# Health Behavior and Metabolic Risk Factors Associated with Normal Weight Obesity in Adolescents

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## Abstract

### Objective

To explore health behaviors and metabolic risk factors in normal weight obese (NWO) adolescents compared with normal weight lean (NWL) peers.

### Design and Methods

A cross-sectional study of 18-year-old students (n = 182, 47% female) in the capital area of Iceland, with body mass index within normal range (BMI, 18.5–24.9 kg/m$^2$). Body composition was estimated via dual energy X-ray absorptiometry, fitness was assessed with maximal oxygen uptake (VO$_2$max) during treadmill test, dietary intake through 24-hour recall, questionnaires explained health behavior and fasting blood samples were taken. NWO was defined as normal BMI and body fat >17.6% in males and >31.6% in females.

### Results

Among normal weight adolescents, 42% (n = 76) were defined as NWO, thereof 61% (n = 46) male participants. Fewer participants with NWO were physically active, ate breakfast on a regular basis, and consumed vegetables frequently compared with NWL. No difference was detected between the two groups in energy- and nutrient intake. The mean difference in aerobic fitness was 5.1 ml/kg/min between the groups in favor of the NWL group (p<0.001). NWO was positively associated with having one or more risk factors for metabolic syndrome (Odds Ratio OR = 2.2; 95% confidence interval CI: 1.2, 3.9) when adjusted for sex. High waist circumference was more prevalent among NWO than NWL, but only among girls (13% vs 4%, p = 0.019).

### Conclusions

High prevalence of NWO was observed in the study group. Promoting healthy lifestyle with regard to nutrition and physical activity in early life should be emphasized regardless of BMI.

## Introduction

Several adult diseases originate from lifestyle factors achieved in early- life and adulthood [1–6]. A recent study from the US demonstrated that risk factors measured in childhood (5–20 years of age) and retained in adulthood predicted cardiovascular diseases and type 2 diabetes, 26 years later [7]. High body fat, especially visceral fat can affect metabolism and increase the risk for metabolic syndrome [8], which can develop into non-alcoholic fatty liver disease [9], cardiovascular diseases and type 2 diabetes [10].

Body mass index (BMI) fails to provide information on total body fatness, therefore a specific type of obesity has been defined; normal weigh obesity (NWO), which applies to individuals with BMI within normal range (BMI, 18.5–24.9 kg/m$^2$) but with excessive body fat [11]. NWO is associated with higher risk of metabolic syndrome, both in young adults [12] and older people [13]. Furthermore, high body fat is associated with higher waist circumference among adolescents [14], which is an independent risk factor, irrespective of BMI, for premature all-cause mortality [15].

Few studies have examined health behaviors associated with NWO, especially in early life. Using data on adolescents in Iceland, the objective of the study was to examine the difference in lifestyle between NWO and those within normal range of BMI with lower body fat (NWL). We further examined risk factors for metabolic syndrome between these two groups, as we hypothesized that those who were NWO were at higher risk of developing metabolic syndrome based on previous studies. Moreover we hypothesized that sedentary lifestyle and consumption of energy dense food items would be associated with NWO.

## Materials and Methods

### Study design and participants

Participants in this cross-sectional study were 18-year-old (17.7–18.9 y) high-school students from three high-schools located in the capital area of Iceland (Caucasian population). These were selected to insure a diverse group of participants by choosing schools offering both traditional academic studies and vocational education. A total of 383 students were randomly selected from the class registers and invited to participate via e-mail. Of those 275 agreed to participate (72% response rate). Since participants had to be apparently healthy and free from ailments medical history was recorded prior to participation.

Measurements for blood pressure, height, weight and waist circumference together with a face-to-face 24 hour dietary recall were conducted in each school. Aerobic fitness was measured in the laboratory on a second day and body composition and bone mineral density was examined with dual energy X-ray absorptiometry (DXA) at the Icelandic Heart Association on a third day. A fourth day was chosen for taking fasting blood samples in the morning; these were taken at the schools. During the course of the study participants answered questionnaires on health behaviors over the internet. Each participant finished all measurements within a span of 7–10 days. The study protocol including consent procedure was approved by the Icelandic Ethical Review Board (VSN07-125-S1), the Icelandic Data Protection Authority (S3612/2008) and the Icelandic Radiation Protection Institute (29092008–26). The principals in the high schools involved, gave permission to contact the students. Written informed consent was obtained from all study participants.

### Measurements

Blood pressure was measured with electronic monitor (ADC Advantage 6013) and the mean value of three measurements with one minute rest in between was used. Anthropometric

measurements were taken with participants wearing light clothing and without shoes, using a standard protocol. Height was measured to the nearest 0.1 cm (Seca 206; Hamburg, Germany) and weight to the nearest 0.1 kg using portable electronic scale (Seca 799). Body mass index was calculated as weight in kilograms divided by height in meters squared (kg/m$^2$). Waist circumference was measured to the nearest 0.1 cm at the narrowest place between the iliac crest and the bottom of the rib cage with a spring loaded inelastic measuring tape. Body composition and bone mineral density were estimated using DXA (GE Lunar IDXA software 11.40.004) after removing all metal objects.

Dietary intake was assessed by face-to-face 24-hour recalls The method was originally designed for the Icelandic national dietary survey and built on a telephone interview, which has been validated; it consists of four steps as has been described earlier [16]. For quantification, participants received a booklet with four portion sizes of 49 dishes or foods, and pictures of standard household equipment in different sizes. All data were entered directly into an interview-based nutrient calculating program, ICEFOOD, based on the National Nutrition Database, ISGEM. Nutrient losses due to food preparation were included in the calculations. Questionnaires on lifestyle and health behaviors offered additional data on dietary habits as well as information on physical activity, sedentary behaviors, smoking, alcohol use and sleep.

To assess aerobic fitness, maximal oxygen uptake (VO$_2$max) was assessed using open circuit spirometry (Parvomedics Trumax 2400; Sandy, UT, USA) with a graded exercise test protocol on a treadmill (Quasar med, HP Cosmos; Traunstein, Germany) as described previously [17, 18]. Briefly, participants ran at constant speed (8–13 km/h) depending upon fitness and the grade of the treadmill was increased 2% every two minutes until volitional exhaustion. Expiratory air was collected (30 s averages) and oxygen consumption and carbon dioxide production calculated and used to calculate the respiratory exchange ratio. Heart rate was measured continuously with a heart rate monitor (Polar), and at the end of each stage, the participants rated their perceived exertion (Borg scale 6–20) [19].

Blood samples were drawn early in the morning after an overnight fast (>12 hours) and analyzed at Landspitali University Hospital for serum total cholesterol (TC), high-density lipoprotein (HDL) cholesterol, triglycerides (TG), glucose and insulin. Low-density lipoprotein (LDL) cholesterol was then calculated by using the equation by Friedewald et al. [20]. The homeostasis model assessment of insulin resistance (HOMA2-IR) was used as an index to estimate insulin resistance. The updated computer HOMA2-IR model with nonlinear solution using the 75th quartile as a cutoff was used to define high HOMA2-IR (http://www.dtu.ox.ac.uk/homacalculator/index.php) [21].

## Outcome assessment—Normal Weight Obesity (NWO)

The subjects whose BMI was 18.5 to 24.9 kg/m$^2$ and with percentage body fat above 17.6% in males and above 31.6% in females were defined as NWO according to Lohman's criteria [22]. Height and weight were measured in 274 subjects and of those 196 (72%) were within normal BMI. For participants with normal BMI, information on body fat was missing for 14 subjects, leaving 182 in the analysis.

## Statistical analysis

In all statistical analyses, we used SPSS software, version 22.0 (SPSS Inc., 2009, IBM Chicago, IL, www.spss.com). Differences in mean values of nutrient intake and anthropometric- and metabolic parameters according to the presence or absence of NWO were tested by the Student t-test (adjusted for sex) when variables had a normal distribution or by the Mann-Whitney nonparametric test otherwise. Statistical differences in categorical variables were calculated

using the chi-square test. When examining the components used to define metabolic syndrome according to the presence or absence of NWO we used the definition from the Joint Interim Statement (JIS) of the IDF Task Force on Epidemiology and Prevention, National Heart, Lung and Blood Institute, American Heart Association, World Heart Federation, International Atherosclerosis Society and International Association for the Study of Obesity [23]. When evaluating some of the component used for the criteria of metabolic syndrome high waist circumference was defined as ≥94 cm for men and ≥80 cm for women, low HDL-cholesterol was defined as <40 mg/dL for men and <50 mg/dL for women, high triglycerides was defined as ≥150 mg/dL, high blood pressure was defined as systolic pressure ≥130 mmHg and/or diastolic pressure ≥85 mmHg and high fasting blood glucose was defined as ≥100 mg/dL [23].

Logistic regression models were used to calculate odds ratios (ORs) and 95% confidence intervals (CIs) for having one or more risk factors for metabolic syndrome using NWO as the explanatory variable. Due to the cross-sectional design of the study and the fact that all participants were in the same age, we only used sex as an adjustment variable in our final model. Since BMI could lie in the causal pathway for developing metabolic syndrome we omitted this variable from the final regression analysis but all participants in the model had BMI within the normal weight range. Lifestyle variables collected and explored as risk factors for NWO in the present study were also not included in the model, since they are probably also intermediate steps in affecting the development of metabolic syndrome and therefore, acting as mediators rather than true confounders. However, there were few lifestyle factors that were different between the groups and for secondary analysis we explored the association when adjusting for sex, calorie intake (continuous), breakfast skipping (yes/no), sleeping enough (yes/no) and aerobic fitness (continuous).

## Results

### Overall findings

In total 274 subjects had measures for height and weight. The mean BMI (±SD) was 23.0 ± 3.8 kg/m$^2$ and 5% were underweight, 72% normal weight, 16% overweight and 7% obese. Those with normal weight and information on body composition (n = 182) were subjects of the present study and among them, 42% (n = 76) were defined as NWO.

### Lifestyle

Characteristic and lifestyle factors were compared between those defined as NWO and those that were normal weight but below the criteria for body fat (NWL) that was chosen to define NWO (Table 1). About 61% of the NWO group consisted of males, and in total 35% of the normal weight females were NWO compared with 48% of the males. Fewer NWO participants were physically active (p = 0.014), ate breakfast (p = 0.015), and consumed vegetables more than 4 times per week (p = 0.008) compared with NWL. No difference was seen in the frequency of consumption of other food items such as soda drinks, sweets, fast food, fruits and fish between the two groups. However, a borderline significance was found for less frequent use of fish oil supplements among NWO compared with NWL (p = 0.057). Furthermore a high proportion of participants in both groups reported that they usually did not get enough sleep during the night; 83% in the NWO group and 72% in the NWL group (p = 0.100).

### Energy- and nutrient intake

Calculated energy- and nutrient intake using the 24-hour recall method revealed no significant difference in intake between the two groups although there was a borderline difference

**Table 1. Characteristic of the 18-year-old participants and lifestyle factors.**

| Variables | Normal weight obesity[a] | | p |
|---|---|---|---|
| | Yes (n = 76) | No (n = 106) | |
| | n (%) | n (%) | |
| Sex | | | |
| - Women | 30 (39.5) | 56 (52.8) | 0.075 |
| - Men | 46 (60.5) | 50 (47.2) | |
| Smoking history | | | |
| - Never/former | 55 (75.3) | 84 (80.0) | 0.460 |
| - Current | 18 (24.7) | 21 (20.0) | |
| Alcohol consumption | | | |
| - Yes | 70 (93.3) | 92 (87.6) | 0.208 |
| Physical activity[b] | | | |
| - Sedentary | 21 (28.0) | 16 (15.2) | 0.014 |
| - Medium active | 25 (33.3) | 26 (24.8) | |
| - Very active | 29 (38.7) | 63 (60.0) | |
| Getting enough sleep | | | |
| - No | 62 (82.7) | 75 (72.1) | 0.100 |
| Daily dietary pattern | | | |
| - Breakfast | 42 (56.0) | 77 (73.3) | 0.015 |
| - Lunch | 65 (86.7) | 87 (82.9) | 0.487 |
| - Dinner | 67 (89.3) | 97 (92.4) | 0.479 |
| - Evening snack | 18 (24.0) | 24 (22.9) | 0.858 |
| Sugary soda drinks | | | |
| - $\geq$ 1 times per week | 55 (75.3) | 81 (77.1) | 0.781 |
| Sugar free soda drinks | | | |
| - $\geq$ 1 times per week | 32 (43.8) | 43 (41.0) | 0.702 |
| Fruits | | | |
| - $\geq$ 4 times per week | 43 (58.9) | 63 (60.0) | 0.884 |
| Vegetables | | | |
| - $\geq$ 4 times per week | 27 (37.0) | 60 (57.1) | 0.008 |
| Sweets | | | |
| - $\geq$ 4 times per week | 25 (33.8) | 47 (44.8) | 0.140 |
| Fast food | | | |
| - $\geq$ 2 times per week | 33 (45.2) | 44 (41.9) | 0.662 |
| Fish oil supplement | | | |
| - Yes | 25 (34.2) | 51 (48.6) | 0.057 |
| Fish meals | | | |
| - $\geq$ 2 times per week | 35 (47.9) | 60 (57.1) | 0.226 |

[a] Normal weight obesity defined as a BMI from 18.5 to 24.9 kg/m2 and percent body fat above 17.6% in males and above 31.6% in females, measured by DXA (dual energy X-ray absorptiometry). Those who are not normal weight obese are within the normal range of BMI and have body fat below that defined for normal weight obesity.

[b] Self-reported physical activity according to questionnaire

All P values were calculated by the chi-square test.

Numbers may not add up to total because of missing values.

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(p = 0.059) in iron intake among females, where the NWO group had on average lower intake than NWL (Table 2).

## Anthropometry, fitness and metabolic parameters

Those in the NWO group were on average 5.1 kg heavier (p <0.001), with 1.3 kg/m$^2$ higher BMI (p <0.001), had 5.5 cm greater waist circumference (p <0.001) and 6.2 percentage points higher body fat (p <0.001) than NWL (Table 3). The mean difference between the groups in aerobic fitness was 3.4 ml/kg/min favoring the NWL group. When adjusted for sex, the mean difference in aerobic fitness increased to 5.1 ml/kg/min (p <0.001). There was no difference between the groups in blood pressure, or bone mineral density. With regard to metabolic parameters females with NWO had a marginally significant tendency for higher values of low density lipoproteins than NWL females (p = 0.069). Higher serum insulin and HOMA-2 insulin resistance was also observed among NWO compared with NWL (p = 0.004 and p = 0.003, respectively). There was no difference between the groups in high density lipoproteins, triglycerides, and blood glucose.

## Metabolic Disorders

Five participants (2.7%) had metabolic syndrome according to the JIS, four of whom had NWO (Table 4). The prevalence of having one risk factor for developing metabolic syndrome was higher among NWO compared with NWL (42% vs. 26%, p = 0.019). In total 58% of the subjects with NWO had one or more risk factors for metabolic syndrome while 39% of NWL were in the same position (p = 0.010). Adjusting for sex, NWO was positively associated with a 2.2 fold increased risk of having one or more risk factors for metabolic syndrome (OR = 2.2; 95% CI: 1.2, 3.9) compared with NWL. When further adjusted for some of the key factors that stood out in the lifestyle (breakfast skipping, sleeping enough and aerobic fitness) among the study participants as well as sex and calorie intake, we found the risk of having one or more risk factors for metabolic syndrome still to be twofold among the NWO group (95% CI: 1.0, 4.1) with a borderline significance (p = 0.067) compared to the NWL group. When examining the prevalence within the cut points for each component used in the definition of metabolic syndrome, we only observed a statistically significant difference for high waist circumference; the prevalence being higher among those with NWO (p = 0.019). High waist circumference was only observed among females in the study, with 10 out of 14 being in the NWO group.

## Discussion

In the present study, high prevalence (42%) of normal weight obesity among 18-year-old Icelandic high school students was observed. These findings are based on having BMI within normal range and Lohman's criteria [22] of percentage body fat above 17.6% in males and 31.6% in females, using DXA to assess body composition. NWO was also found to be associated with less desirable health behaviors and increased metabolic risk.

Surprisingly, NWO was more common among males in our study, opposite to findings from the earliest research on NWO that exclusively considered girls to be affected [11] and a study from Switzerland revealed NWO to be almost non-existent in men [24]. Diverse terms and definitions have been used for NWO and different cut-off points for body fat percentage have been suggested. However, there is currently no consensus on how to define excess fatness by percent body fat [25] and the effect of chosen cut-offs and criteria used has an influence on perceived prevalence of NWO showing prevalence between 5–45% [12, 26, 27]. The cutoffs based on Lohman's criteria [22] have however been widely accepted and used by others in body composition research where the need for empirical cutoffs has risen [18, 28]. The type of measurement used

**Table 2.** Daily energy and nutrient intake using 24-hour dietary recall among 18-year-old students.

| Variables | Normal weight obesity[a] | | p |
|---|---|---|---|
| | Yes (n = 71) | No (n = 103) | |
| | Mean ± SD | Mean ± SD | |
| Energy intake | | | |
| - Kcal | 2559 ± 1108 | 2486 ± 921 | 0.989 |
| - KJ | 10711 ± 4639 | 10402 ± 3817 | 0.989 |
| - Males (kcal) | 3019 ± 1123 | 2870 ± 930 | 0.805 |
| - Females (kcal) | 1931 ± 720 | 2163 ± 767 | 0.166 |
| % of energy from protein | 17.2 ± 5.1 | 17.3 ± 5.1 | 0.710 |
| - Males | 17.8 ± 5.1 | 18.3 ± 4.9 | 0.318 |
| - Females | 16.4 ± 4.9 | 16.5 ± 5.1 | 1.000 |
| % of energy from fat | 31.2 ± 9.3 | 32.6 ± 8.5 | 0.263 |
| - Males | 31.6 ± 8.8 | 32.1 ± 9.2 | 0.795 |
| - Females | 30.6 ± 10.1 | 33.1 ± 7.6 | 0.187 |
| - *Saturated* | *12.4 ± 4.1* | *13.5 ± 4.6* | *0.146* |
| - *Monounsaturated* | *10.0 ± 4.2* | *10.0 ± 3.1* | *0.500* |
| - *Polyunsaturated* | *4.4 ± 2.6* | *4.4 ± 2.2* | *0.523* |
| - *Omega-3 fatty acids* | *0.15 ± 0.3* | *0.20 ± 0.4* | *0.496* |
| % of energy from CHO | 50.7 ± 9.2 | 49.0 ± 8.8 | 0.221 |
| - Males | 49.5 ± 7.3 | 48.6 ± 9.7 | 0.347 |
| - Females | 52.4 ± 11.1 | 49.3 ± 8.0 | 0.319 |
| - *Added sugar* | *10.9 ± 6.8* | *11.5 ± 6.9* | *0.701* |
| - *Alcohol* | *0.51 ± 2.6* | *0.88 ± 4.4* | *0.729* |
| Dietary fiber (g) | 19.4 ± 8.9 | 19.9 ± 8.6 | 0.397 |
| - Males | 21.4 ± 10.1 | 20.5 ± 7.5 | 0.861 |
| - Females | 16.3 ± 8.1 | 18.8 ± 8.4 | 0.116 |
| Vitamin A (µg-RAE)[b] | 943 ± 795 | 1343 ± 2083 | 0.314 |
| - Males | 1064 ± 775 | 1630 ± 2350 | 0.247 |
| - Females | 778 ± 806 | 1152 ± 1903 | 0.483 |
| Retinol (µg) | 639 ± 507 | 1034 ± 1814 | 0.135 |
| - Males | 752 ± 570 | 1349 ± 2327 | 0.151 |
| - Females | 484 ± 360 | 825 ± 1381 | 0.259 |
| Vitamin D (µg) | 5.3 ± 6.4 | 7.4 ± 11.2 | 0.361 |
| - Males | 6.3 ± 6.9 | 7.5 ± 8.4 | 0.451 |
| - Females | 3.9 ± 5.4 | 6.8 ± 12.7 | 0.526 |
| Vitamin E (mg) | 13.6 ± 12.7 | 14.1 ± 16.0 | 0.756 |
| - Males | 16.4 ± 14.7 | 15.1 ± 13.8 | 0.675 |
| - Females | 9.8 ± 8.1 | 12.9 ± 17.2 | 0.844 |
| Total folate (µg-DFE) | 439 ± 306 | 450 ± 268 | 0.531 |
| - Males | 501 ± 307 | 503 ± 263 | 0.799 |
| - Females | 355 ± 288 | 396 ± 257 | 0.248 |
| Vitamin C (mg) | 207 ± 234 | 169 ± 166 | 0.612 |
| - Males | 221 ± 231 | 163 ± 169 | 0.238 |
| - Females | 188 ± 240 | 167 ± 160 | 0.811 |
| Calcium (mg) | 1373 ± 713 | 1335 ± 743 | 0.673 |
| - Males | 1616 ± 703 | 1681 ± 867 | 0.808 |
| - Femals | 1040 ± 587 | 1022 ± 484 | 0.918 |
| Iron (mg) | 16.1 ± 10.7 | 19.7 ± 19.4 | 0.224 |

*(Continued)*

**Table 2.** (*Continued*)

| Variables | Normal weight obesity[a] | | p |
|---|---|---|---|
| | Yes (n = 71) | No (n = 103) | |
| | Mean ± SD | Mean ± SD | |
| - Males | 18.4 ± 9.1 | 19.4 ± 10.1 | 0.741 |
| - Females | 13.1 ± 12.2 | 19.5 ± 24.3 | 0.059 |
| Selenium (μg) | 80.9 ± 43.5 | 79.4 ± 43.6 | 0.742 |
| - Males | 95.2 ± 44.0 | 95.3 ± 49.5 | 0.905 |
| - Females | 61.5 ± 35.1 | 65.1 ± 31.5 | 0.462 |
| Iodine (μg) | 142 ± 101 | 170 ± 142 | 0.328 |
| - Males | 151 ± 92 | 210 ± 163 | 0.151 |
| - Females | 129 ± 113 | 135 ± 120 | 0.462 |

Abbreviations: SD, standard deviation; CHO, carbohydrates.

[a]Normal weight obesity defined as a BMI from 18.5 to 24.9 kg/m2 and percent body fat above 17.6% in males and above 31.6% in females, measured by DXA (dual energy X-ray absorptiometry).

P values were calculated by the Student t-test for percent of energy for fat and saturated fat. Overall means were adjusted for sex. All other P values were calculated using the Mann-Whitney U test.

[b]As retinol activity equivalents

for assessing body fat may also impact the results since skinfold thickness measurements have been shown to systematically underestimate body fat percentage when compared with DXA [29]. A recent study from Brazil reported only 9% prevalence of normal weight obesity among 23–25 years old participants, but they used skinfolds to estimate body fat and chose higher cut points for body fat to classify NWO [12]. Another study where DXA was used and body fat percentage was divided into sex-specific tertiles showed that already at what was defined as medium body fat (15.3–20.7% in men and 29.8–34.9% in women) metabolic abnormalities were evident [30]. These findings indicate the importance of lower cut-offs for NWO.

In our study, NWO was associated both with lower fitness, measured as $VO_2max$, and with lower physical activity levels according to self-reported data from participants. While NWO studies with actual fitness measures are few, physical inactivity has been suggested to be associated with NWO in former studies [12, 25, 31]. Fewer studies have investigated the associations between dietary intake and NWO and, in agreement with our findings, an association has seldom been found with either amount of energy, the proportion of macronutrients or single nutrients [31, 32]. There are two exceptions. First, a study among Korean adults, in which very high carbohydrate diet (≥73.9% of energy compared with <59.9%), and particularly when consumed as snack, was positively associated with metabolically obese normal weight participants (MONW) and high protein diet was found to be preventive (≥17.1% of energy from protein compared with <12.2%) [33]. Apart from the slightly different definitions of NWO and MONW, this macronutrient composition is far from what is common in the other studies with a more westernized diet. Second, the Brazilian study of Madeira et al. [12] only considered the percentage of energy from fat in the diet and found it to be higher among NWO than NWL young adults.

Considering the quality of diet in our study, both groups were on average slightly above the recommendations for consumption of saturated fat and added sugar, which is recommended to be below 10% of the total energy intake. Both groups were also on average below the Icelandic recommendation for fiber- and vitamin D intake and the NWO group was on average below the recommendations for selenium intake. Looking at food choices the NWO participants were

**Table 3. Normal weight obesity according to anthropometric, fitness and metabolic parameters– 18-year-old students.**

| Variables | Normal weight obesity[a] | | p |
|---|---|---|---|
| | Yes (n = 76) | No (n = 106) | |
| | Mean ± SD | Mean ± SD | |
| Height (cm) | 179.9 ± 9.2 | 175.5 ± 9.3 | 0.254 |
| - Males | 181.9 ± 7.7 | 182.7 ± 7.1 | 0.679 |
| - Females | 169.2 ± 4.8 | 169.0 ± 5.3 | 0.744 |
| Weight (kg) | 70.0 ± 9.1 | 64.9 ± 8.4 | <0.001 |
| - Males | 73.7 ± 9.1 | 70.5 ± 7.7 | 0.046 |
| - Females | 64.3 ± 5.7 | 59.9 ± 5.2 | 0.001 |
| BMI (kg/m$^2$) | 22.3 ± 1.8 | 21.0 ± 1.5 | <0.001 |
| - Males | 22.2 ± 1.8 | 21.2 ± 1.5 | 0.001 |
| - Females | 22.5 ± 1.8 | 21.0 ± 1.5 | <0.001 |
| Waist circumference (cm) | 79.2 ± 5.5 | 73.7 ± 4.6 | <0.001 |
| - Males | 80.3 ± 5.4 | 76.0 ± 3.5 | <0.001 |
| - Females | 77.5 ± 5.1 | 71.7 ± 4.7 | <0.001 |
| Body fat (%) | 26.9 ± 7.2 | 20.7 ± 7.2 | <0.001 |
| - Males | 21.8 ± 3.9 | 13.7 ± 2.2 | <0.001 |
| - Females | 34.7 ± 2.4 | 27.0 ± 3.3 | <0.001 |
| Bone mineral density (g/cm$^2$) | 1.23 ± 0.11 | 1.23 ± 0.11 | 0.167 |
| - Males | 1.27 ± 0.11 | 1.28 ± 0.11 | 0.418 |
| - Females | 1.16 ± 0.08 | 1.19 ± 0.10 | 0.245 |
| Aerobic fitness, VO$_2$ (ml/kg/min) | 45.9 ± 8.2 | 49.3 ± 8.2 | <0.001 |
| - Males | 50.9 ± 5.7 | 55.8 ± 5.5 | <0.001 |
| - Females | 37.8 ± 4.3 | 43.2 ± 4.9 | <0.001 |
| High density lipoprotein (mg/dL) | 55.3 ± 11.6 | 58.0 ± 13.5 | 0.236 |
| - Males | 51.1 ± 11.0 | 50.3 ± 9.2 | 0.772 |
| - Females | 61.3 ± 10.1 | 64.8 ± 13.0 | 0.411 |
| Low density lipoprotein (mg/dL) | 93.1 ± 22.7 | 88.7 ± 20.9 | 0.143 |
| - Males | 89.6 ± 21.2 | 88.1 ± 18.3 | 0.620 |
| - Females | 98.6 ± 24.1 | 89.3 ± 23.0 | 0.069 |
| Triglycerides (mg/dL) | 94.4 ± 43.2 | 83.4 ± 32.9 | 0.119 |
| - Males | 92.1 ± 45.1 | 79.6 ± 31.2 | 0.188 |
| - Females | 98.1 ± 40.7 | 86.7 ± 34.2 | 0.238 |
| Systolic blood pressure (mmHg) | 120.6 ± 11.0 | 120.3 ± 9.5 | 0.370 |
| - Males | 123.8 ± 10.8 | 124.0 ± 9.8 | 0.928 |
| - Females | 115.8 ± 9.6 | 118.2 ± 8.9 | 0.235 |
| Diastolic blood pressure (mmHg) | 70.1 ± 7.3 | 70.5 ± 6.4 | 0.565 |
| - Males | 70.8 ± 7.3 | 70.2 ± 7.1 | 0.706 |
| - Females | 69.0 ± 7.3 | 70.7 ± 5.8 | 0.149 |
| Blood glucose (mg/dL) | 83.6 ± 14.4 | 80.9 ± 5.8 | 0.119 |
| - Males | 85.2 ± 17.9 | 82.2 ± 5.8 | 0.670 |
| - Females | 81.1 ± 5.8 | 79.7 ± 5.7 | 0.217 |
| Serum Insulin (µU/mL) | 9.0 ± 5.8 | 6.7 ± 2.8 | 0.004 |
| - Males | 9.2 ± 6.8 | 6.5 ± 2.5 | 0.054 |
| - Females | 8.8 ± 3.7 | 6.9 ± 3.1 | 0.023 |
| HOMA-2 insulin resistance | 1.6 ± 1.0 | 1.2 ± 0.5 | 0.003 |
| - Males | 1.7 ± 1.2 | 1.2 ± 0.4 | 0.052 |

(*Continued*)

**Table 3.** (*Continued*)

| Variables | Normal weight obesity[a] | | p |
|---|---|---|---|
| | Yes (n = 76) | No (n = 106) | |
| | Mean ± SD | Mean ± SD | |
| - Females | 1.6 ± 0.6 | 1.2 ± 0.6 | 0.020 |

[a]Normal weight obesity defined as a BMI from 18.5 to 24.9 kg/m2 and percent body fat above 17.6% in males and above 31.6% in females, measured by DXA (dual energy X-ray absorptiometry).
P values were calculated by the Student t-test for systolic blood pressure, aerobic fitness and bone mineral density. Overall means were adjusted for sex. All other P values were calculated using the Mann-Whitney U test.

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eating vegetables less regularly and there was a trend towards less prevalent use of fish oil supplements, which may indicate a generally lower intake of both omega-3 fatty acids, vitamin D, and fiber among the NWO group despite not being observed from the 24-hour recalls. Correspondingly, in Finland low intakes of healthy foods such as root vegetables, cereals and fish were observed among NWO individuals along with higher consumption of unhealthier choices. The authors also suggested low fibre intake as a potential risk factor for NWO [31]. Considering physical activity and nutrition as opposites of energy balance the findings of the present study, with NWO consuming similar amounts of energy as NWL while engaging in less physical activity as well as being less fit and having less preferable eating habits, are in line with suggestions of

**Table 4. Prevalence of metabolic syndrome and its components among 18-year-old students who are normal weight obese or normal weight lean.**

| Variables | Normal weight obese[a] (n = 76) | Normal weight lean (n = 106) | p[b] |
|---|---|---|---|
| | n (%) | n (%) | |
| Metabolic syndrome—JIS[c] | | | 0.019[c] |
| - Zero risk factor | 32 (42) | 65 (61) | |
| - One risk factor | 32 (42) | 27 (26) | |
| - Two risk factors | 8 (11) | 13 (12) | |
| - Three risk factors | 4 (5) | 1 (1) | |
| High waist circumference[d] | 10 (13) | 4 (4) | 0.019 |
| Low HDL-cholesterol[e] | 5 (7) | 8 (8) | 0.802 |
| High Triglycerides[f] | 6 (8) | 4 (8) | 0.235 |
| High blood pressure[g] | 17 (22) | 21 (20) | 0.676 |
| High blood Glucose[h] | 2 (3) | 1 (1) | 0.382 |
| HOMA2-IR[i] ≥1.8 | 20 (26) | 18 (17) | 0.135 |

[a]Normal weight obesity defined as a BMI from 18.5 to 24.9 kg/m2 and percent body fat above 17.6% in males and above 31.6% in females, measured by DXA (dual energy X-ray absorptiometry).
[b]P value calculated by the chi-square test.
[c]Metabolic syndrome defined according to the Joint Interim Statement (JIS) of the IDF Task Force on Epidemiology and Prevention, National Heart, Lung and Blood Institute, American Heart Association, World Heart Federation, International Atherosclerosis Society and International Association for the Study of Obesity.
[d]High waist circumference (≥94 cm for men and ≥80 cm for women).
[e]Low HDL-cholesterol (<40 mg/dL for men and <50 mg/dL for women).
[f]High triglycerides (≥150 mg/dL).
[g]High blood pressure (systolic pressure ≥130 mmHg and/or diastolic pressure ≥85 mmHg).
[h]High fasting blood glucose (≥100 mg/dL).
[i]Cut-off point for high HOMA2-IR was set above the 75th quartile.

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the importance of higher energy throughput to maintain leanness [34]. Energy balance may be easier to achieve when energy expenditure is higher compared with a lower energy expenditure where food restriction may be required to keep the balance [35].

In our study, only 56% of the NWO participants reported eating breakfast on a daily basis, compared with 73% of their NWL peers. Yet, both groups consumed, on average, the same amount of calories suggesting that missing a breakfast might lead to excess hunger or rebound overeating [36] resulting in consumption of large portion sizes at following meals. A large study from the US has reported that breakfast skipping children and adolescents have higher BMI z-scores, waist circumference and prevalence of obesity compared with breakfast consumers [37]. These results are similar to ours with regard to waist circumference, an important risk factor for premature all-cause mortality especially at younger ages [15], as those defined with NWO had on average higher waist circumference than their NWL counterparts.

The growing number of research considering NWO and metabolic risk factors in recent years has led to general acceptance and concern over the metabolic dysregulation found among people classified as NWO [25]. Likewise, our results showed that even at young age, metabolic risk was considerably higher among NWO participants compared with the NWL group, with high waist circumference being most alarming. Even though the participants included in this study were all within the range considered as normal-weight according to BMI, the difference in average BMI between NWO and NWL was notable. By adjusting for BMI, the risk of having one or more risk factors for metabolic syndrome diminished. Body composition of persons with BMI values close to 25 kg/m$^2$ (25–27 kg/m$^2$ for men and 24–26 kg/m$^2$ for women) may commonly be misclassified and it has been suggested that simple formula based on a single DXA scan could be used for evaluating fatness of individuals instead of relying on BMI in clinical practice [38].

## Strengths and limitations

The precise laboratory measures we used to assess fatness and fitness support the validity of the findings. Our study is however limited by the cross-sectional design, which does not allow for the determination of cause and effect relationships. Also, the present study is affected by relatively few participants, but it must be stated that the students came from three high schools located in the capital area of Iceland. There are 31 high schools in total in Iceland and according to Statistics Iceland (http://www.statice.is/), there were 4.623 people who were 18 years old living in Iceland at the time of study recruitment. With 268 students participating in the present study, we have almost 6% of the population of 18-year-olds living in the country. Furthermore, the study sample reasonably reflects 18-year-old adolescent in Iceland since it was recruited from metropolitan Reykjavik where 67% of all Icelandic high-school students are enrolled and all academic structures are presented. One of the strengths of our study is that all participants are the same age, which eliminates the confounding effect of age and many other age-dependent covariates, but the rate of NWO increases with age[13, 39]. Furthermore, this age group was chosen since adolescents in Iceland formally gain independence from their parents/caregivers at 18 years and that may be associated with more rapid changes in health behaviors than in prior years. In many other countries this age often means the end of high-school and leaving home with increased autonomy in decision-making [40]. Generally, adolescence is a period characterized by changes in body composition and health behaviors [41] and studies on NWO at this age are lacking.

## Conclusion

The concept of NWO has recently gained attention since it is an important risk factor for cardiovascular disease and metabolic dysregulation, but it has yet to be recognized and included

in clinical practice [42]. If BMI is used as the only measure of adiposity, those with NWO will go undiagnosed despite having an increased cardiovascular disease risk. BMI may fail to identify up to half of individuals with excess percent fat mass [38]. Our results should stress how important it is to create preventive public policy, focusing on behavioral modifications irrespective of BMI, to react on the association of NWO with metabolic imbalances at this early age. Such implementations could limit further complications that may arise as these individuals get older.

## Supporting Information

**S1 Dataset. Raw data.**
(XLSX)

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## Author Contributions

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**Validation:** ASO JET SAA.

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**Writing – original draft:** ASO JET.

**Writing – review & editing:** ASO JET SAA.

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