Lack of Effect of Exercise Time of Day on Acute Energy Intake in Healthy Men

Katriona J.M. O'Donoghue, Paul A. Fournier, and Kym J. Guelfi

Although the manipulation of exercise and dietary intake to achieve successful weight loss has been extensively studied, it is unclear how the time of day that exercise is performed may affect subsequent energy intake. The purpose of the current study was to investigate the effect of an acute bout of exercise performed in the morning compared with an equivalent bout of exercise performed in the afternoon on short-term energy intake. Nine healthy male participants completed 3 trials: morning exercise (AM), afternoon exercise (PM), or control (no exercise; CON) in a randomized counterbalanced design. Exercise consisted of 45 min of treadmill running at 75% VO$_{2\text{peak}}$. Energy intake was assessed over a 26-hr period with the participants eating ad libitum from a standard assortment of food items of known quantity and composition. There was no significant difference in overall energy intake ($M \pm SD$; CON 23,505 ± 6,938 kJ, AM 24,957 ± 5,607 kJ, PM 24,560 ± 5,988 kJ; $p = .590$) or macronutrient preferences during the 26-hr period examined between trials. Likewise, no differences in energy intake or macronutrient preferences were observed at any of the specific individual meal periods examined (i.e., breakfast, lunch, dinner) between trials. These results suggest that the time of day that exercise is performed does not significantly affect short-term energy intake in healthy men.

Keywords: food intake, appetite, energy balance, macronutrient preferences

Imbeault, & Doucet, (2004) and the length of time over which energy intake is measured (King, Tremblay, & Blundell, 1997).

Another aspect of exercise that may influence energy intake is the time of day that exercise is performed. Although morning exercise before breakfast has been promoted for achieving weight loss based on the higher availability of circulating free fatty acids (McCarty, 1995), it is possible that exercising at this time of the day may provide more potential opportunities to compensate for increased energy expenditure as the day progresses (i.e., at breakfast, lunch, and the evening meal) compared with exercise performed in the afternoon (evening meal only). Indeed, it has been reported that energy intake varies over the course of a day in the natural environment, with more food ingested in the evening than in the morning (de Castro, 1987, 2004). However, the influence of the time of day that exercise is performed on daily energy consumption remains unclear.

Only one previous study attempted to investigate this issue. Maraki, Tsolfiou, Malkova, Mutrie, and Higgins (2005) examined the acute effect of a 1-hr muscle- and aerobic-conditioning exercise class performed in the morning (8:15 a.m.) compared with the evening (7:15 p.m.) on energy intake over a 24-hr period based on self-recorded food diaries in healthy-weight women. No significant differences in energy intake were observed between the morning and evening exercise trials (Maraki et al., 2005).
However, it is important to note that the caloric expenditure during the exercise sessions was not strictly matched and that self-reported dietary records are typically susceptible to inaccurate reporting (Bingham, 1987; Poppitt, Swann, & Prentice, 1998). In addition, menstrual-cycle phase, a factor that may independently influence food intake, was not standardized between trials (Gong, Garrel, & Calloway, 1989). Consequently, the purpose of the current study was to examine the acute effect of exercise performed in the morning compared with the afternoon on energy intake under more controlled conditions in men, with the energy expenditure during exercise strictly matched and the quantification of energy intake using a buffet of food items of precisely known quantity and composition from which the participants could consume ad libitum.

Methods

Participants

Nine healthy, physically active men (age 20 ± 3 years, body-mass index 22.4 ± 1.6 kg/m², peak aerobic capacity [VO₂peak] 58.8 ± 5.6 ml · kg⁻¹ · min⁻¹) were recruited. These participants had maintained a stable body weight (± 2 kg) for a period of 6 months preceding the study and were not taking any medications or on any special diet that may influence food intake. Three of the participants preferred to exercise in the morning, and the others preferred afternoon exercise. Despite these preferences, all participants were regularly exercising during the afternoon at the time of the study. The participants were not informed that their food intake would be monitored during the study, to minimize any conscious alteration in food intake. One of the participants had maintained a stable body weight (± 2 kg) for a period of 6 months preceding the study and was not taking any medications or on any special diet that may influence food intake. Three of the participants preferred to exercise in the morning, and the others preferred afternoon exercise. Despite these preferences, all participants were regularly exercising during the afternoon at the time of the study. The participants were not informed that their food intake would be monitored during the study, to minimize any conscious alteration in food intake, but were personally debriefed after the completion of all trials. Written informed consent was provided by each participant, and the project was approved by the institutional human ethics committee.

Experimental Design

Each participant came to the laboratory on four separate occasions, with at least 1 week between visits. First was a familiarization session, followed by three experimental trials administered in a randomized counterbalanced design: morning exercise (a.m.), evening exercise (p.m.), and a control session (no exercise). The day before the first experimental trial, each participant was asked to record all food and drinks he consumed and then to replicate this on the day before each subsequent trial. In addition, participants were asked to refrain from alcohol consumption and vigorous physical activity on the day before each experimental trial.

Familiarization Session

During the familiarization session the height and body mass of each participant were recorded. Peak oxygen uptake (VO₂peak) was then determined using an incremental treadmill protocol to establish the speed necessary to elicit 75% VO₂peak for the subsequent experimental sessions. The incremental test consisted of 3-min stages of progressively increasing speed (1% gradient), with 1-min rests allowed between intervals until voluntary exhaustion was reached. During the test the participants breathed through a mouthpiece into an online gas-analysis system. This system consisted of a ventilometer (Morgan, Kent, UK) to measure the volume of inspired air and oxygen and carbon dioxide analyzers (Ametek Applied Electrochemistry S-3A/I and CD-3A AEI Technologies, Pittsburgh, PA) to measure the concentration of these gases in expired air. After the exercise test participants completed a questionnaire detailing their regular food choices for breakfast, lunch, dinner, and snacks to ensure that the foods provided in the experimental trials would be palatable.

Assessment of Energy Intake

For each of the main meals (breakfast, lunch, and evening meal), the participants were presented with their own individual array of foods and drinks (including water) from which they were free to consume ad libitum without being observed. The items provided were in excess of expected consumption and standardized for all trials and included a variety of foods considered regular food
choices for breakfast (i.e., breakfast cereals, bread, spreads, yogurt, fruit, milk, and juice), lunch (i.e., sandwiches, fruit, yogurt, and juice), and dinner (i.e., pasta, meat sauce, bread, vegetables, juice, and milk). Each food item was of precisely known weight and composition, and the macronutrient content of each meal period was approximately 50% carbohydrate, 30% fat, and 15% protein. In addition, certain foods and drinks were available at each main meal for the participants to take from the laboratory and consume as snacks throughout the day (i.e., muesli bars, fruit, nuts, chocolate, and cookies). Participants were instructed that only food provided at the laboratory could be consumed and that all snack items not consumed were to be returned to the laboratory before the consumption of the next main meal. All remaining food was reweighed after the participant had left the laboratory to calculate total energy consumed, along with the carbohydrate, fat, and protein composition of each meal period: (a) breakfast period, breakfast and morning snacks; (b) lunch period, lunch and afternoon snacks; (c) evening meal period, evening meal and snacks; (d) and follow-up breakfast. These calculations were based on the composition determined from food labels and a commercially available software program (Foodworks, Xyris Software, Highgate Hill, QLD, Australia). In addition, relative energy intake (REI) was calculated by subtracting the energy expended during the exercise session from total energy expenditure based on indirect calorimetry was similar between trials (p = .207). In addition, there was no significant difference in the environmental temperature (control 20.2 ± 1.0 °C, a.m. 20.5 ± 1.2 °C, p.m. 20.3 ± 1.1 °C; p = .898) or the number of steps recorded by pedometer between the three trials (control 5,861 ± 3,964 steps, a.m. 5,443 ± 3,775 steps, p.m. 6,998 ± 2,445 steps; p = .604).

Data Analysis

Each dependent variable was compared between trials using repeated-measures analysis of variance, with post hoc pairwise comparisons using Bonferroni adjustment to determine where any differences were. Statistical significance was accepted as p < .05 (SPSS 15.0 for Windows). All results are presented as M ± SD unless otherwise specified.

### Results

#### Exercise Sessions

The a.m. and p.m. exercise sessions were well matched, with no significant differences in oxygen consumption (p = .583), relative percentage of oxygen consumption (p = .591), or heart rate (p = .125) between trials (Table 1). Although the respiratory-exchange ratio was significantly higher during p.m. exercise than a.m. exercise (p = .007), the overall energy expenditure based on indirect calorimetry was similar between trials (p = .207). In addition, there was no significant difference in the environmental temperature (control 20.2 ± 1.0 °C, a.m. 20.5 ± 1.2 °C, p.m. 20.3 ± 1.1 °C; p = .898) or the number of steps recorded by pedometer between the three trials (control 5,861 ± 3,964 steps, a.m. 5,443 ± 3,775 steps, p.m. 6,998 ± 2,445 steps; p = .604).

#### Energy Intake

There were no significant differences in energy intake between trials at any of the individual meal periods examined: breakfast (p = .885), lunch (p = .823), evening meal (p = .326), and follow-up breakfast (p = .589; Table 2). With respect to overall energy intake across the entire 26-hr period (all meals including the follow-up breakfast),

### Table 1 Characteristics of 45 min of Treadmill Running in the Morning (7 a.m.) Compared With the Afternoon (5 p.m.), N = 9, M ± SD

<table>
<thead>
<tr>
<th></th>
<th>Morning</th>
<th>Afternoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO₂ (ml · kg⁻¹ · min⁻¹)</td>
<td>43.4 ± 5.8</td>
<td>44.7 ± 6.9</td>
</tr>
<tr>
<td>Percentage of VO₂max</td>
<td>74 ± 4</td>
<td>76 ± 6</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>183 ± 8</td>
<td>184 ± 8</td>
</tr>
<tr>
<td>Respiratory-exchange ratio</td>
<td>0.87 ± 0.04</td>
<td>0.92 ± 0.03*</td>
</tr>
<tr>
<td>Energy expenditure (kJ)</td>
<td>2,831 ± 519</td>
<td>2,898 ± 570</td>
</tr>
</tbody>
</table>

*Significant difference from a.m. exercise (p < .05).

### Table 2 Effect of Morning Exercise (7 a.m.), Afternoon Exercise (5 p.m.), and Rest (Control) on Energy Intake, kJ, N = 9, M ± SD

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Morning</th>
<th>Afternoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast period (8:30 a.m. to 12:30 p.m.)</td>
<td>5,947 ± 2,488</td>
<td>6,087 ± 1,963</td>
<td>6,256 ± 2,660</td>
</tr>
<tr>
<td>Lunch period (1 p.m. to 4:30 p.m.)</td>
<td>4,959 ± 2,106</td>
<td>5,166 ± 1,695</td>
<td>4,712 ± 1,718</td>
</tr>
<tr>
<td>Dinner period (6:30 p.m. to sleep)</td>
<td>9,069 ± 3,168</td>
<td>9,893 ± 2,486</td>
<td>10,099 ± 3,606</td>
</tr>
<tr>
<td>Day total</td>
<td>19,975 ± 5,909</td>
<td>21,145 ± 4,507</td>
<td>21,067 ± 5,192</td>
</tr>
<tr>
<td>Follow-up breakfast</td>
<td>3,530 ± 1,234</td>
<td>3,811 ± 1,791</td>
<td>3,492 ± 1,149</td>
</tr>
<tr>
<td>Overall</td>
<td>23,505 ± 6,938</td>
<td>24,957 ± 5,607</td>
<td>24,560 ± 5,988</td>
</tr>
</tbody>
</table>

*Note. Day total = sum of kJ intake on initial day (not including follow-up breakfast); overall = sum of kJ intake for entire 26-hr period (including follow-up breakfast).
there was also no significant difference between trials ($p = .590$). Likewise, no significant differences in energy intake were observed between trials when the initial day was considered alone (excluding the follow-up breakfast; $p = .630$).

Although there were no significant differences in energy intake between trials during specific meal periods, there was a significant difference in energy intake across meals irrespective of trial ($p < .001$). Significantly more energy was consumed during the evening period than in all other meal periods examined, and the least energy was consumed during the follow-up breakfast (breakfast $6,097 \pm 2,299$ kJ, lunch $4,946 \pm 1,787$ kJ, evening $9,687 \pm 3,032$ kJ, follow-up breakfast $3,611 \pm 1,372$ kJ).

**REI**

When the energy expended during the exercise sessions (above resting energy expenditure) was subtracted from the energy intake during the subsequent individual meal period, the resulting REI was significantly lower postexercise ($p < .02$). That is, REI during the breakfast meal period was significantly lower after a.m. exercise ($3,494 \pm 1,664$ kJ) than either the p.m. exercise ($6,256 \pm 2,660$ kJ; $p = .016$) or control trial ($5,477 \pm 2,488$ kJ; $p = .019$). Likewise, REI during the evening period was significantly lower after p.m. exercise ($7,440 \pm 3,391$ kJ) than for the control trial ($9,096 \pm 3,391$ kJ; $p = .029$) and also tended to be lower than the a.m. exercise trial ($9,893 \pm 2,486$ kJ; $p = .070$). However, when the extra energy expended during the exercise sessions was subtracted from the overall 26-hr energy intake, the resulting overall REI was similar between all trials ($p = .554$; Figure 1). Likewise, when REI was calculated for the initial day only (not including the kilojoules consumed during the follow-up breakfast), energy intake was similar between trials ($p = .484$).

**Macronutrient Preferences**

No significant differences in the amount of carbohydrate, fat, or protein ingested were observed between trials at any of the specific meal periods examined, regardless of whether results were expressed in absolute grams ($p = .533$, $p = .409$, and $p = .995$, respectively) or as a percentage of total energy intake ($p = .215$, $p = .286$, and $p = .225$). Likewise there was no significant difference in the overall 26-hr intake of each of the macronutrients between the three trials (Table 3). Although the absolute amount of carbohydrate consumption varied between meal periods ($p < .001$), with significantly greater carbohydrate intake during the evening meal period ($341 \pm 120$ g) than all other periods (breakfast $206 \pm 92$ g, lunch $152 \pm 63$ g, follow-up breakfast $128 \pm 47$ g), there was no main effect for meal period when results were expressed as a percentage of contribution to total energy intake ($p = .257$). With

![Figure 1](image.png) --- Effect of morning exercise (AM; 7 a.m.), afternoon exercise (PM; 5 p.m.), and rest (CON) on absolute (black bars) and relative (white bars) energy intake over a 26-hr period ($N = 9, M \pm SE$).

<table>
<thead>
<tr>
<th>Macronutrient</th>
<th>Control</th>
<th>Morning</th>
<th>Afternoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate</td>
<td>g</td>
<td>% kJ</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>796 ± 261</td>
<td>54 ± 6</td>
<td>206 ± 92</td>
</tr>
<tr>
<td>% kJ</td>
<td>838 ± 227</td>
<td>54 ± 7</td>
<td>152 ± 63</td>
</tr>
<tr>
<td>g</td>
<td>844 ± 223</td>
<td>55 ± 4</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>g</td>
<td>% kJ</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>184 ± 57</td>
<td>29 ± 4</td>
<td>128 ± 47</td>
</tr>
<tr>
<td>% kJ</td>
<td>197 ± 53</td>
<td>29 ± 5</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>192 ± 53</td>
<td>29 ± 4</td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>g</td>
<td>% kJ</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>172 ± 52</td>
<td>13 ± 2</td>
<td>128 ± 47</td>
</tr>
<tr>
<td>% kJ</td>
<td>182 ± 40</td>
<td>12 ± 1</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>182 ± 51</td>
<td>13 ± 2</td>
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</tr>
</tbody>
</table>
respect to absolute fat intake, there was a main effect of meal period \( (p < .001) \), with significantly less consumed during the follow-up breakfast \( (27 \pm 13 \text{ g}) \) than at the initial breakfast \( (53 \pm 20 \text{ g}) \) and evening meal \( (64 \pm 21 \text{ g}) \). However, when results were expressed as a percentage of total energy intake, fat consumption was lower during the evening meal period than the initial breakfast period \( (p = .037) \). Similarly, absolute protein intake was significantly less in the follow-up breakfast \( (21 \pm 8 \text{ g}) \) and greater during the evening meal \( (88 \pm 29 \text{ g}) \) than for all other meal periods \( (breakfast \ 34 \pm 13 \text{ g}, lunch \ 35 \pm 17 \text{ g}) \). Protein intake as a percentage of total energy intake was higher in the dinner meal than the initial breakfast \( (p = .001) \) and follow-up breakfast \( (p = .002) \) periods only.

**Discussion**

The primary aim of this study was to examine the effect of an acute bout of exercise performed in the morning before breakfast with an equivalent bout of exercise performed before the evening meal on 24-hr energy intake in healthy men. No significant differences were observed in overall energy intake between morning and afternoon exercise trials or the resting control. Similarly, no significant differences were apparent between trials when energy intake was calculated for the initial day only (excluding breakfast the following day) or at any of the specific individual meal periods (i.e., breakfast, lunch, or evening period). These results support the findings of Maraki et al. (2005), who reported no effect of the time of day of an aerobics class (morning vs. evening) on self-reported 24-hr energy intake or consumption in an immediate postexercise meal in healthy-weight women. In addition, the observation that the greatest energy intake occurred during the evening meal period (irrespective of trial) is consistent with the observations of de Castro (2004), who reported significantly greater energy intake between 6 and 10 p.m. than in other periods throughout the day based on self-reported intake of a large cohort of free-living individuals.

In determining the effect of an acute bout of exercise on subsequent energy intake, it is also important to consider overall energy balance by accounting for the energy expended during exercise above resting energy expenditure (King et al., 1994). Our participants were instructed to minimize movement throughout the day after leaving the laboratory. Although pedometers only provide a basic indication of physical activity levels, the similar number of steps recorded in each trial suggests that there were no large differences in behavior outside the laboratory between trials. Therefore it is likely that the laboratory-based exercise was the only main difference in energy expenditure between trials. When the extra energy expended during this exercise bout was subtracted from the overall 24-hr energy intake, the resulting REI remained similar between all trials. This finding contrasts with that of Maraki et al. (2005), who reported significantly lower 24-hr REI during their morning exercise trial than the control but no difference between evening exercise and control. In the current study, only when the immediate postexercise meal period was considered in isolation from the rest of the experimental period was REI significantly lower after both a.m. and p.m. exercise than the resting control trial.

The lower REI observed in the immediate postexercise meal can be related to other studies that examined the effect of an acute bout of exercise (independent of exercise time of day) on energy intake in the postexercise meal. Such investigations have also typically observed no difference (Imbeault et al., 1997; Lluch, King, & Blundell, 1998) or greater (Martins, Morgan, Bloom, & Robertson, 2007; Pomerleau et al., 2004) absolute energy intake in the postexercise meal but lower REI after exercise than with control conditions. However, lower absolute energy intake postexercise has also been reported (Kissileff et al., 1990). Reasons for these contrasting findings may be related to the methodology used to quantify energy intake or differences in experimental design including participant characteristics, timing of the postexercise meal, and whether exercise was performed in the fasted or fed state. Regardless, the implications of such studies reporting changes in the postexercise meal in isolation may be limited given that in the current study the lower REI in the immediate postexercise meal was not accompanied by a significant difference in REI between exercise (a.m. or p.m.) and control when the entire 26-hr period was examined. This highlights the importance of extending such studies past the postexercise meal alone, because alterations in energy intake during subsequent meals may compensate for any acute changes. This notion is supported by Pomerleau et al., who also observed significantly lower REI in the immediate postexercise meal (lunch) after both high- and low-intensity exercise compared with a control condition but no difference in REI when considering intake over the entire day. Despite the lack of statistical difference in overall REI between exercise and control conditions in the current study, it is important to acknowledge that the large variability in energy intake between participants likely makes detecting small (but relevant) differences in food intake difficult. This is an important issue given that even small changes in energy intake throughout a day, if continued long-term, may have a significant impact on energy balance. In the current study REI was ~1,500 kJ lower in the exercise trials (a.m. and p.m.) than in the control group when considering the initial day alone. Whether this difference in energy balance is clinically relevant in the long term remains to be determined. Regardless, the primary focus of the current study was the comparison between a.m. and p.m. exercise, not between exercise and control. Based on the current results, there is no indication of difference (significant or otherwise) in energy intake between the a.m. and p.m. trials.

In addition to examining the effect of exercise time of day on energy intake, we examined alterations in macronutrient preferences for carbohydrate, fat, and protein. We observed similar macronutrient intake at each specific meal period, as well as over the entire
26-hr period between trials, regardless of whether results were expressed as an absolute amount or as a percentage contribution to total energy intake. However, there were differences in absolute macronutrient intake between meal periods (irrespective of trial), with the greatest intake of each macronutrient during the evening meal period, likely as a result of the higher overall energy intake at that time. This finding is in agreement with that of de Castro (2004), who reported significantly greater consumption of carbohydrate, fat, and protein between 6 and 10 p.m. than in other periods throughout the day, possibly as a result of learned cultural or lifestyle habits (Kramer, Rock, & Engell, 1992).

Overall, the primary finding of this study was that energy intake was similar whether exercise was performed in the a.m. or p.m., regardless of whether individual meals were examined in isolation or over the entire 26-hr period. However, it is important to note that during the a.m. trial all energy intake took place after the exercise session, whereas in the p.m. trial only the dinner period and follow-up breakfast followed the exercise session. Future studies should extend the period over which energy intake is monitored in the day after afternoon exercise. Another limitation relates to the overfeeding that is commonly observed in studies using a variety of foods from which participants can consume ad libitum (Arvaniti et al., 2000). The excessive intake of our participants (~20,000 kJ/day) appears comparable to other studies reporting intake of ~7,000 kJ from a single buffet-type meal (Arvaniti et al., 2000; Imbeault et al., 1997). Although such intake is greater than under free-living conditions, any effect of overfeeding should be of a similar magnitude during each experimental trial, thereby still allowing for the detection of differences between conditions. Furthermore, the buffet method of quantifying energy intake remains preferable for laboratory-based studies of repeated-measures design (Arvaniti et al., 2000; Stubbins et al., 1998). Finally, it is important to acknowledge that the effect of exercise on energy intake appears to be mediated, at least in part, by peripheral hormonal signals such as peptide tyrosine-tyrosine, pancreatic polypeptide, and glucagon-like peptide-1 (Martins, Morgan, et al., 2007; Shorten, Wallman, & Guelfi, 2009). Whether the effect of exercise on the circulating levels of appetite-related hormones is moderated by exercise time of day remains to be determined.

Taken together these findings suggest that the time of day exercise is performed does not significantly influence energy intake over an acute 26-hr period in normal-weight men. Whether similar findings would be observed in women or overweight individuals is not known. Our participants were regular exercisers with a relatively high level of aerobic fitness. Indeed, it has been reported that regular exercise may improve short-term regulation of food intake (Long, Hart, & Morgan, 2002; Martins, Truby, & Morgan, 2007), raising the possibility that different results may be observed in a sedentary population. Nevertheless, based on the findings of this study, we propose that healthy individuals attempting to manage their weight should not feel constrained to exercise at any particular time of day. This may have important practical implications, given the popular view that exercising in the morning may be more effective for achieving weight loss based on the higher availability of circulating free fatty acids (McCarty, 1995) and lower exercise respiratory-exchange rate in the morning fasted state indicating greater fat oxidation (Bergman & Brooks, 1999). On the other hand some may argue that afternoon exercise may be more beneficial for weight management given that self-selected exercise intensity may be higher at this time than in the morning (Atkinson, Todd, Reilly, & Waterhouse, 2005), which in turn may provide for greater overall energy expenditure. Furthermore, if exercise is perceived to be easier at this time of day, long-term adherence may be enhanced (Atkinson, Drust, George, Reilly, & Waterhouse, 2006). Our findings, combined with the fact that altering an individual’s preferred time of day to exercise may become a barrier to participation, suggest that it may not be critical whether exercise is performed in the morning or in the evening, as long as it is performed and a healthy lifestyle is maintained.

Acknowledgments

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References


