# Perceived Exertion during Exercise Is Associated with Children's Energy Intake

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## ABSTRACT

FEARNBACH, S. N., T. D. MASTERSON, H. A. SCHLECHTER, E. LOKEN, D. S. DOWNS, D. THIVEL, and K. L. KELLER. Perceived Exertion during Exercise Is Associated with Children's Energy Intake. *Med. Sci. Sports Exerc.*, Vol. 49, No. 4, pp. 785–792, 2017. **Purpose**: To examine the individual-level factors that predict energy intake (EI) after imposed exercise (EX) and sedentary time (SED) in children. **Methods**: Healthy-weight children ages 9–12 yr ($n$ = 20) reported to the laboratory for one baseline and two experimental visits (EX and SED) each separated by 1 wk in a randomized crossover design. Percent body fat, weight (kg), and height (m) were used to calculate fat-mass index (FM index) and fat-free mass index (FFM index; kg·m$^{-2}$). On the EX day, children exercised at 70% estimated $\dot{V}O_{2peak}$ for 30 min on a cycle ergometer, whereas cardiovascular responses and RPE were measured. Objective EI (kcal) was measured at identical meals (breakfast, lunch, snack, and dinner) on the EX and SED days. **Results**: Total EI was not statistically different between the EX and SED days ($t$ = 1.8, $P$ = 0.09). FFM index was positively associated with EI on the EX day ($r$ = 0.54, $P$ < 0.05). RPE was also positively associated with EI on the EX day ($r$ = 0.82, $P$ < 0.001). Together, FFM index and RPE explained 77% of the variability in EX day EI ($F_{(2,17)}$ = 26.4, $P$ < 0.001). For each unit increase in RPE, children consumed approximately 270 more calories on the EX day. A similar pattern of associations was observed on the SED day. **Conclusions**: FFM index was positively associated with EI on the EX day. Despite experiencing the same 70% relative exercise intensity, increased perceived difficulty predicted greater EI on both the EX and SED day. These findings demonstrate a role for both FFM and RPE in explaining EI variability in children. **Key Words:** BODY COMPOSITION, RPE, PEDIATRIC, ENERGY BALANCE, NUTRITION

Previous studies have shown individual differences in the energy intake (EI) response to exercise, but homeostatic or cognitive mechanisms underlying these differences are unclear. In particular, there is limited research in this area in children. In regard to homeostatic mechanisms, there have been studies examining changes in gut peptides, inflammatory markers, and substrate or macronutrient utilization as possible factors that influence postexercise EI (15,16,32). In addition, fat-free mass (FFM) is a known predictor of daily EI in adolescents and adults, predominantly through its effects on resting metabolic rate and total energy expenditure (EE) (4,8,9,27). Furthermore, it has been proposed that cognitive factors also contribute to additional variability in daily EI. For example, studies in adults have shown that increased perceived difficulty of exercise may be associated with caloric compensation and predicts weight regain after successful weight loss (6). This weight regain is assumed to be related to greater EI by participants, but has not been tested.

The majority of studies looking at the effects of exercise on subsequent food intake have focused on homeostatic mechanisms. In particular, there are several pathways by which the body signals information about EE to increase EI and properly compensate for the activity-related energy deficit. These include, but are not limited to, gut–brain signaling

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Submitted for publication July 2016.
Accepted for publication November 2016.
Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.acsm-msse.org).

0195-9131/17/4904-0785/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0000000000001165

pathways and markers of glycogen store utilization (15,16,30). But homeostatic regulation of energy balance is not limited to metabolic changes associated with acute fluctuations in EE. Body composition, including FFM and fat mass (FM), serves as a longer-term indicator of energy balance. FFM is a large determinant of resting metabolic rate, which contributes greatly to total daily EE (2). In addition, FFM has been shown to be a better predictor of EI than FM in both adolescents and adults (3,8,9,27). However, research in younger children is lacking. Also, the conditions under which FFM is most strongly associated with EI have not been examined. For example, it is not known whether the association between FFM and EI is affected by an exercise-induced energy deficit.

Aside from the homeostatic regulation of EI, there are also cognitive factors that influence eating behaviors. For example, perceived exertion may predict individual responses to a set exercise bout. However, there has been limited research examining whether the perceived difficulty experienced during exercise is associated with subsequent behaviors, above and beyond the effects of the physical stress associated with exercise (26,37). Of particular interest to the current study, it is unknown whether the perceived difficulty of exercise is associated with postexercise EI. It is vital to understand the potential consequences of imposed exercise in a sample of children who are at risk for becoming overweight before implementing prescribed exercise on a broader scale.

The purpose of the current paper was to understand individual-level factors that may contribute to differences in daily EI after participation in 30 min of 70% estimated $\dot{V}O_{2max}$ intensity cycling exercise. In particular, we examined the associations between body composition (i.e., FFM and FM), cardiovascular responses to exercise (e.g., HR), ratings of perceived exertion, and EI across the experimental day. We hypothesized that children's FFM would be positively associated with total EI, in line with previous research in adolescents and adults. Since the exercise bout was tailored to the same relative intensity of 70% $\dot{V}O_{2max}$, we hypothesized that total EI would be positively related to children’s ratings of perceived exertion during the exercise, independent of the controlled cardiovascular response to the exercise.

## METHODS

### Study Design

We conducted a within-subjects, crossover design study with a community-based sample of 20 children between the ages of 9 and 12 yr. The overall purpose of the study was to investigate the effects of imposed exercise versus imposed sedentariness on children's total EI over the course of a day. This article addresses a secondary aim to determine child characteristics that predict individual differences in postexercise EI. Children completed one baseline and two experimental visits (exercise day [EX], sedentary day in a preassigned randomized order [SED]) each separated by 1 wk. For all three visits, children arrived to the laboratory after an overnight fast. The baseline visit consisted of a 4-h session in the morning, which served to familiarize children with eating in a laboratory environment (breakfast and lunch) and collect baseline fitness and anthropometric measurements. Outside of meal and exercise testing periods, children had access to a series of toys, books, and games, and could switch freely between activities. The EX and SED days were identical, and consisted of the same 4-h morning session in the laboratory, followed by 5 h of free-living time at home, and then an in-laboratory dinner session. The only difference was that the morning sedentary play time was interrupted by the 30-min exercise bout on the EX day. On the first study visit, a parent-signed informed consent for their child and children provided verbal and written assent before their participation. Children and their parents received modest financial compensation for their time. This study was approved by the institutional review board (00578) and the Clinical Research Center Advisory Committee (330) of The Pennsylvania State University.

### Participants

Children were recruited using flyers and online media postings in local schools and businesses located around the university. Interested parents completed a phone screening to determine eligibility. Children were considered eligible if by parental report they were normal weight (<85th age- and sex-specific body mass index [BMI] percentile) with at least one biological parent who was overweight or obese (BMI > 25 $kg \cdot m^{-2}$), without food allergies, medical conditions or contraindications to exercise testing, and were not participating in competitive sports which could skew test results (year-round or more than three practice sessions per week). Children's liking and willingness to eat the test-meal foods was also confirmed at screening, before enrollment in the study. Both child and parent weight status were confirmed by measurement at the baseline visit. One male child was retained in the study despite being in the overweight category (89th BMI percentile) after baseline measurements. This participant was not a statistical outlier compared to the group average in regard to body composition (e.g., % body fat) or any of the behavioral measures (e.g., food intake, exercise test performance), and removing him from the analyses did not affect the statistical significance of or conclusions from our findings. All 20 children who were initially enrolled in the study completed all three visits. Sample characteristics for these 20 children are listed in Table 1.

### Baseline Measurements

**Anthropometrics and body composition.** Before breakfast on the baseline visit, anthropometrics (height and weight) were measured to the nearest 0.1 cm and 0.1 kg by a trained researcher. Children and their parents were each weighed and measured twice in light clothing, using a standard scale (Detecto model 437, Webb City, MO) and stadiometer (Seca model 202, Chino, CA). Height (m) and weight (kg) were converted to BMI ($kg \cdot m^{-2}$) for the parent, and age- and

TABLE 1. Participant characteristics ($n$ = 20).

| | Mean ± SD (Range) |
|---|---|
| Age (yr) | 10.3 ± 1.1 (9–12) |
| BMI percentile | 41.6 ± 21.7 (9–89) |
| % body fat | 15.6 ± 4.4 (6.7–26.6) |
| FM index (kg·m$^{-2}$) | 2.7 ± 0.9 (1.1–4.4) |
| FFM index (kg·m$^{-2}$) | 14.3 ± 1.5 (12.1–18.3) |
| | ***N* (%)** |
| Sex | |
| Male | 12 (60) |
| Female | 8 (40) |
| Race | |
| White | 20 (100) |
| Non-white | 0 (0) |

sex-specific BMI $z$ score and BMI percentile for the child using the Centers for Disease Control and Prevention conversion program (14).

Body composition was measured using bioelectrical impedance analysis (Tanita model BF-350, Arlington Heights, IL). Percent body fat (%BF) was multiplied by body weight (kg) to calculate fat mass (FM; kg). The difference between body weight and FM was taken to calculate FFM (kg). This method has previously been validated against dual-energy x-ray absorptiometry with children in our age range (41). To control for differences in body composition as a function of child height, FFM index and FM index were calculated by dividing the absolute FFM and FM, respectively, by the height squared (kg·m$^{-2}$) (43).

**Fitness testing.** Two hours into the baseline visit, children completed the YMCA graded submaximal cycle test to estimate cardiorespiratory fitness (28). Children were outfitted with a Polar Heart Rate Transmitter chest strap and wrist unit receiver (Polar Electro Inc. model T31-Coded, Lake Success, NY). Participants remained seated for 5 min, whereas a researcher explained the procedure and instructed the child on the use of the Borg Scale for RPE (5,13,23,34). The Borg RPE Scale (ranging from 6 to 20) has previously been described as a valid and reliable measure, and is suitable for use with children within this age range (5,13,23,34). At the end of the 5-min period, a supervising nurse obtained resting HR and blood pressure (BP) measurements. Children were then familiarized with the cycle ergometer (Lode Corival V2, Lode Holding BV, Groningen, The Netherlands) and completed a 3-min warm-up, followed by the YMCA submaximal cycle test. The YMCA cycle test follows a branching, multistage format to determine the relationship between HR and work rate to estimate the individual's $\dot{V}O_{2max}$. Children are required to pedal at a constant rate (50 ± 2 rpm) while researchers adjust the resistance (i.e., work rate) on the cycle ergometer at each stage. HR values are recorded every minute, whereas BP and RPE are measured every 3 min. The test ends once a participant has completed two separate workload stages that result in steady-state HR (±5 bpm) between 110 and 150 bpm. $\dot{V}O_{2max}$ was estimated using the graph plot and extrapolation technique (28). This estimated $\dot{V}O_{2max}$ was used to determine the work rate for the 70% intensity cycle test on the EX day (described below).

## 70% Intensity Exercise Protocol

Two hours into the EX day session, children completed the cycle ergometer exercise test. Participants were outfitted with the HR monitor, and resting HR and BP measurements were taken. After a 3-min warm-up, children exercised at their individual 70% estimated $\dot{V}O_{2max}$ for 30 min. The starting work rate (in watts) was determined from the linear association between HR and work rate established during the submaximal exercise test. The work rate was either confirmed or adjusted throughout the test to maintain a target HR between 70% and 80% age-predicted maximum HR (e.g., 10-yr-old: 147–168 bpm). HR values were recorded every minute, whereas BP and RPE were measured every 3 min. Children could request water at any point during the test. Researchers and the attending nurse encouraged children throughout the exercise protocol with positive verbal cues, cheering, and clapping. After completion of the exercise test, participants had a 5-min cool-down period on the bike, followed by 10 min of light stretching.

## Accelerometer Measurements

Children wore an ActiGraph GT3X-BT accelerometer on their nondominant wrist for 10 h on each testing day (EX, SED). In addition, children wore a second accelerometer on their nondominant ankle for the YMCA submaximal cycle test and the 30-min exercise test (70% individual estimated aerobic capacity) to more accurately measure activity in the seated position on the cycle ergometer. We used this hybrid measure to estimate activity-related EE, extracted for each child for the entire 10-h period. All data were validated and scored in ActiLife 6 software (ActiGraph, LLC, Pensacola, FL) using Freedson Combination (1998) to calculate Activity-related EE (40).

## Food Intake Measurement

**Test-meal procedures.** Children arrived to the laboratory after an overnight fast on all three testing days. Objective EI (kcal) was measured at breakfast, lunch, snack, and dinner test meals. The use of laboratory-based test meals for the measurement of food intake, including reliability against other measurement tools, has been discussed previously (12,22,33). Meals were identical on the EX and SED days. Fullness ratings were completed before and after each laboratory meal on a vertical 150-mm visual analog scale (VAS) referred to as "Freddy Fullness" (29). On the first visit, children conducted taste tests to report liking and wanting for each breakfast, lunch, and snack food on a VAS. On the second visit, children tasted and rated liking and wanting on a VAS for each dinner food.

## Breakfast

All children were required to consume a standardized breakfast on all three test days consisting of an English muffin toasted with one tablespoon butter, banana, and

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orange juice (285 kcal total) (see Table, Supplemental Digital Content 1, Laboratory test-meal menu, http://links.lww.com/MSS/A809). Children were considered to have finished the meal if they consumed > 95% of each individual food item within 30 min. All 20 children met these requirements at each of the three breakfast meals.

### Lunch

Children were offered an identical lunch meal on all three test days. Prior to the first visit, children were given the opportunity to select from a preset menu of available items for lunch. Children chose a sandwich (peanut butter and jelly or deli meat and cheese), a vegetable (carrots or tomatoes) with ranch dip, a fruit (apple slices or grapes), and a salty snack (pretzels or baked chips). All children also received brownies and a bottle of water with their lunch. All serving sizes were controlled to ensure that any combination of food items provided approximately the same number of total calories (997–1014 kcal), which provided > 50% of children's caloric needs for the day. Possible food choices and serving sizes are reported in Supplementary Table 1 (see Table, Supplemental Digital Content 1, Laboratory test-meal menu, http://links.lww.com/MSS/A809). Children were instructed that they had up to 30 min to eat freely from the food items provided. If they were finished before the 30 min had elapsed, they notified a researcher.

### Snack

The snack (302 kcal) (see Table, Supplemental Digital Content 1, Laboratory test-meal menu, http://links.lww.com/MSS/A809) was preweighed and packed for children to take home during free-living time on the EX and SED days. Parents were given written and verbal instructions to provide the snack at a set time and to return any packaging and uneaten food items to researchers upon arrival for dinner. Compliance was checked by sending text message reminders to parents at snack time and requesting a response. Children were reminded by the researchers and the parent that they could eat as much or as little as they would like of any of the snack foods. Written and verbal instructions were also given to not eat or drink anything except water for the 2 h before dinner. Upon return, packaging was reweighed.

### Dinner

On the EX and SED days, children reported to the laboratory at least 2 h fasted for an *ad libitum* dinner test-meal (1227+ kcal) (see Table, Supplemental Digital Content 1, Laboratory test-meal menu, http://links.lww.com/MSS/A809). Children were instructed that they had up to 30 min to eat as much or as little as they would like from the available foods. They were also able to request additional servings of the foods at this meal. A researcher was available in the room during the meal and prompted the child if they finished a serving of a particular food. Children could also notify the researcher if they finished eating before the 30 min had elapsed.

**Nutrient analysis.** Premeal and postmeal weights for each food item were measured to the nearest 0.1 g and used to calculate intake in grams. This was later converted to EI (kcal) by meal (breakfast, lunch, snack, and dinner) in SPSS Statistics (Version 22; IBM Corporation, Armonk, NY) using nutrition label information. Total EI (kcal) was computed as the sum of EI from each of the individual meals (breakfast, lunch, snack, and dinner EI).

### Statistical Analysis

Sample size calculations ($n$ = 20) were derived using G*Power software (version 3.1.9.2) for the original aim to compare within-subject differences in EI as a function of condition (EX vs. SED) using paired-samples $t$ tests (18). The secondary aim of investigating predictors of individual differences in EI was not considered in the sample size calculation. Descriptive statistics for participant characteristics (i.e., means and standard deviations on continuous variables and frequencies on categorical variables) were calculated on the full sample. Paired $t$-tests were performed to test differences in total EI between the EX and SED days. Pearson's correlations were computed to determine the associations between body composition (FFMI, FMI), exercise test variables (RPE, HR, fitness), and intake variables. Partial correlations were used to test whether the relationship between RPE and EI was independent of likely covariates (e.g., HR, fitness level). Multiple linear regressions were performed to predict individual variability in postexercise EI; dependent variable = EX day EI (kcal), independent variables = RPE, HR, FFMI, and/or FMI. A maximum of two independent variables were entered into each model. One male child was a statistical outlier on RPE ratings during the 70% exercise test, reporting more than 3 SD below the group mean on the RPE scale (rating of 9, compared to the group mean 15 ± 2). Results are reported excluding this outlier. Data were analyzed using SPSS Statistics version 22.0 (IBM Corporation). Tests were considered significant at $P < 0.05$.

## RESULTS

Descriptive statistics for exercise test variables (RPE, HR, fitness), and intake are listed in Table 2. Total EI was not statistically different between the EX and SED days

TABLE 2. Descriptive statistics for exercise test variables and intake on the experimental days.

| | Mean ± SD (Range) |
|---|---|
| RPE average during 70% test[a,b] | 15 ± 2 (12–18) |
| HR average during 70% test (bpm) | 159 ± 7 (140–169) |
| Baseline fitness ($mL \cdot kg^{-1} \cdot min^{-1}$) | 48 ± 6 (36–58) |
| EX day EI (kcal) | 2171 ± 566 (1285–3194) |
| SED day EI (kcal) | 2088 ± 497 (1401–3085) |

[a]Results are reported without the RPE outlier.
[b]Possible range on Borg Scale = 6–20.

TABLE 3. Correlations between body composition, exercise test variables, and intake.

| | FFMI | FMI | RPE[a] | HR | Fitness | EX Day EI | SED Day EI |
|---|---|---|---|---|---|---|---|
| FFM index (kg·m$^{-2}$) | 1 | 0.39 | 0.29 | 0.44 | −0.30 | 0.53* | 0.41 |
| FM index (kg·m$^{-2}$) | | 1 | 0.25 | 0.12 | −0.74** | 0.38 | 0.33 |
| RPE average during 70% test[a] | | | 1 | −0.50* | −0.24 | 0.82** | 0.79** |
| HR average during 70% test (bpm) | | | | 1 | −0.01 | −0.29 | −0.21 |
| Baseline fitness (mL·kg$^{-1}$·min$^{-1}$) | | | | | 1 | −0.23 | −0.14 |
| EX day EI (kcal) | | | | | | 1 | 0.93** |
| SED day EI (kcal) | | | | | | | 1 |

[a]Results are reported without the RPE outlier.
*$P < 0.05$, **$P < 0.01$.

($P > 0.05$), and intake on the 2 d was highly correlated ($r$ = 0.93, $P < 0.001$). A summary of the correlation results is reported in Table 3. FFMI was positively associated with EI on the EX day ($r$ = 0.53, $P < 0.05$) (Fig. 1), but not the SED day ($P > 0.05$). FMI was negatively associated with baseline fitness ($r$ = − 0.74, $P < 0.01$), but was not associated with RPE or HR responses to 70% exercise test. There were no significant associations between FMI and intake.

In addition, RPE was positively associated with EI on the EX day ($r$ = 0.82, $P < 0.001$) (Fig. 2). Partial correlations revealed that this finding was not explained by children's baseline fitness level, average HR responses to the 70% exercise test, or activity-related EE (mean ± SD = 288 ± 72 kcal). In regression analyses, FFMI and RPE, together, explained 77% of the variability in EI on the EX day ($F_{(2,17)}$ = 26.4, $P < 0.001$) (Table 4). For each unit increase in FFMI, children's EX Day EI increased by 118 kcal (Table 4). For each unit increase in perceived difficulty of exercise on the RPE scale, children's EX Day EI increased by approximately 270 kcal (Table 4).

Similar associations were found between RPE during exercise ($r$ = 0.79, $P < 0.001$) and FFM index ($r$ = 0.41, $P$ = 0.08) and EI on the SED day, although only the correlation between RPE and EI reached significance (Table 3). Together, RPE and FFM index predicted 66% of the variability in SED Day EI ($F_{(2,17)}$ = 15.7, $P < 0.001$), but only RPE was a significant predictor in the model (RPE, $P < 0.001$; FFM index, $P$ = 0.16) (data not shown). For each unit increase in RPE, children's SED Day EI increased by approximately 230 kcal (data not shown).

## DISCUSSION

The purpose of the current study was to examine individual differences in *ad libitum* EI in children at risk for becoming overweight according to family history. Our findings demonstrate a role for both FFM and RPE in EI regulation in children. In line with our hypothesis, FFM was positively associated with daily EI. We also confirmed our hypothesis that total EI would be positively related to children's RPE during the 70% intensity exercise bout, and this was independent of the controlled cardiovascular response to the exercise (e.g., HR). Each unit increase on the Borg Scale was associated with a 270-calorie increase in EI across the EX day. Similar associations were found on the SED day, given that EI was highly correlated between the two testing days.

There is a growing body of literature on the influences of body composition on appetite regulation and energy balance. In particular, FFM has been shown to be positively related to daily EI and meal size (3,9). FFM may exert its effects on EI through its influence on resting metabolic rate and total EE, as seen in adolescents and adults (3,8,9,27,44). Our group recently showed in 7- to 10-yr-old children that FFM was also positively related to activation in reward areas of the brain (e.g., substantia nigra, amygdala) in response to

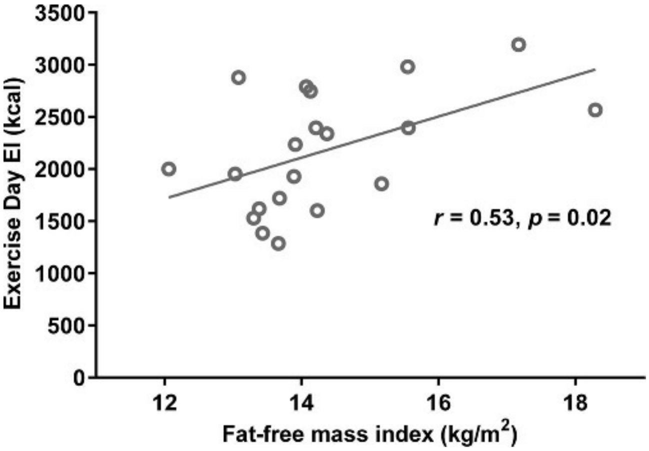


**FIGURE 1—Correlation between FFM index and EI on the EX day; $r$ = 0.53, $P < 0.05$.**

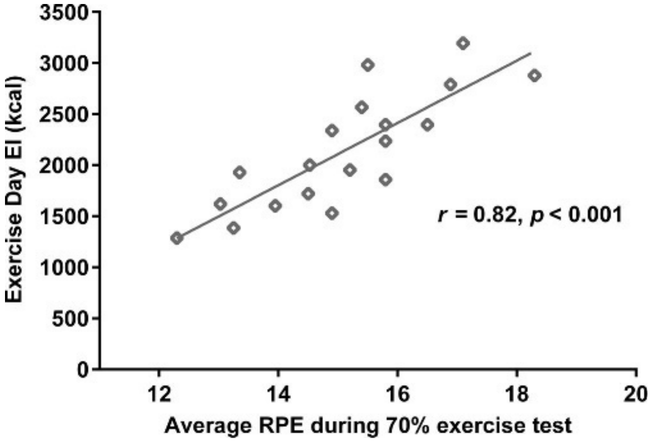


**FIGURE 2—Correlation between RPE and EI on the EX day; $r$ = 0.82, $P < 0.001$.**

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TABLE 4. Linear regression prediction of EI on the EX day, using RPE and FFM index.

| Model | Beta | Standard Error | *t* | *P* |
|---|---|---|---|---|
| Constant | −3648.2 | 828.5.0 | −4.4 | 0.001 |
| RPE | 271.1 | 46.7 | 5.8 | 0.001 |
| FFMI (kg·m$^{-2}$) | 118.3 | 47.8 | 2.5 | 0.025 |

Note: $F_{(2,17)}$ = 26.4, $P$ < 0.001, $R^2$ = 0.77.

pictures of high-energy dense foods (19). These results provide evidence of a potential mechanism for the positive association between FFM and food intake demonstrated previously (3,8) and in the present cohort. We also found a positive association between FFM and EI on the SED day, but it did not reach significance ($P$ = 0.08) in this small cohort. EI and EE have previously been shown to have a stronger linear association at higher levels of EE (35,36). One possible explanation for our current findings it that children had lower activity-related EE on the SED day compared with the EX day.

Although the association between FM and EI was in the positive direction on both experimental days, these correlations did not reach significance (both $P$ > 0.10). However, we recruited only healthy weight children; therefore, variation in FM was limited. In a cohort with greater diversity in body weight, ethnicity, and socioeconomic status, we recently reported that adiposity was positively related to total EI and intake of savory-fat foods in a laboratory setting (20). However, total EI was also positively related to FFM and estimated resting EE (20). In addition, EI was only measured at a single meal in the previous study, whereas the current study design allowed for self-regulation over the course of multiple meals, which could explain differences in results between studies. Another recent study in adolescents with obesity demonstrated that even though FM was positively associated with EI assessed by 3-d food records, skeletal muscle mass (lean body tissue) was the strongest predictor of food intake (8). Collectively, these findings suggest that in youth, lean body mass may be a better predictor of EI than fat mass, consistent with studies in adults (3,27,44).

Although EI is generally under good homeostatic control in healthy populations, psychological factors can also influence eating behavior. Despite experiencing the same 70% relative exercise intensity, children varied in their perceived difficulty of the exercise. Higher average RPE during the exercise bout predicted greater EI on the EX day. These findings suggest that greater perceived difficulty of exercise may result in overcompensation for the energy expended through greater EI at subsequent meals, at least in the short term. It is worth noting that because intake was highly correlated across the two experimental days, RPE was also positively associated with EI on the SED day. RPE was also positively associated with EI at each of the meals (i.e., lunch, snack, dinner) on both the EX and SED days (data not shown). It is possible that individuals with a higher RPE scores during the 70% exercise generally tend to consume more calories day-to-day. Importantly, the association between RPE and intake was significant within the context of a model that controlled for differences in children's body size (i.e., FFMI). In other words, children who think exercise is more difficult may generally have a tendency to eat more, independent of body weight. Based on the cross-sectional design of the current study, the direction of the more general relationship between RPE and EI across multiple eating occasions cannot be determined.

These findings are in line with a previous study that demonstrated that higher perceived difficulty of exercise was associated with greater weight regain following successful weight loss (6). Women in this study were formerly overweight and had completed a weight loss intervention and weight was tracked over the following year. RPE was measured in response to a submaximal walking exercise. In this study, RPE, but not physiological exertion during the submaximal exercise, was positively associated with weight regain (6). The authors suggested that women who have higher RPE during exercise may also have trouble restricting EI, which could predispose them towards greater weight regain (6). However, objective intake was not measured and, therefore, conclusions about energy compensation from this study cannot be made. However, the hypothesis that weight regain may be attributable to increased EI is in accordance with the results of the current study, wherein we found that RPE was positively associated with short-term EI. The increase in EI was independent of the physiological responses to exercise (i.e., HR), activity-related EE during the exercise bout, or children’s baseline fitness levels. We propose that this relationship between RPE and EI is specifically a cognitive phenomenon, and the large effect size warrants further investigation into this particular result. Given the limited sample size and exploratory nature of our study, additional studies should be conducted to confirm this relationship. In addition, studies examining the associations between RPE at multiple exercise intensities and subsequent EI would greatly expand our understanding of this phenomenon.

This is the first study to our knowledge that attributes individual differences in postexercise energy compensation to the perceived difficulty of the exercise bout. There is a diverse body of evidence on other cognitive factors related to postexercise eating behavior. One study in adults demonstrated that compensatory eating following 50 min of 70% intensity exercise was associated with an enhanced implicit wanting for food (21). Some individuals may not receive the same benefit from imposed exercise due to an increase in the hedonic response to food following exercise-induced EE. Other research has suggested that RPE and energy compensation following exercise may be related to increased subjective hunger ratings (31), higher levels of disinhibition (7), and greater emotional eating (11), among other cognitive factors. We did not find an effect of rated liking, wanting, or fullness levels on the significance of our main outcomes for the current study (all $P$ < 0.05, data not shown). While we did not measure affect in the current study, previous research in adults has shown that negative affect during exercise can influence subsequent EI (42).

Researchers have suggested that at submaximal exertion levels, perceived exertion is dominated by cognitive factors and affective responses to exercise, while higher intensity exercise induces heightened sensory attention to the physiological response to the exercise (24,26,37). Based on the design of the current study, we cannot determine whether children had reached an intensity level (i.e., ventilatory threshold) at which the physiological responses became more apparent (24,26). It is important to note that not all behavioral compensatory responses to exercise are deliberate or intentional (30). In the current study, we are unsure whether children with higher RPE actively chose to consume more calories on both days, or whether this effect was passive. Further investigation into the psychological factors associated with postexercise eating behavior would be extremely valuable.

This study represents a novel examination of individual differences in postexercise energy compensation that may influence eating behaviors. Some strengths of the study are worth noting. In particular, the design included a controlled, individualized exercise bout to maintain 70% relative intensity, which allowed us to better distinguish physiological effort (e.g., cardiovascular responses) from perceived difficulty. In addition, we obtained objective measures of EI at multiple test meals, which limits misreporting biases associated with self-reported food intake (10). The study was designed to facilitate familiarity with the laboratory environment (research personnel, test meals, and exercise testing) during a baseline visit to the Clinical Research Center, which reduced the novelty effect on the outcome variables of interest. We also completed the study with 100% retention of enrolled participants, and full compliance with instructions and protocols across all three testing days.

Despite the strengths of the study, there were some limitations. We had a small sample size and we were underpowered to address secondary outcomes. It is important to note that the correlations between RPE and EI ($r = 0.82$, $r = 0.79$) were actually higher than the previously reported test–retest reliability of the instrument ($r = 0.78$) (25), so interpretations regarding this finding should be made with caution. The study design should be replicated before firm conclusions can be made on the effects of RPE and FFM on daily EI in children. In addition, the homogeneity of the sample limits generalizability of our results to other populations. We used a less sensitive measure of "at risk for becoming overweight" based on a single parental factor, and we did not assess additional genetic, family, or environmental influences on child weight status and risk for obesity. Future studies could include a more diverse sample of children characterized by a well-defined obesity risk phenotype. In regard to the test meals, we used a standard 285-kcal breakfast rather than tailoring the caloric content to children's individual energy needs. Therefore, the breakfast provided a smaller proportion of total EI in children with higher body weights. Finally, we did not measure additional homeostatic factors (e.g., gut peptides, inflammatory markers) that might also represent individual differences in appetite regulation.

Pending successful replication of the current findings, future studies looking to incorporate exercise as a strategy for maintaining energy balance may find it valuable to determine strategies to decrease perceived exertion during exercise. A recent study suggested that distraction using virtual reality during treadmill exercise was effective in increasing enjoyment of exercise (1). Other research has shown that listening to music during exercise increases enjoyment (17,38). Finally, a study in adolescent girls demonstrated that RPE was significantly lower during a self-selected exercise session compared to a prescribed session of matched intensity (72% $\dot{V}O_{2peak}$) (25). These are just three examples of many possible strategies (39) to examine in the future to determine whether increasing enjoyment or decreasing perceived exertion of exercise is effective in reducing the likelihood of a compensatory response in postexercise food intake.

In conclusion, FFM and perceived exertion represent individual-level factors that may contribute to short-term differences in EI and eating behavior, but additional research is needed to confirm these results. These preliminary findings may be useful in future intervention research looking to incorporate exercise.

This project was supported by Agriculture and Food Research Initiative Grant 2011-67001-30117 from the USDA National Institute of Food and Agriculture, Program A2121. The project described was also supported by the National Center for Advancing Translational Sciences, National Institutes of Health, through grant UL1 TR000127. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH. We would like to thank the Penn State Clinical and Translational Science Institute, including the Clinical Research Center and the Biostatistics, Epidemiology, and Research Design services. Finally, we would like to acknowledge the Metabolic Kitchen and Children's Eating Behavior Laboratory at Penn State.

The authors have no conflicts of interest to disclose. The results of the present study do not constitute endorsement by the American College of Sports Medicine. All results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

APPLIED SCIENCES

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