS2-16114; approved on 14 September 2016).

2.2. Study Participants

Data from 9588 participants (5162 women and 4426 men) with no history of cancer were analyzed. The basic characteristics included sex, age, lifestyle factors (diet type, smoking, drinking and coffee drinking), biochemical information (total cholesterol; TC, triglycerides; TG, low-density lipoprotein; LDL-C with cut-point of 130 mg/dL [21], high-density lipoprotein; HDL-C) and anthropometric measures (waist-hip ratio; body mass index; BMI, and body fat, and WHR, with cut-points of <0.9 for men and <0.8 for women [22].

Details of dietary intake were collected using questionnaires contained in the biobank [23]. Participants were categorized as omnivores (people who consumed food of both plant and animal origin), former vegetarians (people who have adhered to a vegetarian diet for at least 6 months in their lifetime but who were no longer on vegetarian diet during recruitment into the biobank), lacto-ovo vegetarian (people that consumed eggs, milk, and dairy products) and strict vegetarian (people who consumed plant-based food). Vegetarians included people who avoided all animal flesh, including fish and poultry. Further stratifications were made by exercise levels, which were estimated from the physical activity questionnaire. Exercise was defined as physical activity at least 3 times a week lasting
were omnivores, former vegetarians, lacto-ovo vegetarians, and strict vegetarians had mean HDL-C levels of 53.31 ± 0.19 mg/dL, 54.56 ± 0.75 mg/dL, and 49.73 ± 1.9 mg/dL, respectively. Likewise, non-exercisers who were non-vegetarians, former vegetarians, lacto-ovo vegetarians, and strict vegetarians had mean HDL-C levels of 53.31 ± 0.19 mg/dL, 54.56 ± 0.75 mg/dL, 50.01 ± 0.71 mg/dL, and 49.73 ± 1.9 mg/dL. The highest level of HDL-C was found in exercisers and specifically among omnivores (55.2 mg/dL) while the lowest level was found in exercisers who were strict vegetarians (Table 1 and Figure 1).

3. Results

The final recruits included 4025 exercisers and 5563 non-exercisers (Table 1). Overall, male and female exercisers were associated with higher HDL-C compared to non-exercisers. Exercisers who were omnivores, former vegetarians, lacto-ovo vegetarians, and strict vegetarians had mean HDL-C (mean ± SE) levels of 55.2 ± 0.22 mg/dL, 53.21 ± 0.89 mg/dL, 49.78 ± 0.93 mg/dL, and 47 ± 3.05 mg/dL, respectively. Likewise, non-exercisers who were non-vegetarians, former vegetarians, lacto-ovo vegetarians, and strict vegetarians had mean HDL-C levels of 53.31 ± 0.19 mg/dL, 54.56 ± 0.75 mg/dL, 50.01 ± 0.71 mg/dL, and 49.73 ± 1.9 mg/dL. The highest level of HDL-C was found in exercisers and specifically among omnivores (55.2 mg/dL) while the lowest level was found in exercisers who were strict vegetarians (Table 1 and Figure 1).

Figure 1. Mean HDL-C levels (mg/dL) according to diet group and exercise.

Table 2 shows the association between diet type, exercise, and HDL. After adjusting for sex, age, TC, TG, LDL-C, WHR, BMI, body fat, smoking, drinking, and coffee intake, HDL-C levels were significantly higher in exercisers compared to non-exercisers. Compared with omnivores, strict vegetarians had lower levels of HDL-C (β = −5.705; p = 0.001) followed by the lacto-ovo vegetarians (β = −3.900; p < 0.001) and former vegetarians (β = −0.329; p = 0.475). The test for trend was significant (p < 0.001). After categorization based on exercise status, the decreasing trend in HDL among the different diet types was more striking in the exercise group (Table 3). The decrease was in a dose-response manner (p < 0.001). The β values were −13.984 (p < 0.001) for strict vegetarians, −4.419 (p < 0.001) for lacto-ovo...
vegetarians, and −1.864 (p = 0.019) for former vegetarians, respectively. Further analyses showed antagonistic interactions between diet and exercise (p = 0.009).

Table 1. Mean HDL-C levels among study participants by exercise level and diet type.

| Variables                      | No Exercise (n = 5563) | Exercise (n = 4025) | p-Value |
|--------------------------------|------------------------|---------------------|---------|
| Diet Type                      | N Mean HDL (SE)        | N Mean HDL (SE)     |         |
| Omnivore                       | 4927 53.31 (0.19)      | 3662 55.20 (0.22)   | 0.0003  |
| Former vegetarian              | 353 54.56 (0.75)       | 191 53.21 (0.89)    |         |
| Lacto-ovo vegetarian           | 254 50.01 (0.71)       | 163 49.78 (0.93)    |         |
| Strict vegetarian              | 29 49.73 (1.90)        | 9 47.00 (3.05)      |         |
| Sex                            |                        |                     |         |
| Female                         | 3061 57.84 (0.24)      | 2101 59.36 (0.29)   | 0.0062  |
| Male                           | 2502 47.56 (0.22)      | 1924 49.97 (0.26)   |         |
| Age (years)                    |                        |                     | <0.0001 |
| ≤40                            | 2051 53.90 (0.29)      | 526 55.11 (0.59)    |         |
| 41–50                          | 1713 53.08 (0.32)      | 884 55.13 (0.45)    |         |
| 51–60                          | 1238 52.87 (0.37)      | 1514 54.52 (0.34)   |         |
| >60                            | 561 51.91 (0.52)       | 1101 55.03 (0.41)   |         |
| TC (mg/dl)                     |                        |                     | <0.0001 |
| <200                           | 3377 51.88 (0.21)      | 2228 52.55 (0.26)   |         |
| ≥200                           | 2186 55.28 (0.29)      | 1797 57.75 (0.33)   |         |
| TG (mg/dl)                     |                        |                     | 0.0051  |
| <150                           | 4327 56.05 (0.19)      | 3226 57.36 (0.23)   |         |
| ≥150                           | 1236 43.31 (0.25)      | 799 44.82 (0.32)    |         |
| LDL-C (mg/dl)                  |                        |                     | 0.0241  |
| <130                           | 3482 53.74 (0.24)      | 2428 54.95 (0.29)   |         |
| ≥130                           | 2081 52.34 (0.25)      | 1597 54.74 (0.30)   |         |
| WHR                            | Male <0.9; Female <0.8 |                     | 0.1157  |
| Male ≥0.9; Female ≥0.8         | 3413 52.15 (0.22)      | 2533 54.29 (0.26)   |         |
| BMI (Kg/m²)                    | <18.5                  |                     | <0.0001 |
| 18.5 ≤ BMI < 24                | 179 65.42 (1.07)       | 71 68.37 (1.78)     |         |
| 24 ≤ BMI < 27                  | 2604 57.56 (0.25)      | 1971 58.68 (0.31)   |         |
| BMI ≥ 27                       | 1588 49.87 (0.29)      | 1264 52.21 (0.34)   |         |
| Body Fat (%)                   |                         |                     | <0.0001 |
| Male <25; Female <30 (Ref)     | 2789 55.64 (0.26)      | 2250 56.21 (0.30)   |         |
| Male ≥25; Female ≥30           | 2774 50.78 (0.23)      | 1775 53.18 (0.30)   |         |
| Smoking habit                  | No                     |                     | <0.0001 |
| Former                         | 4260 54.89 (0.20)      | 3186 56.31 (0.24)   |         |
| Current                        | 560 48.79 (0.48)       | 543 50.16 (0.51)    |         |
| Drinking                       | No                     |                     | <0.0001 |
| Former                         | 5021 53.48 (0.18)      | 3588 55.37 (0.23)   |         |
| Current                        | 128 45.09 (0.94)       | 153 47.90 (0.86)    |         |
| Coffee drinking                | No                     |                     | <0.0001 |
| Yes                            | 3743 52.57 (0.21)      | 2757 54.52 (0.25)   |         |
|                                |                        |                     | 0.2096  |

Data are expressed as means ± SE. TC indicates total cholesterol; TG, triglycerides; LDL, low-density lipoprotein; WHR, waist-hip ratio; BMI, body mass index.
Table 2. Association of HDL-C with diet type and associated factors.

| Variable                        | B-Coefficient | p-Value | B-Coefficient | p-Value |
|--------------------------------|---------------|---------|---------------|---------|
| Diet Type (Ref: Omnivore), n = 8589 |               |         |               |         |
| Former vegetarian, n = 544       | −0.306        | 0.5064  | −1.864        | 0.0194  |
| Lacto-ovo vegetarian, n = 417     | −3.894        | <0.0001 | −4.419        | <0.0001 |
| Strict vegetarian, n = 38        | −5.683        | 0.0008  | −13.984       | <0.0001 |
| P for trend                      |               |         |               |         |
| Exercise (Ref: no)               |               |         |               |         |
| Yes                             | 1.146         | <0.0001 |               |         |
| Sex (Ref: female)                |               |         |               |         |
| Male                            | −7.841        | <0.0001 |               |         |
| Age (Ref: 30–40)                 |               |         |               |         |
| 41–50                           | 0.144         | 0.6253  | −0.594        | 0.3204  |
| 51–60                           | −0.318        | 0.3011  | −1.297        | 0.0208  |
| 61–70                           | −0.185        | 0.6053  | −0.646        | 0.2771  |
| TC (Ref: <200)                   |               |         |               |         |
| ≥200                            | 10.282        | <0.0001 |               |         |
| TG (Ref: <150)                   |               |         |               |         |
| ≥150                            | −10.168       | <0.0001 |               |         |
| LDL-C (Ref: <130)                |               |         |               |         |
| ≥130                            | −6.142        | <0.0001 |               |         |
| WHR (Ref: Normal)               |               |         |               |         |
| Abnormal                        | −2.281        | <0.0001 |               |         |
| BMI (Ref: 18.5 ≤ BMI < 24)       |               |         |               |         |
| <18.5                           | 5.602         | <0.0001 |               |         |
| 24 ≤ BMI < 27                   | −3.159        | <0.0001 |               |         |
| BMI ≥ 27                        | −4.469        | <0.0001 |               |         |
| Body Fat Rate (Ref: Normal)      |               |         |               |         |
| Abnormal                        | −1.758        | <0.0001 |               |         |
| Smoking habit (Ref: no)          |               |         |               |         |
| Former                          | −0.463        | 0.2094  | −0.483        | 0.4569  |
| Current                         | −2.051        | <0.0001 |               |         |
| Drinking (Ref: no)               |               |         |               |         |
| Former                          | −0.483        | 0.4569  |               |         |
| Current                         | 4.296         | <0.0001 |               |         |
| Coffee drinking (Ref: no)        |               |         |               |         |
| Yes                             | 0.592         | 0.0099  |               |         |

Ref. = reference group.

Table 3. Association of HDL with diet type based on physical exercise.

| Variables                        | No Exercise (n = 5563) | Exercise (n = 4025) |
|----------------------------------|------------------------|---------------------|
|                                  | β-Coefficient | p-Value | β-Coefficient | p-Value |
| Diet Type (Ref: Omnivore), n = 8589 |            |         |            |         |
| Former vegetarian, n = 544       | 0.549        | 0.3263  | −1.864       | 0.0194  |
| Lacto-ovo vegetarian, n = 417     | −3.563       | <0.0001 | −4.419       | <0.0001 |
| Strict vegetarian, n = 38        | −3.134       | 0.0963  | −13.984      | <0.0001 |
| P for trend                      |             |         |             | <0.0001 |
| Sex (Ref: female)                |             |         |             | <0.0001 |
| Male                             | −7.840       | <0.0001 | −7.960       | <0.0001 |
| Age (Ref: 30–40)                 |             |         |             |         |
| 41–50                            | 0.341        | 0.3129  | −0.594       | 0.3204  |
| 51–60                            | 0.216        | 0.5708  | −1.297       | 0.0208  |
| 61–70                            | −0.558       | 0.2643  | −0.646       | 0.2771  |
Table 3. Cont.

| Variables                        | No Exercise (n = 5563) | Exercise (n = 4025) |
|----------------------------------|------------------------|---------------------|
|                                  | β-Coefficient | p-Value | β-Coefficient | p-Value |
| TC (Ref: <200) ≥200              | 10.022       | <0.0001 | 10.625       | <0.0001 |
| TG (Ref: <150) ≥150              | -9.750       | <0.0001 | -10.798      | <0.0001 |
| LDL-C (Ref: <130) ≥130           | -5.711       | <0.0001 | -6.691       | <0.0001 |
| WHR (Ref: Ref: Normal) Abnormal  | -2.233       | <0.0001 | -2.437       | <0.0001 |
| BMI (Ref: 18.5 ≤ BMI < 24) <18.5 | 5.016        | <0.0001 | 7.234        | <0.0001 |
| 24 ≤ BMI < 27                   | -3.450       | <0.0001 | -2.738       | <0.0001 |
| BMI ≥ 27                        | -4.532       | <0.0001 | -4.344       | <0.0001 |
| Body Fat Rate (Ref: Normal) Abnormal | -1.833    | <0.0001 | -1.710       | 0.0001  |
| Smoking habit (Ref: no) Former   | -0.647       | 0.1910  | -0.123       | 0.8263  |
| Current                         | -2.375       | <0.0001 | -1.646       | 0.0196  |
| Drinking (Ref: no) Former       | -0.088       | 0.9253  | -0.826       | 0.3658  |
| Current                         | 5.406        | <0.0001 | 2.6732       | 0.0001  |
| Coffee drinking (Ref: no) Yes    | 0.636        | 0.0302  | 0.529        | 0.1508  |

Diet * exercise (p < 0.0001). Ref. = reference group.

4. Discussion

To our knowledge, this study is the first to examine the combined effect of diets and exercise on HDL cholesterol levels in Taiwan. We found that vegetarian diets were associated with lower HDL-C levels. Similar results have been previously reported [17]. We also found that when compared with omnivorous diet, strict vegetarian diets were associated with lower HDL-C (β = -5.683) followed by Lacto-ovo vegetarian (β = -3.894) and former vegetarian (β = -0.306) diets. Results from a previous meta-analysis showed no differences between plasma HDL-C of vegetarians and omnivores [26]. However, the study is limited in that it was based on unadjusted estimates. In the current study, we adjusted for several variables. In another study, a vegetarian diet was associated with a 3.9 mg/dL decrease in HDL-C [27]. Another study investigating the impact of diet on lipid profile reported significant associations with other lipid fractions but not HDL-C [6].

Physical activity alone has a positive impact on HDL cholesterol [12]. Of the lipid fractions, HDL-C is reported to be the most sensitive to exercise [11]. However, we found that the addition of exercise led to greater reductions in HDL-C levels of strict vegetarians (β = -13.984) and lacto-ovo vegetarians (β = -4.419) compared with the omnivores. Only modest reductions were observed in former vegetarians (β = -1.864). Nonetheless, the test for trend was found to be significant. In their review, Ho and colleagues found that a combination of diet and exercise intervention led to greater improvements in HDL-C, but the difference became nonsignificant at one year of follow-up [15]. However, we found in the current study that regular exercise in conjunction with strict vegetarian diets were associated with greater reductions in HDL cholesterol levels. Increased HDL-C has been linked to a running distance in vegetarians [19]. However, the diverse forms of vegetarian diets were not considered. While assessing HDL-C levels, previous studies have mostly considered exercise and diets separately. In the current study, it was necessary to combine both variables considering their significant impact on metabolic risk factors associated with cardiovascular disease [15].
Physical inactivity and poor diet are responsible for heart disease, which is the second leading cause of death in Taiwan. Based on a 2015 survey conducted by the Health Promotion Administration (HPA), about 76% of Taiwanese individuals do not get sufficient exercise. However, efforts have been made to increase awareness of the benefits of exercise on health. Taiwan is one of the countries with the highest rate of vegetarianism. Such a plant-based culture has been cultivated by Buddhist vegetarian practices [28]. Despite this, the prevalence of heart disease in the Island remains relatively high. As mentioned above, there is evidence to show that plant-based diets have antioxidants and can protect against heart disease. Although a vegetarian diet has been associated with decreased HDL-C [29], exercising is considered to be an excellent way for vegetarians to boost their HDL-C levels [11]. Both the vegetable-rich diet and exercise training have been traditionally considered beneficial for cardiovascular health. However, based on the current study, a combination of these two factors appear detrimental. The underlying mechanism through which exercise plus a strict vegetarian diet would lower HDL-C remains to be clarified. Of note, a strict vegetarian diet does not contain dairy food and eggs, hence may not contain trans fatty acids and saturated fatty acids that can sufficiently raise HDL-C.

As stated above, HDL-C has been associated with heart diseases. However, causal associations between HDL-C and atherosclerotic cardiovascular disease (ASCVD) risk have been widely reported in epidemiologic but not Mendelian studies [30]. According to the 2019 European Society of Cardiology and European Atherosclerosis Society (ESC/EAS) Guidelines for the management of dyslipidemias, elevating levels of HDL-C do not reduce cardiovascular disease risk [30]. Nevertheless, updated dyslipidemia guidelines in Asia and the Middle East have suggested that HDL-C is important for improving risk estimates of ASCVD [2]. Of note, it is worth investigating HDL-C considering that dyslipidemia in Asia is mostly characterized by low-HDL-C as stated earlier. Moreover, region-wide guidelines for the management of dyslipidemia in Asia is yet to be fully established [2].

Despite our findings, the study limitations are worth mentioning. First, the information was based on self-report, hence we may not rule out the possibility of recall bias. Second, there was no information on the average daily nutrient intake. Besides, this study involved only a limited number of strict vegetarians who exercised regularly, so the results may have been influenced by individual variance. Finally, delineating between cardio-versus strength training and their impact on HDL-C would be valuable. However, our physical activity questionnaire did not have information on the appropriate intensity and energy expenditure measures.

5. Conclusions

Broadly speaking, we found that (1) HDL-C levels were higher in exercisers compared to non-exercisers. (2) Regular exercise in conjunction with strict vegetarian diets led to greater reductions in HDL cholesterol levels. Compared with omnivores, strict vegetarians were associated with lower HDL-C followed by lacto-ovo vegetarians. Based on these findings, regular exercise together with strict vegetarian diets might not serve as healthful behaviors to be implemented in everyday life considering the negative impact on HDL-C. We conclude that, while these results are significant, caution must be exercised. Stronger study designs are needed to understand whether associations observed are causal.

Author Contributions: Conceptualization, S.-L.C., O.N.N., W.-Y.L., C.C.H., M.-C.C. and Y.-P.L.; Data curation, K.-J.L., P.-H.C. and W.-Y.L.; Formal analysis, K.-J.L., P.-H.C. and C.C.H.; Methodology, S.-L.C., O.N.N., M.-C.C., C.-C.L. and Y.-P.L.; Resources, Y.-P.L.; Software, M.-C.C.; Supervision, M.-C.C. and Y.-P.L.; Writing—Original draft, S.-L.C.; Writing—Review & editing, K.-J.L., O.N.N., P.-H.C., W.-Y.L., C.C.H., C.-C.L. and Y.-P.L. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Ministry of Science and Technology (MOST 105-2627-M-040-002, 106-2627-M-040-002, 107-2627-M-040-002).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.
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