Effect of fish oil supplementation combined with high-intensity interval training in newly diagnosed non-obese type 2 diabetes: a randomized controlled trial

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(Received 20 July, 2019; Accepted 29 September, 2019)

The additive effect of high-intensity interval training to fish oil supplementation on newly diagnosed type 2 diabetes is unknown. 173 newly diagnosed type 2 diabetes patients were randomly assigned into the control group (received corn oil), fish oil group (eicosapentaenoic acid, EPA:docosahexaenoic acid, DHA = 3:2, total 2.0 g/day), and the fish oil + high-intensity interval training group. Three instructed high-intensity interval training sessions (Monday, Wednesday, and Friday; 10 × 60-s cycling bouts) were performed for 3 months. Glycaemic control was assayed by serum haemoglobin A1c, fast glucose, fast insulin, and adiponectin. Homeostatic model assessment of insulin resistance was utilized to determine the homeostasis of pancreatic function. Fat mass, triglycerides, total cholesterol, low-density lipoproteins, and high-density lipoproteins were measured to indicate cardiovascular risk. Within and between groups analysis were performed with linear mixed-effects modeling (95% CIs and p values). When compared with fish oil, fish oil + high-intensity interval training intervention has significant additive beneficial effects on haemoglobin A1c (p<0.01), fast glucose (p<0.001), homeostatic model assessment of insulin resistance (p<0.05), adiponectin (p<0.05), fat mass (p<0.01), and total cholesterol (p<0.01), but not on fast insulin level to newly diagnosed non-obese type 2 diabetes. High-intensity interval training has an additive effect on fish oil supplementation on glycaemic control, insulin resistance, cardiovascular risk, and fat mass, which indicates the potential necessity of combining high-intensity interval training with fish oil.

Key Words: fish oil, high-intensity interval training, type 2 diabetes, lipoproteins

Characterized by hyperglycemia, relative lack of insulin, and insulin resistance, type 2 diabetes (T2D) has turned into a serious and prevalent threat to human health, which primarily occurs as a result of obesity and lack of exercise. Alternative therapy focused on lifestyle intervention to lower cardiovascular risk factors and maintain normal blood glucose levels is recommended to improve patients’ life expectancy.

Unsaturated fatty acids are commonly recommended for dietary adjustments in T2D to decrease the risk of cardiovascular disease, including ischemic heart disease and stroke. Among which, omega-3 polyunsaturated fatty acids (ω-3 PUFAs) shows encouraging effects on insulin sensitivity, glycemic control, and chronic inflammation. Fish and other marine oils are available methods to supplement ω-3 PUFAs, which contain ω-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

It must be mentioned that a great deal of controversy in recent years about the role of fish oil in diabetes, and recent meta-analyses reach different conclusions about its potential impact.

Moderate to vigorous exercise per week (more than 150 min) is recommended by the American Diabetes Association for the prevention and treatment of T2D. It is fantastic to realize that high-intensity interval training (HIIT) can elicit the same physiological remodeling and health benefit as traditional exercise training or moderate-intensity continuous training with less time commitment, less total exercise volume, and high compliance. It is further testified that two weeks of low-volume HIIT can promote glycemic regulation and increase insulin sensitivity in healthy adults.

As a time-efficient and easy to follow exercise, the additive effect of low-volume HIIT combined with fish oil supplementation on T2D has not been indicated, especially in Chinese with less obese T2D patients compared with developed countries. Thus, this randomized controlled trial (RCT) is performed to detect the additive effect of HIIT on the newly diagnosed non-obese Chinese T2D patients with well-arranged fish oil supplementation.

Methods and Materials

Participants. This study was conducted in the fourth Hospital of Hebei Medical University between October 2017 and December 2018. Newly diagnosed T2D patients (within the past 1–2 month) were screened, and non-obese patients (fat mass <30%) with glycated haemoglobin A1c (HbA1c) <7.8%, impaired glucose tolerance but not requiring hypoglycaemic therapy, and light physical activity evaluated by the International Physical Activity Questionnaire (IPAQ) were enrolled. And the detailed clinical information was supplied in Table 1. Exclusion criteria were diabetes patients requiring the usage of any medication or dietary supplements to minimize the confounding effects of medication usage; with eating disorders, other physical disorders, and psychological deficits; high lipidemia; high hyperinsulinemia; abnormal blood pressure; or attending another clinical trial.

A total of 239 participants were eligibility, among which, 25 participants were excluded, 19 participants did not meet the inclusion criteria after serious consideration, and 22 participants...
did not respond (15 subjects declined to participate and 7 subjects were not available). Then, the remaining participants (n = 173) were randomized into the control group (n = 59), fish oil (FO) group (n = 54), and FO + HIIT group (n = 60). The ethics approval was obtained from the Medical Ethics Committee of the fourth Hospital of Hebei Medical University according to the Declaration of Helsinki and the written informed consents were given by all the participants. Total 10 participants withdrew from the cohort study for various reasons: unable to follow up, unwilling to proceed, or unable to comply with the intervention (detailed information could be referred in Fig. 1).

**Fish oil and corn oil capsules preparation.** Fish oil and control corn oil (CO) were standardized to 1 g per capsule with same appearance and taste, which were manufactured by the Neptunus Bioengineering Co., Ltd (Hangzhou, China) as previous reported. 500 mg of EPA + DHA (EPA:DHA = 3:2) were provided by each FO capsule, and other major fatty acids, such as C14:0 (34.6 mg), C16:0 (71.4 mg), C16:1 (56 mg), C18:1n-9 (58.4 mg), and C20:0 (39.4 mg) were also supplied. 2.0 g/day EPA plus DHA was given, which were consistent with previous trials and between the upper safe limit recommended by the US Food and Drug Administration (FDA) (3 g/day) and Europe.

### Table 1. Baseline characteristics of the study participants

|                          | Control (n = 54) | FO (n = 51) | FO + HIIT (n = 58) |
|--------------------------|-----------------|------------|-------------------|
| Age (years)              | 43.7 ± 8.6      | 45.6 ± 5.9 | 44.3 ± 6.2        |
| Sex, n (%)               |                 |            |                   |
| Male                     | 29 (49%)        | 27 (50%)   | 30 (50%)          |
| Female                   | 30 (51%)        | 27 (50%)   | 30 (50%)          |
| Duration of diabetes (days) | 28.0 (32.0)   | 34.0 (29.0) | 31.0 (35.0)       |
| HbA1c (%)                | 7.47 ± 0.25     | 7.39 ± 0.35| 7.46 ± 0.34       |
| Glucose (mmol/L)         | 8.68 ± 0.35     | 8.92 ± 0.34| 8.77 ± 0.51       |
| Insulin (mIU/L)          | 13.64 ± 1.39    | 13.56 ± 1.58| 13.58 ± 1.40     |
| HOMA-IR                  | 5.02 ± 0.43     | 4.90 ± 0.41| 5.08 ± 0.60       |
| Triglycerides (mmol/L)   | 1.94 ± 0.48     | 1.95 ± 0.66| 1.90 ± 0.49       |
| Total cholesterol (mmol/L)| 4.79 ± 0.52    | 4.94 ± 0.54| 5.03 ± 0.48       |
| LDL cholesterol (mmol/L) | 3.01 ± 0.31     | 3.04 ± 0.35| 3.03 ± 0.36       |
| HDL cholesterol (mmol/L) | 1.22 ± 0.06     | 1.15 ± 0.04| 1.18 ± 0.03       |
| BMI (kg/m²)              | 25.15 ± 2.50    | 24.69 ± 2.37| 25.28 ± 2.35     |
| Weight (kg)              | 67.50 ± 7.56    | 69.38 ± 7.12| 68.24 ± 6.47     |
| Fat mass (%)             | 28.58 ± 1.37    | 28.47 ± 1.38| 29.38 ± 1.74     |
| Systolic blood pressure (mmHg) | 115.7 ± 8.8 | 116.3 ± 9.0 | 115.9 ± 7.4 |
| Diastolic blood pressure (mmHg) | 79.5 ± 9.2   | 77.0 ± 7.8 | 78.6 ± 8.9 |
| EPA (%FAME)              | 0.88 ± 0.05     | 0.92 ± 0.07| 0.90 ± 0.11       |
| DHA (%FAME)              | 2.32 ± 0.51     | 2.38 ± 0.57| 2.40 ± 0.35       |
| Adiponectin (μg/ml)      | 5.05 ± 0.33     | 5.09 ± 0.33| 4.97 ± 0.28       |

**Fig. 1.** Flow chart of the study. FO, fish oil; HIIT, high intensity interval training.
Major fatty acids, such as C16:0 (121 mg), C18:1n-9 (299 mg), and C18:2n-6 (534 mg), were added in each CO capsule. **High-intensity interval training.** HIIT was performed on a bicycle ergometer (LifeCycle R1, Life Fitness, Schiller Park, IL) with constant watt mode arrange from 80 to 100 revolutions/min pedal cadence, which could elicit a ~90% maximum heat rate during the intervals. Each training session comprised a warm-up (3-min), 10 × 60-s cycling intervals interspersed with 60-s of recovery, and 2-min cool-down to rest, for a total of 25 min. Three supervised HIIT sessions (Monday, Wednesday, and Friday) were performed every week for a total of three months.

**Clinical characteristics assessment.** Body weight, percentage body fat mass, diastolic blood pressure, and systolic blood pressure were determined with a bioimpedance analyzer (HLC-723G8, Tosoh corp., Tokyo, Japan). Serum glucose, triglycerides (TGs), total cholesterol (TC), high-density lipoproteins (HDL) cholesterol, and low-density lipoproteins (LDL) cholesterol were determined with an automatic biochemical analyzer (AU2700 biochemistry analyzer, Olympus, Rungis, France). Serum insulin was tested with an electrochemiluminescence immunoassay in the automated analyzer (E170, Roche Diagnostics, Indianapolis, IN). Pancreatic homeostasis model assessment-estimated insulin resistance (HOMA-IR) index was calculated as: HOMA-IR = [glucose (mmol/L) × insulin (μIU/ml)]/22.5.

**Statistical analysis.** Categorical variables were shown as frequencies with percentages and normally distributed variables were shown as means ± SDs. For the temporal trends analysis within the group, linear mixed-effects modeling (95% CIs and p values) was utilized for repeated measures over time (month 1, month 2, and month 3), which was further utilized to explore the additive beneficial health effects between groups at month 3.

**Results**

**Participants enrolled.** 173 participants were included in this trial on month 1, while 3 months later, 5 participants in the control group, 3 participants in the FO group, and 2 participants in the FO + HIIT group withdrew. Finally, total of 163 participants were analyzed in this investigation (Fig. 1): 54 participants (age: 43.7 ± 8.6 years; 51.0% female) in the control group (CO

| Table 2. Effects of fish oil supplementation alone or with HIIT on glycemic control in newly diagnosed type 2 diabetes |
| Variables | n | Mean ± SD | From baseline to Month 9, mean (95%CI) |
|-----------|---|----------|-------------------------------------|
| **HbA1c (%)** | | | Between group difference in change |
| Control | 54 | 7.47 ± 0.25 | 7.46 ± 0.19 | 7.41 ± 0.22 | 7.44 ± 0.27 | -0.01 (-0.02, 0.002) | NA |
| FO | 51 | 7.39 ± 0.35 | 7.16 ± 0.43 | 6.98 ± 0.41 | 6.81 ± 0.45 | -0.52 (-0.66, -0.28) | NA |
| FO + HIIT | 58 | 7.46 ± 0.34 | 7.19 ± 0.41 | 7.02 ± 0.30 | 6.74 ± 0.24 | -0.72 (-0.96, -0.48) | NA |
| FO vs Control | NA | NA | NA | NA | NA | -0.55 (-0.75, -0.35) | NA |
| FO vs HIIT | NA | NA | NA | NA | NA | -0.84 (-1.04, -0.64) | NA |
| FO + HIIT vs Control | NA | NA | NA | NA | NA | -0.30 (-0.49, -0.09) | NA |
| **Glucose (mmol/L)** | | | | | | | |
| Control | 54 | 8.68 ± 0.35 | 8.59 ± 0.43 | 8.62 ± 0.34 | 8.70 ± 0.42 | 0.02 (-0.37, 0.41) | NA |
| FO | 51 | 8.92 ± 0.34 | 8.78 ± 0.43 | 8.75 ± 0.44 | 8.73 ± 0.40 | -0.19 (-0.58, 0.2) | NA |
| FO + HIIT | 58 | 8.77 ± 0.51 | 8.70 ± 0.38 | 8.32 ± 0.55 | 7.83 ± 0.48 | -0.93 (-1.32, -0.54) | NA |
| FO vs Control | NA | NA | NA | NA | NA | -0.21 (-0.53, 0.11) | NA |
| FO vs HIIT | NA | NA | NA | NA | NA | -0.96 (1.28, -0.62) | NA |
| FO vs FO + HIIT | NA | NA | NA | NA | NA | -0.75 (-1.07, -0.43) | NA |
| **Insulin (μIU/L)** | | | | | | | |
| Control | 54 | 13.64 ± 1.39 | 13.31 ± 1.41 | 13.52 ± 1.31 | 13.57 ± 1.38 | -0.05 (-0.54, 0.44) | NA |
| FO | 51 | 13.56 ± 1.58 | 13.67 ± 1.61 | 13.70 ± 1.43 | 13.85 ± 1.42 | 0.29 (-0.2, 0.79) | NA |
| FO + HIIT | 58 | 13.58 ± 1.40 | 13.71 ± 1.43 | 13.82 ± 1.45 | 13.89 ± 1.45 | 0.31 (-0.18, 0.80) | NA |
| FO vs Control | NA | NA | NA | NA | NA | 0.34 (-0.15, 0.83) b | NA |
| FO vs HIIT | NA | NA | NA | NA | NA | -0.36 (-0.13, 0.85) b | NA |
| FO vs FO + HIIT | NA | NA | NA | NA | NA | 0.02 (-0.47, 0.51) | NA |
| **HOMA-IR** | | | | | | | |
| Control | 54 | 5.02 ± 0.43 | 5.09 ± 0.40 | 5.11 ± 0.70 | 4.92 ± 0.47 | -0.1 (-0.63, 0.52) | NA |
| FO | 51 | 4.90 ± 0.41 | 4.59 ± 0.39 | 4.41 ± 0.35 | 3.87 ± 0.35 | -1.03 (-1.53, -0.50) | NA |
| FO + HIIT | 58 | 5.08 ± 0.60 | 4.73 ± 0.41 | 4.41 ± 0.35 | 3.67 ± 0.32 | -1.31 (-1.84, -0.78) | NA |
| FO vs Control | NA | NA | NA | NA | NA | -0.93 (-1.55, -0.31) | NA |
| FO vs HIIT | NA | NA | NA | NA | NA | -1.41 (-2.03, -0.79) | NA |
| FO vs FO + HIIT | NA | NA | NA | NA | NA | -0.48 (-1.10, 0.14) | NA |
| **Adiponectin (μg/ml)** | | | | | | | |
| Control | 54 | 5.05 ± 0.33 | 4.98 ± 0.38 | 5.02 ± 0.44 | 5.08 ± 0.26 | -0.03 (-0.741, 0.68) | NA |
| FO | 51 | 5.09 ± 0.33 | 5.27 ± 0.35 | 5.53 ± 0.33 | 5.28 ± 0.33 | 0.19 (-0.52, 0.90) | NA |
| FO + HIIT | 58 | 4.97 ± 0.28 | 5.22 ± 0.23 | 5.54 ± 0.26 | 5.25 ± 0.27 | 0.28 (-0.43, 0.99) | NA |
| FO vs Control | NA | NA | NA | NA | NA | 0.16 (-0.18, 0.50) | NA |
| FO vs HIIT | NA | NA | NA | NA | NA | 0.25 (-0.09, 0.59) | NA |
| FO vs FO + HIIT | NA | NA | NA | NA | NA | 0.08 (-0.26, 0.42) | NA |

Values are expressed as means ± SDs. *p<0.001, †p<0.01, ‡p<0.05.

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HIIT intervention shows an additive effect on glycemic control. The primary goal of life intervention is to improve insulin sensitivity in terms of glycemic control, and such effects of fish oil and or HIIT were shown in Table 2. The levels of HbA1c, fast glucose, HOMA-IR, and adiponectin could be notably altered with baseline (p<0.001 or p<0.01) affected by both FO intervention and FO + HIIT intervention at month 3 when compared with the control group, which could also be altered by FO intervention and FO + HIIT intervention at month 3 compared with baseline (p<0.001 or p<0.01) (Table 3). All of these indicated that both FO intervention and FO + HIIT intervention could significantly promote glycemic control and insulin sensitivity in the newly diagnosed T2D. It was worth noting that the levels of HbA1c, fast glucose, HOMA-IR, and adiponectin could be notably altered by FO + HIIT intervention when compared with FO intervention at month 3 (p<0.001 or p<0.05), which suggested FO + HIIT intervention could have additive beneficial health effects than sole FO intervention. It must be pointed out that no significant between-group change (FO vs FO + HIIT) of fast insulin was observed at month 3, while the change in HOMA-IR represented a significant improvement in tissue insulin resistance.

HIIT intervention shows an additive effect on cardiovascular adaptations. The levels of triglycerides, total cholesterol, and LDL cholesterol could be notably (p<0.001 or p<0.01) affected by both FO and FO + HIIT intervention at month 3 when compared with the control group, which could also be altered by FO intervention and FO + HIIT intervention at month 3 compared with baseline (p<0.001 or p<0.01) (Table 3). All of these indicated that both FO and FO + HIIT intervention could significantly affect the levels of triglycerides, total cholesterol, and LDL cholesterol in the newly diagnosed T2D. While as to the fat mass, FO alone did not affect it, while FO + HIIT could significantly affect it at 3 months when compared with the baseline (p<0.001). It was further demonstrated that FO + HIIT intervention could change fat mass and total cholesterol level when compared with FO intervention, which indicated that HIIT had an additive effect on beneficial cardiovascular adaptations and fat mass when combined with FO intervention to lower cardiovascular risk.

### Table 3. Effects of fish oil supplementation alone or with HIIT on Lipid variables in newly diagnosed type 2 diabetes

| Variables                | n   | Baseline Mean ± SD | Month 1 Mean ± SD | Month 2 Mean ± SD | Month 3 Mean ± SD | Within group change | Between group change |
|--------------------------|-----|--------------------|-------------------|-------------------|-------------------|---------------------|---------------------|
| Fat mass (%)             |     |                    |                   |                   |                   |                     |                     |
| Control                  | 54  | 28.58 ± 1.37       | 28.65 ± 1.52      | 28.71 ± 1.65      | 28.61 ± 0.56      | 0.03 (–0.37, 0.43)  | NA                  |
| FO                       | 51  | 28.47 ± 1.38       | 28.43 ± 1.58      | 28.40 ± 1.50      | 28.31 ± 1.46      | –0.16 (–0.56, 0.34) | NA                  |
| FO + HIIT                | 58  | 29.38 ± 1.74       | 29.18 ± 1.50      | 28.67 ± 1.58      | 28.65 ± 1.33      | –0.73 (–1.15, –0.33)*| NA                  |
| FO vs Control            | NA  | NA                 | NA                | NA                | NA                | –0.19 (–0.60, 0.22) | NA                  |
| FO + HIIT vs Control     | NA  | NA                 | NA                | NA                | NA                | –0.76 (–1.17, –0.35)*| NA                  |
| FO vs FO + HIIT          | NA  | NA                 | NA                | NA                | NA                | –0.57 (–0.98, –0.16)*| NA                  |
| Triglycerides (mmol/L)   |     |                    |                   |                   |                   |                     |                     |
| Control                  | 54  | 1.94 ± 0.48        | 1.97 ± 0.23       | 2.01 ± 0.34       | 2.05 ± 0.37       | 0.11 (–0.04, 0.26)*| NA                  |
| FO                       | 51  | 1.95 ± 0.66        | 1.89 ± 0.36       | 1.79 ± 0.16       | 1.63 ± 0.20       | –0.32 (–0.47, –0.17)*| NA                  |
| FO + HIIT                | 58  | 1.90 ± 0.49        | 1.85 ± 0.38       | 1.72 ± 0.36       | 1.54 ± 0.25       | –0.36 (–0.51, –0.21)*| NA                  |
| FO vs Control            | NA  | NA                 | NA                | NA                | NA                | –0.43 (–0.60, –0.26)*| NA                  |
| FO + HIIT vs Control     | NA  | NA                 | NA                | NA                | NA                | –0.49 (–0.66, –0.32)*| NA                  |
| FO vs FO + HIIT          | NA  | NA                 | NA                | NA                | NA                | –0.06 (–0.23, 0.11) | NA                  |
| Total cholesterol (mmol/L) |     |                    |                   |                   |                   |                     |                     |
| Control                  | 54  | 4.79 ± 0.52        | 5.29 ± 0.52       | 5.38 ± 0.54       | 5.25 ± 0.47       | 0.45 (0.08, 0.82)*  | NA                  |
| FO                       | 51  | 4.94 ± 0.54        | 4.95 ± 0.61       | 4.94 ± 0.52       | 4.67 ± 0.58       | –0.27 (–0.64, 0.12)*| NA                  |
| FO + HIIT                | 58  | 5.03 ± 0.48        | 5.01 ± 0.62       | 4.76 ± 0.51       | 4.56 ± 0.52       | –0.47 (–0.84, –0.10)*| NA                  |
| FO vs Control            | NA  | NA                 | NA                | NA                | NA                | –0.73 (–1.03, –0.43)*| NA                  |
| FO + HIIT vs Control     | NA  | NA                 | NA                | NA                | NA                | –0.93 (–1.23, –0.63)*| NA                  |
| FO vs FO + HIIT          | NA  | NA                 | NA                | NA                | NA                | –0.20 (–0.50, 0.1)*  | NA                  |
| LDL cholesterol (mmol/L) |     |                    |                   |                   |                   |                     |                     |
| Control                  | 54  | 3.01 ± 0.31        | 3.03 ± 0.29       | 3.04 ± 0.35       | 3.10 ± 0.34       | 0.09 (–0.02, 0.20)  | NA                  |
| FO                       | 51  | 3.04 ± 0.35        | 2.92 ± 0.35       | 2.79 ± 0.34       | 2.63 ± 0.35       | –0.41 (–0.52, –0.3)*| NA                  |
| FO + HIIT                | 58  | 3.03 ± 0.36        | 2.98 ± 0.37       | 2.74 ± 0.35       | 2.56 ± 0.34       | –0.44 (–0.55, –0.33)*| NA                  |
| FO vs Control            | NA  | NA                 | NA                | NA                | NA                | –0.50 (–0.64, –0.36)*| NA                  |
| FO + HIIT vs Control     | NA  | NA                 | NA                | NA                | NA                | –0.54 (–0.68, –0.40)*| NA                  |
| FO vs FO + HIIT          | NA  | NA                 | NA                | NA                | NA                | –0.04 (–0.18, 0.10) | NA                  |
| HDL cholesterol (mmol/L) |     |                    |                   |                   |                   |                     |                     |
| Control                  | 54  | 1.22 ± 0.06        | 1.19 ± 0.08       | 1.18 ± 0.03       | 1.20 ± 0.03       | –0.02 (–0.29, –0.07) | NA                  |
| FO                       | 51  | 1.15 ± 0.04        | 1.16 ± 0.04       | 1.18 ± 0.04       | 1.21 ± 0.02       | 0.06 (–0.05, 0.17)* | NA                  |
| FO + HIIT                | 58  | 1.18 ± 0.03        | 1.19 ± 0.03       | 1.22 ± 0.08       | 1.27 ± 0.07       | 0.09 (–0.02, 0.20)* | NA                  |
| FO vs Control            | NA  | NA                 | NA                | NA                | NA                | 0.08 (–0.04, 0.20)  | NA                  |
| FO + HIIT vs Control     | NA  | NA                 | NA                | NA                | NA                | 0.11 (–0.01, 0.23)* | NA                  |
| FO vs FO + HIIT          | NA  | NA                 | NA                | NA                | NA                | 0.03 (–0.09, 0.15)  | NA                  |

Values are expressed as means ± SDs. *p<0.001. *p<0.01. *p<0.05.
Discussion

Obese participants were not enrolled in this RCT, for obesity is not common in Chinese T2D patients, while such patients are recommended to lose weight by the American Diabetes Association. Although the results need further multicenter testification, this RCT proposes a relative easy way to compliance and demonstrates that when compared with FO, FO + HIIT intervention have significant additive beneficial effects on improving the HbA1c, fast glucose, HOMA-IR, adiponectin, fat mass, and total cholesterol, but not on fast insulin level to newly diagnosed non-obese T2D. In another word, additional HIIT intervention can enhance the effects of FO on the insulin resistance as indicated by HOMA-IR and adiponectin (an insulin-sensitizing hormone), change the metabolism as indicated by HbA1c, glucose, and total cholesterol, and alter fat mass.

A lack of physical activity is believed to cause 7% of T2D, and it is demonstrated that decreased content or biogenesis of mitochondria can lead to insulin resistance and T2D. While, six sessions of low-volume HIIT over 2 weeks can significantly up-regulate the mitochondrial capacity of skeletal muscle, which may contribute to the alleviation of T2D. In rat, it is proved that both insulin-dependent and -independent glucose uptake can be improved by short-term replacement of starch with isomaltulose. It is further testified that 2 weeks of HIIT on cycle ergometer can reduce hyperglycemia, ameliorate insulin action, and improve pancreatic β-cell function.

The type and characteristics of fats in the diet is vital, for saturated fat and trans fats increase the risk and polyunsaturated and monounsaturated fat decrease the risk of development of T2D. It should be mentioned that in contrast to our findings, a recent 16 RCTs meta-analysis suggests that the increased ω-3 PUFA intake does not show a beneficial effect on glycemic control in T2D patients, while the habitual intake of ω-3 and ω-6 PUFAs are not considered, which makes it hard to compare.

Therefore, to rule out the confounding effects of habitual ω-3 PUFAs consumption and maintain the optimal ratio of ω-3 to ω-6 PUFA, standardized fish oil capsule is applied in this investigation to minimize the heterogeneity. There is also another possibility for the inconsistent effects of FO supplementation on humans, which can be attributed to a threshold phospholipid enrichment in tissue membranes. Low dose and short-time duration of FO supplementation can not reach the threshold to metabolize both glucose and protein, and obtain observable values associated with positive health outcomes.

Although the additive effects of HIIT on fish oil supplementation about glycemic control, insulin resistance, cardiovascular risk, and fat mass beyond 3 months remain unclear and need further exploration with a longer duration in the newly diagnosed T2D patients, this investigation provides a novel and easy to follow option of fish oil supplementation combined with HIIT for patients with newly diagnosed T2D.

Conclusion

In summary, the FO + HIIT intervention is superior to FO intervention due to its greater effects on glycemic control, insulin resistance, cardiovascular risk, and fat mass.

Funding

The study was supported the Key Scientific and Technological Research Projects of Hebei Health and Family Planning Commission (20170203).

Conflict of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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