The Acute Effects of Dairy Calcium Intake on Fat Metabolism During Exercise and Endurance Exercise Performance

Kimberly M. White, Roseann M. Lyle, Michael G. Flynn, Dorothy Teegarden, and Shawn S. Donkin

The purpose of this study was to test the effect of acute dairy calcium intake on exercise energy metabolism and endurance performance. Trained female runners completed two trials. Each trial consisted of a 90-min glycogen depletion run followed by a self-paced 10K time trial, conducted one hour after consumption of a high dairy (500 mg Ca\(^{2+}\)) or low dairy (80 mg Ca\(^{2+}\)) meal. During the 90-min run, blood samples and respiratory gases were collected. No treatment main effects of acute dairy intake were found for respiratory exchange ratio (RER), calculated fat oxidation, lactate, glycerol, or 10K time. Following this protocol, acute dairy calcium intake did not alter fat utilization or endurance performance in trained female runners.

Key Words: dairy calcium, fat oxidation, glycogen sparing, time trial

Dietary calcium from both supplemental and dairy sources has been shown to increase resting whole-body fat oxidation in humans (8, 15, 27) although not in all investigations (26). This increase has been observed after both long-term adaptation to a high dairy diet (15) and in response to an acute dairy or supplemental calcium load (8, 27). Only one study has examined the ability of calcium to increase fat oxidation during exercise. Melanson et al. (25) placed men and women on a low (1 serving, ~500 mg Ca\(^{2+}\)) or high (3-4 servings, ~1400 mg Ca\(^{2+}\)) dairy diet for 7 days. On the 7th day, 24-hour fat oxidation was measured in a room calorimeter during energy balance or acute energy deficit induced by cycling at 70% VO\(_{2}\) peak to expend ~400 kcal. Fat oxidation was significantly increased only after the high dairy diet during the exercise session. It is unclear whether or not this result is due to dairy calcium or the natural increase in fat oxidation during exercise. To date, the relationship between acute calcium intake and fat oxidation during endurance exercise, and the result on exercise performance, has not been examined.
The importance of free fatty acids (FFA) as a fuel source during endurance exercise is well established (17, 39). Endogenous triglycerides (17) as well as intramuscular triglycerides (IMTG, 39) supply free fatty acids to the skeletal muscle mitochondria for oxidation during exercise of moderate intensity, ~50-65% maximal oxygen uptake ($\text{VO}_2\text{max}$) (31). An increase in the proportion of fatty acids used for energy should decrease the rate of glycogen breakdown, sparing muscle glycogen to improve endurance exercise capacity (32). Depletion of glycogen stores results in the inability to continue exercise; therefore, glycogen levels and utilization are considered to be a primary limiting factor of endurance performance (37).

Because the amount of fat oxidized during exercise is partially determined by the amount of available substrate (32), dietary interventions including fasting (2, 32), L-carnitine supplementation (32, 38), ingestion of medium-chain (12) and long-chain triglyceride solutions (32), and adaptation to a high fat diet (6, 16) have been investigated for their potential to increase the amount of free fatty acid delivered to the skeletal muscle during exercise. Fasting and high-fat diets increase fat oxidation but do not improve performance, probably due to reduced carbohydrate availability (2, 6, 16, 32). Conversely, ingestion of L-carnitine or triglyceride solutions does not improve fat oxidation or endurance performance (12, 32, 38). Dietary calcium is attractive as a potential ergogenic aid to improve performance since it may increase lipolysis to provide more substrate to the working muscle (41) as well as increase utilization of substrate via improved fat oxidation (8, 15, 27).

Increased use of FFA leading to a sparing of muscle glycogen may improve endurance performance, which is often defined as total exercise time to exhaustion or time to complete a set distance. Traditionally, endurance performance has been measured using subject-determined time to exhaustion trials. Jeukendrup et al. (21) have determined that time trial protocols provide a better evaluation of endurance performance than time to exhaustion tests. A variation of a single time trial protocol is to add a steady-state exercise bout prior to the time trial. Russell et al. (30) found that a 10K time trial performed after a 90-min run at 65% $\text{VO}_2\text{max}$ was highly reproducible and reliable. The authors conclude that this “preloaded time trial” is an appropriate model to use when estimating the effect of ergogenic aids or varied training protocols on endurance performance.

The purpose of this study was to determine the effect of acute dairy calcium intake on exercise energy metabolism, specifically fat oxidation, and endurance running performance using a pre-loaded time trial protocol. It was hypothesized that dairy intake immediately prior to the protocol would improve fat oxidation during exercise and decrease the time to complete a subsequent 10K time trial.

**Methods**

**Subjects**

Participants in this study were endurance trained female runners ($n = 19$) ages 18-30. Inclusionary criteria included a $\text{VO}_2\text{max} \geq 40 \text{ mL/kg/min}$ and absence of medication, which could interfere with calcium absorption. A calcium screening questionnaire (23) was used to assess baseline habitual dietary calcium intake.
Supplemental calcium use was also recorded. Exclusionary criteria included lactose intolerance, allergies to dairy foods, current lactation or pregnancy, and use of over-the-counter weight loss aids. Subjects did not carbohydrate-load or participate in a race during the study. All procedures were approved by the Committee on the Use of Human Subjects in Research at Purdue University and subjects consented to participation.

Pre-Experimental Protocol

Each subject reported to the laboratory once prior to testing to complete inclusionary and calcium screening questionnaires. Menstrual cycle day was recorded and height, weight, blood pressure, and VO$_{2max}$ were assessed.

Measurement of VO$_{2max}$

Subjects were fitted with a mouthpiece, headgear, and noseclip. Respiratory gases were analyzed during the entire test using the ParvoMedics True Max 2400 Metabolic Measurement System (Sandy, UT) and heart rate was monitored via telemetry (Polar Electro Inc., Lake Success, NY). The initial workload for the treadmill VO$_{2max}$ test was set at 3 mph less than the subject’s estimated 10K race time. Speed was increased 1 mph every three min for 12 min. At the end of this period, the incline was increased 2% every two min. The test was terminated at voluntary exhaustion. Criteria for achieving VO$_{2max}$ were one of the following: 1) RER $\geq$ 1.15, 2) heart rate $\pm$ 10 beats per min of the estimated maximum heart rate, or 3) plateau in VO$_2$ (failure to increase more than 150 mL/min) (3).

Randomization

Following baseline testing, subjects were randomly assigned to the control or dairy group for the first performance test. Subjects were given the opposing meal for the second performance test.

Timeline

For subjects with normal menstrual cycles ($n = 14$), the first performance test was scheduled on day 5 to 10 of the menstrual cycle and the second performance test was then conducted one month later, again on cycle day 5 to 10. For subjects with irregular menstrual cycles (less than 10 to 12 cycles in the last year, $n = 2$ high calcium, $n = 3$ low calcium), the tests were conducted one month apart. Menstrual cycle status was not used as exclusionary criteria due to the low number of qualified runners in the recruitment area.

Pre-Test Meal

Participants were provided with a high carbohydrate pre-test meal to be eaten 4 hours prior to the trial and then asked to fast until reporting to the laboratory. If the test was in the morning, the pre-test meal was eaten just prior to sleep the night before, and the subject then reported to the laboratory fasted. Although the length
of the fast between subjects differed, both trials for an individual were conducted at the same time of day. The pre-test meal (684 kcal, 148 g carbohydrate, 14 g protein, and 8.5 g fat) was designed to provide the subjects with approximately 3.0 g/kg carbohydrate (9).

**Test Meal**

One hour prior to the exercise trial, subjects consumed either the control or test shake. The base for both shakes was frozen strawberries (100g), one medium banana (114 g), and non-calcium fortified orange juice. Carbohydrate content (2 g/kg) was adjusted by the amount of orange juice included in the shake.

The high calcium test shake was made with 15 oz (428 g) fat-free vanilla yogurt. The low calcium control shake contained low-calcium soy protein powder (22 g) and fat-free vanilla pudding (140 g). The high (500 mg) and low (80 mg) calcium shakes were matched for calorie and macronutrient content (8). The mean caloric content of the shakes was 519.78 ± 27.14 kcal and 523.33 ± 43.63 kcal for the control and dairy meals, respectively. The mean carbohydrate content of the shakes was 117.44 ± 6.78 g and 118.33 ± 10.91 g for the control and dairy meals, respectively. Both shakes contained 12.5 grams protein and were fat free to remove any effect of dietary fat on endogenous fat utilization.

**Performance Test**

The performance test for this study began with a glycogen-depleting phase followed by a time trial (30). A 10K time trial was used to simulate a competitive event. For the depletion phase, subjects ran for 90 min on a treadmill at 70% VO\textsubscript{2max}, followed by a 5 min break. The distance counter was then reset, stopwatch started, and the time trial begun. Photocells interfaced with the treadmill allowed the subject to self-determine her appropriate speed by moving forward or falling back to speed up or slow down, respectively. The speed and time displays were covered, and subjects were not informed of their time until after the second trial. Water was consumed as needed. At the start of recovery following completion of the 10K, subjects were provided with a carbohydrate-electrolyte fluid replacement drink and cooled down in the laboratory.

Endurance exercise performance is difficult to measure and differences between treatment conditions are often small. It is well known that environmental conditions, particularly air temperature and humidity, effect endurance exercise performance (10). Climate was matched as closely as possible for each test using the laboratory air conditioning, and runners were cooled with an electric fan.

**Between-Test Food Intake**

To ensure adequate glycogen repletion after the first trial, subjects were counseled to consume a diet approximately 60% carbohydrate, 15% protein, and 25% fat in the month between tests. Three-day food records were maintained each week between tests and analyzed using the NutriBase 5 Clinical Edition (Cybersoft, Phoenix, AZ) food analysis software.
Measurement of Respiratory Exchange Ratio (RER)

Thirty minutes after consumption of the test meal, subjects were fitted with a mouthpiece and noseclip for a 10 min collection of respiratory gases that were analyzed using the ParvoMedics True Max 2400 Metabolic Measurement System (Sandy, UT) for postprandial RER. During the 90-min depletion phase of the performance test, RER was measured for 2 min every 15 min. Fat oxidation was calculated assuming a non-protein respiratory quotient (19).

Blood Sample Collection, Storage, and Analysis

Fingertips were heated in warm water for 5 min to facilitate blood sampling. Approximately 200 μL of blood was drawn from a fingerstick into heparanized capillary tubes immediately before the glycogen depleting run. Fingertip blood samples were again obtained after 45 min while running, and immediately after the 90 min run (1). Whole blood (50 μL) was deproteinized by the addition of cold 8% perchloric acid (200 μL) and centrifuged for 10 min at 4°C and 2800 rpm. A 60 μL aliquot of the extract was stored at –80°C for later lactate analysis by enzymatic method (24). Of the remaining acid extract, 120 μL was mixed with 50 μL cold potassium hydroxide and stored at –80°C for later glycerol analysis using an enzymatic kit (Sigma-Aldrich, St. Louis, MO, 11). Absorbance of all samples was determined using a Spectronic Genesys 5 Spectrophotometer (Fischer Scientific International, 1). Chemicals were obtained from Sigma-Aldrich (St. Louis, MO). All samples were measured in duplicate.

Training

Subjects were instructed to document their training routine for the week before each performance test. Exercise was not permitted within 24 hours of the performance tests, and subjects were asked not to participate in a single run more than a total of 90 min in the week prior to beginning the study and between tests.

Statistical Analysis

All statistical analyses were performed using SAS statistical software package (version 8.01). Assumption checking (normality, homogeneity of variance, and random distribution) was performed on all data. Kruskal-Wallis non-parametric alternative in ANOVA was used for data that violated normality assumptions. Outliers were defined as greater than 2 standard deviations beyond the mean. Descriptive statistics (mean, median, and standard deviation) were calculated for baseline age, height, weight, blood pressure, and VO2max as well as dietary intake. One-way ANOVA was used to analyze treatment effect on 10K time. Repeated measures ANOVA were used to compare treatment effects on RER, lactate, and glycerol data between the control and dairy groups. Means were considered significantly different when \( P \leq 0.05 \). For all analyses, Tukey post-hoc testing was used to determine the
differences between groups when treatment differences were detected. Additionally, all data was analyzed for an order effect of treatment. All data are presented as mean ± standard deviation (SD).

Results

Subjects

To assess performance outcomes, participants were endurance-trained female runners (VO\textsubscript{2max} 48.79 ± 6.51 mL/kg/min). Baseline subject characteristics are presented in Table 1. The average weekly mileage reported by subjects at baseline (30.42 ± 14.75) matched documented training for the weeks prior to each test. No differences were observed in training habits during the study as subjects averaged 27.09 ± 17.78 and 31.59 ± 24.66 miles ($P = 0.3$) in the week before the first and second performance tests, respectively.

Habitual Diet Information

Dietary intake information, obtained from three-day food records completed between performance tests, is presented in Table 2. Subjects followed counseling to consume a diet of approximately 60% carbohydrate, 15% protein, and 25% fat between the two performance tests. The range of habitual calcium intakes from all sources, calculated from 3-day food records, was 603.43 to 2466.58 mg/day from all, with a mean of 1171.86 ± 477.0 mg/day.

Respiratory Exchange Ratio

The mean postprandial resting RER for all subjects was 1.00 ± 0.01 and 1.02 ± 0.02 for the dairy and control treatments, respectively, with no differences found

Table 1  Baseline Subject Characteristics ($n = 19$)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>23.26 ± 3.57</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>64.74 ± 2.79</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.24 ± 5.18</td>
</tr>
<tr>
<td>BMI (kg/m\textsuperscript{2})</td>
<td>21.53 ± 1.27</td>
</tr>
<tr>
<td>Systolic Blood Pressure</td>
<td>113.89 ± 8.08</td>
</tr>
<tr>
<td>Diastolic Blood Pressure</td>
<td>76.00 ± 6.31</td>
</tr>
<tr>
<td>VO\textsubscript{2max} (mL/kg/min)</td>
<td>48.79 ± 6.51</td>
</tr>
<tr>
<td>Miles (per week)$^1$</td>
<td>30.42 ± 14.75</td>
</tr>
<tr>
<td>Habitual Calcium Intake (mg)$^2$</td>
<td>1125.05 ± 588.44</td>
</tr>
</tbody>
</table>

*Note. All values are mean ± standard deviation. $^1$Self-reported at baseline; $^2$Data obtained from calcium screening questionnaire plus supplemental intake.*
between groups. For RER measured during the 90-min run, repeated measures
ANOVA demonstrated significant within trial time effects; however no time ×
treatment effects were found (Figure 1). Utilizing VO$_{2\text{max}}$, body weight, weekly
mileage, test time (morning or afternoon), and daily calorie intake as covariates
did not change the results. Additionally, average habitual calcium intake was not
a significant covariate.

Using the wide range of calcium intakes reported in 3-day food records, cor-
rrelations between RER, and habitual calcium intake were used to further investigate
a differential effect of habitual intake on an acute response to dairy. No significant
correlations were found between RER and total daily calcium intake ($r = 0.11,$
$P = 0.51$) or total daily calcium intake adjusted for daily caloric intake ($r = 0.05,$
$P = 0.79$).

**Fat Oxidation**

Fat oxidation was calculated from RER, VO$_2$ (L/min), and VCO$_2$ (L/min) at each
time point (18). As shown in Table 3, no differences were found between groups
for postprandial resting fat oxidation. As with RER data, no significant time ×
treatment effects were found for fat oxidation ($n = 19$). Repeated measures ANOVA
demonstrated a significant time effect during exercise ($P < 0.0001$, Table 3). Neither
VO$_{2\text{max}}$, body weight, weekly mileage, test time (morning or afternoon), daily calorie
intake, nor daily habitual calcium intake were significant covariates.

**Blood Lactate and Glycerol**

Blood samples collected before, during, and after the 90-min run were analyzed for
lactate and glycerol as indices of carbohydrate and fat metabolism, respectively.
No treatment or time × treatment effects were found for blood lactate or glycerol
(Figure 2).

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**Table 2** Between-Test Dietary Intake (n = 19), Data Obtained From
3-Day Food Records

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories (kcal/day)</td>
<td>2004.04 ± 701.72</td>
</tr>
<tr>
<td>Carbohydrate (g/day)</td>
<td>297.27 ± 104.54</td>
</tr>
<tr>
<td>% Carbohydrate</td>
<td>59.69 ± 8.13</td>
</tr>
<tr>
<td>Protein (g/day)</td>
<td>77.66 ± 29.49</td>
</tr>
<tr>
<td>% Protein</td>
<td>15.71 ± 3.74</td>
</tr>
<tr>
<td>Fat (g/day)</td>
<td>59.74 ± 27.81</td>
</tr>
<tr>
<td>% Fat</td>
<td>26.51 ± 7.22</td>
</tr>
<tr>
<td>Dietary Calcium (mg/day)</td>
<td>1171.86 ± 477.00</td>
</tr>
<tr>
<td>Calcium/Calories (mg/kcal)</td>
<td>0.61 ± 0.23</td>
</tr>
</tbody>
</table>

*Note.* All values are mean ± standard deviation.
Repeated measures ANOVA time effects ($P < 0.0001$). *$P < 0.05$ versus 0 min. No time × treatment effects. Data expressed as mean ± SE.

### Table 3  Fat Oxidation (g/min) For All Subjects

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Control ($n = 19$)</th>
<th>Dairy ($n = 19$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>-0.04 ± 0.04</td>
<td>-0.03 ± 0.02</td>
</tr>
<tr>
<td>0</td>
<td>0.23 ± 0.14</td>
<td>0.21 ± 0.18</td>
</tr>
<tr>
<td>15’</td>
<td>0.12 ± 0.09</td>
<td>0.12 ± 0.08</td>
</tr>
<tr>
<td>30’</td>
<td>0.18 ± 0.15</td>
<td>0.14 ± 0.08</td>
</tr>
<tr>
<td>45’</td>
<td>0.19 ± 0.06</td>
<td>0.19 ± 0.09</td>
</tr>
<tr>
<td>60’</td>
<td>0.19 ± 0.08</td>
<td>0.21 ± 0.09</td>
</tr>
<tr>
<td>75</td>
<td>0.21 ± 0.1</td>
<td>0.22 ± 0.1</td>
</tr>
<tr>
<td>90</td>
<td>0.21 ± 0.11</td>
<td>0.23 ± 0.1</td>
</tr>
</tbody>
</table>

*Note.* All values are mean ± standard deviation. *$P < 0.0001$, significant time effect versus 0 min (within trial). No time × treatment effects were observed.
One subject in the habitual LC group developed problems with her iliotibial band during her second time trial, so her performance data is not included in this analysis. Mean 10K times for the dairy (n = 18) and control (n = 18) treatments were 53.09 ± 1.86 and 53.11 ± 1.52 min, respectively (P = 0.99). No treatment effect was found for 10K time. Data had equal variance, but was not normal by the Anderson-Darling test (P < 0.05). One outlier was found in the data for the dairy trial (78.63 min). After removal of this data point, data followed normality assumptions, but no treatment effect was found. After removal of the outlier from the dataset, mean 10K times for the dairy (n = 17) and control (n = 17) treatments were 51.59 ± 1.17 and 52.37 ± 1.41 min, respectively (P = 0.34). No effect of treatment order was found (P = 0.86). Neither VO\textsubscript{2max}, body weight, weekly mileage, test time (morning or afternoon), daily calorie intake, nor daily habitual calcium intake were significant covariates. Individual 10K (n = 17) times are presented in Figure 3.

Correlations were investigated between 10K time and habitual calcium intake and RER. No significant correlations were found between performance time and total daily calcium intake (r = 0.11, P = 0.51), total daily calcium intake adjusted for total daily caloric intake (r = 0.16, P = 0.36), or average exercise RER (r = −0.06, 0.71).

**Discussion**

The purpose of the current study was to determine the effect of acute dairy calcium intake on fat oxidation during endurance exercise, specifically a 90-min treadmill run at 70% VO\textsubscript{2max}. A further purpose was to determine the effect of the calcium load on performance as defined by the time to complete a 10K time trial following the 90-min glycogen-depleting run. No treatment effects were found for fat oxidation or 10K performance time.

![Figure 2](image-url) — Blood lactate (left) and glycerol (right) data for dairy treatment (dashed line) and control (solid line). By repeated measures ANOVA, no time or time × treatment effects. Data expressed as mean ± standard error.
Subjects

The amount of fat used as fuel during exercise is gender dependent. During moderate intensity endurance exercise, females have been found to utilize more total lipid than males following the same diet and training regimens (35). Further investigation has revealed that utilization of one specific source of fatty acids, IMTG, is negligible in males but accounts for 25.0 ± 6.0% of leg oxygen uptake in females (29). Since men and women may use fat differently as a fuel source during exercise, the current study examined the effect of acute dairy calcium intake on fat oxidation in female athletes only. Of concern in a female subject population is use of oral contraceptives. This practice was noted but not controlled in the current protocol.

Figure 3 — 10K time following 90 min glycogen depletion run for each individual after ingestion of high dairy or low dairy control test meal.
However, it does not appear that oral contraceptive use alters fat oxidation at rest (20) or during endurance exercise (18, 33) and therefore should not affect the outcomes of this study.

**Substrate Utilization and Performance**

No differences were found between treatment groups for postprandial resting fat oxidation. This finding is in agreement with Gunther et al. (15), who also did not observe acute increases in 4 hours postprandial resting fat oxidation in response to a high versus low calcium meal. However, the resting metabolic response to a meal does not necessarily correspond to exercise metabolism. Wu et al. (40) observed differences in fat oxidation during exercise at 65% $\text{VO}_{2\text{max}}$ following consumption of pre-exercise meals of varying glycemic indices, even when thermic effect of the meal at rest was the same among treatment groups. Acute calcium intake has been shown to increase resting postprandial fat oxidation (8, 27); however, to alter exercise metabolism ingestion of 500 mg of dairy calcium 1 hour prior to exercise may not have been sufficient to alter oxidation of free fatty acids from either adipose tissue or IMTG stores. Evidence from Melanson et al. (25) suggests adaptation to a week long high dairy diet increases fat oxidation during exercise in untrained individuals. In the current study, neither an effect of acute calcium intake nor a differential response to habitual calcium intake was observed, and average exercise RER was not correlated to habitual calcium intake. A possible explanation for the lack of both acute and habitual effect is the macronutrient content of the pre-test shake.

The magnitude of RER, lactate, and glycerol response in this study were similar to those found by Andrews et al. (1), who supplemented female runners with a carbohydrate beverage during a 24.2 km treadmill run. However, no differences in these parameters were found between treatment groups or when adjusting by habitual calcium intake. The macronutrient composition of the test meal may have affected these results since carbohydrate intake increases RER and consumption of a high carbohydrate meal 4 hours prior to exercise has been shown to decrease fatty acid levels during exercise (1, 7, 9). In the current study, the carbohydrate content of the pre-test meal consumed 4 hours prior to arriving at the lab (3g/kg, ~148 g carbohydrate) plus the test shake consumed 1 h prior to running (2g/kg, ~117 g carbohydrate) was too high and may have masked the ability of calcium to decrease RER and increase fat oxidation.

Dietary protein has been found to increase calcium absorption, but also calcium excretion (22). It is possible that the protein content of the pre-test shake (12.5 g) decreased the amount of calcium absorbed, leading to the lack of acute response to dairy. However, acute feeding of whey protein, the same protein source used in the shakes, improved calcium absorption in rats and led to an increase in bone mineral content (42). In a study by Kerstetter et al. (22), protein excretion was increased with a high protein diet (2.1 g/kg/day) but not a medium protein diet (1.0 g/kg/day). In the current study, the average protein intake was approximately 1.2 g/kg/day, based on a mean body weight of ~65 kg and reported dietary protein intake of ~78 g/day, of which ~16% was accounted for by the test meal. Therefore, it is unlikely that the protein content of the pre-test shake or habitual protein consumption altered calcium absorption.
Another potential explanation for the lack of treatment effect may involve levels of parathyroid hormone (PTH), which are hypothesized to modulate calcium’s effect on fat oxidation (15). High levels of PTH, usually found with a low-calcium diet (15), are known to impair carnitine palmitoyl transferase I activity, inhibiting the rate limiting step of fatty acid transfer into the mitochondria, and decreasing long chain fatty acid oxidation (31). An acute exercise bout may decrease serum calcium and induce a stimulatory effect on PTH (4, 14, 36). This increase in PTH, although blunted, is also observed in response to a pre-exercise calcium load (13, 14). If PTH increases during exercise regardless of calcium intake, and if the primary mechanism for increased fat oxidation due to calcium intake is suppression of the calcitropic hormones (15, 41), this response may not be observed during exercise and a corresponding effect on performance may also not be observed. The dairy group did complete the 10K time trial an average of 0.78 min faster than the control trial; however, the results of this study do not confirm the hypothesis that dairy calcium intake prior to endurance exercise will improve running performance.

Limitations and Recommendations for Future Research

Further research is needed to clarify the effects of calcium intake on endurance exercise performance when carbohydrate intake prior to exercise is limited. To help achieve a lower pre-test carbohydrate load, the effects of dairy food source calcium compared with sources of supplemental calcium may provide additional insight to the potential role of calcium as an ergogenic aid.

A major limitation of this protocol was the inability to standardize the length of fasting before the pre-test meal as muscle glycogen and substrate oxidation depend on the timing of pre-exercise nutrient intake (7). For all subjects, the pre-test meal was standardized; however, the length of fast between the pre-test meal and the test shake varied. Neufer et al. (28) compared the effect of a carbohydrate feeding 5 min prior to an exercise bout preceded by either a 12 hour overnight fast or a separate 200 g carbohydrate meal 4 hours prior. During 45 min of steady state cycling followed by a 15 min performance trial, the carbohydrate feedings given 4 hours and again 5 min prior increased RER and reduced blood glycerol compared to the longer pre-exercise fast. Therefore, in the current study, although there was not a statistical difference in substrate oxidation between trials in the morning and afternoon, it is likely the subjects who completed the trial in the morning after an overnight fast oxidized more fat than those completing the trials in the afternoon with only a 4-hour fast between the pre-test meal and test shake. Future protocols should standardize test time.

To assess performance, endurance trained athletes were used in the protocol. Increases in fat oxidation are well-known adaptations to endurance training. Furthermore, resting levels of PTH may be reduced in endurance trained individuals (5), and endurance training is also known to improve the utilization of fat for energy and spare muscle glycogen (37). Given the proposed inverse relationship between PTH and fat oxidation, it is interesting that endurance training results in both decreased PTH and improved fat oxidation. Therefore, the capacity of the body to decrease PTH and increase fat oxidation in response to calcium intake may
already be maximized in trained athletes, and a response on substrate metabolism and subsequent performance may not be observed. Future studies should include measurement of PTH and an investigation of the ability of calcium to increase fat oxidation during exercise in untrained individuals using an adapted protocol of shorter duration. This information may be pertinent to weight loss or maintenance of reduced body weight.

Overall, the current study provides preliminary insight into the relationship between pre-exercise dairy calcium intake, fat oxidation, and endurance running performance. Additional studies are needed to draw definitive conclusions on the role of dairy food as an ergogenic aid.

Acknowledgments

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References


