

Research article

A Comparison of the Maximal Fat Oxidation Rates of Three Different Time Periods in The Fatmax Stage

Kerem T. Özgünen ¹✉, Çiğdem Özdemir ¹, Selcen Korkmaz-Eryılmaz ², Abdullah Kılıcı ², Özgür Günaştı ¹ and Sanlı S. Kurdak ¹

¹ Çukurova University, Medical Faculty, Department of Physiology, Division of Sports Physiology and ² Department of Physical Education and Sports, Adana, Turkey

Abstract

This study aimed to compare the maximal fat oxidation (MFO) rates obtained from the stage average, last 2 min average, and highest value in the Fatmax stage determined with a 6 min step protocol. A total of 35 overweight, sedentary healthy men (age: 25.4 ± 0.7 years, body mass index: 26.0 ± 0.6 kg/m²) participated in the study. Substrate oxidation was calculated using breath-by-breath gas exchange data for each stage. When the change in the fat oxidation rate for every min throughout the Fatmax stage was evaluated, the average value of the 4th min was significantly lower than that of the 2nd and 3rd min ($p < 0.01$). In addition, the 5th and 6th min fat oxidation rates were significantly lower than the rates of the 1st, 2nd, 3rd, and 4th min (0.30 ± 0.01 and 0.29 ± 0.01 g/min for the 5th and 6th min, respectively, vs. 0.35 ± 0.02 , 0.34 ± 0.02 , 0.33 ± 0.02 , and 0.31 ± 0.01 g/min for the 1st, 2nd, 3rd, and 4th min, respectively; $p < 0.01$). Most of the participants had MFO rates in the 1st min of the stage (16/35 participants), and the MFO rates of the remaining participants were observed in the 2nd, 3rd, and 4th min (7/35, 4/35, and 8/35 participants, respectively). None of the participants had MFO rates in the 5th or 6th min. The individual MFO rate (highest fat oxidation rate during Fatmax) was significantly higher than the fat oxidation rate calculated with the last 2 min average values (0.36 ± 0.02 and 0.30 ± 0.01 g/min, respectively; $p < 0.05$). In conclusion, the calculation of the fat oxidation rate by averaging the last portion of the Fatmax stage data may cause the underestimation of the MFO rate, which probably occurs earlier in the Fatmax stage.

Key words: Exercise intensity, substrate oxidation, indirect calorimetry, oxygen consumption, respiratory quotient.

Introduction

In recent years, there has been increased interest in fat metabolism in the field of both sports sciences and medicine. During long-distance events, increasing the reliance on fat can help athletes save glycogen reserves for high-intensity situations later in the events. The impairment of fat oxidation has been associated with the development of obesity and type 2 diabetes, and endurance training has been reported to improve fat oxidation and reduce body weight (Rosenkilde et al., 2015). With the aim of utilizing as much fat as possible in a certain period of time, the main strategy should be to exercise with low-moderate intensity. In particular, professional organizations such as the American College of Sports Medicine and American Medical Association recommend regular aerobic activity as part of a weight loss program with a special emphasis on low-intensity exercises for individuals interested in weight loss or

control (Haskell et al., 2007).

It is well known that energy production shifts from fat to carbohydrates with an increase in the intensity of physical activity (Christensen and Hansen, 1939; Maunder et al., 2018). The specific intensity at which the fat oxidation rate is maximal (commonly presented as a percentage of the maximal oxygen uptake) is defined as Lipoxmax, Fatoxmax, or Fatmax by different researchers (Brun et al., 2011) and provides a measure of the maximal fat oxidation (MFO; the highest rate of fat oxidation observed at various intensities) (Randell et al., 2017). The determination protocol is often called the Fatmax test; exercise intensity could be individualized with the Fatmax test, and a suitable exercise prescription could be prepared according to the subjects' metabolic responses (Besnier et al., 2015; Dumortier et al., 2003; Tan et al., 2016). Athletic training programs, programs for weight or body fat loss, and exercise programs that treat or prevent welfare diseases may be the potential applications of Fatmax (Jeukendrup and Achten, 2001).

Lipids are oxidized predominantly at submaximal exercise intensities ($< 65\% \dot{V}O_{2max}$); however, an exercise intensity that exceeds $65\% \dot{V}O_{2max}$ produces a shift in energy contribution favoring carbohydrates (Purdom et al., 2018). Therefore, Fatmax can be achieved at low-to-moderate exercise intensities ($35\text{--}65\% \dot{V}O_{2max}$) (Jeukendrup and Wallis, 2005). Different approaches have been proposed to determine the MFO. One approach is to perform a single graded exercise test and determine Fatmax. In another approach, four to six continuous prolonged exercise tests are performed on separate days at the exercise intensities used in the graded exercise test (Achten et al., 2002). In the graded tests, the duration of each stage generally varies from 2 to 6 min, whereas the duration of the stages in the prolonged exercise tests is much longer (Achten et al., 2002; Alkahtani, 2014; Croci et al., 2014; Haufe et al., 2010; Meyer et al., 2007; Marzouki et al., 2014). Although the relatively shorter protocols make the Fatmax test more practical, 6 min intervals are recommended especially for sedentary individuals because of their delay in reaching a steady state (Bordenave et al., 2007).

Depending on the approach of researchers, a specific time period of the Fatmax stage data is typically used to calculate substrate oxidation. In the studies in which 6 min intervals were chosen, investigators have used the last 30 s (Schwindling et al., 2014), 1 min (Isacco et al., 2015), 2 min (Besnier et al., 2015; Bordenave et al., 2008; Borel et al., 2015), or 3 min (Gmada et al., 2012; Marzouki et al.,

2014) average values to calculate substrate oxidation. Although Achten et al. reported that 3 min intervals are appropriate for well-trained subjects to reach steady state (Achten et al., 2002), interval durations longer than 3 min have been recommended for sedentary individuals to avoid overestimating the fat oxidation rate (Bordenave et al., 2007). Furthermore, 3 min steps in the graded exercise protocol may be too short for obese individuals to reach steady state (Dandanell et al., 2017).

To our knowledge, changes in fat oxidation rates throughout the Fatmax stage have not been evaluated. Therefore, this study aimed to compare the MFO rates obtained from the stage average of Fatmax, last 2 min average of Fatmax, and highest value of Fatmax determined with a 6 min step protocol.

Methods

Participants and intervention content

A total of 35 healthy, sedentary males with an average age of 25.4 ± 0.7 years participated in this study (see Table 1 for anthropometric and physical characteristics). The study was explained to all participants in detail, and informed consent forms were acquired. Measurements were performed following the approval of the Ethics Committee and carried out in accordance with the Declaration of Helsinki. All tests were conducted at the Sports Physiology Research and Analysis Laboratory of the Physiology Department of Çukurova University, Medical Faculty. Participants with a history of any disease or drug use were excluded from the study. Calorie restrictions were not applied in terms of nutrition.

Table 1. Physical characteristics of the participants. BMI, Body mass index. Values are given as the mean \pm SEM

Variables	n = 35
Age, y	25.4 ± 0.7
Height, m	1.79 ± 0.01
Body mass, kg	83.2 ± 2.4
BMI, kg/m ²	26.0 ± 0.6
Peak $\dot{V}O_2$, mL/min	2875.7 ± 68.2
Peak $\dot{V}O_2$, mL/min/kg	35.0 ± 0.7
Body fat, %	18.6 ± 0.9
Muscle mass, %	35.9 ± 0.7

Anthropometric measurement

The participants visited the laboratory after 12 h of overnight fasting. Anthropometric measurements were performed before the exercise by the same person. Body mass and height were determined with a scale and a stadiometer. Circumference measurements were performed with a non-elastic measuring tape. Body fat estimates were derived according to Siri (1961). Body density, which was used in the Siri formula, was calculated for the men (Jackson and Pollock, 1978). The Martin formula was used to estimate body muscle mass (Martin et al., 1990).

Exercise protocol

Two separate exercise tests were performed at least 48 h apart. A maximal cardiopulmonary exercise test was performed on the first visit, and the Fatmax test was performed

on the second visit. Both tests were performed on a treadmill (HP Cosmos, Nussdorf – Traunstein, Germany). Breath-by-breath gas measurements were taken throughout the exercise using an indirect calorimetric system (PFT Cosmed, Rome, Italy). The volume and gas calibration of the system was performed using a 3 L calibration syringe and calibration gases, respectively (16% O₂ and 5% CO₂). The heart rate was recorded continuously by telemetry using a heart rate monitor (Cosmed, Rome, Italy).

Maximal cardiopulmonary exercise test

The participants started the test at 4 km/h, and the speed was increased by 0.5 km/h every min until exhaustion. The test was terminated if one or more of the following criteria were fulfilled: reaching up to 90% of the maximum heart rate according to the 220-age formula, formation of an oxygen uptake plateau, continuation of a non-protein respiratory quotient (npRQ) value at and over 1.15 (Balady et al., 2010).

Fatmax test

Fatmax was determined with an incremental treadmill walking test after at least 12 h of fasting. The participants performed a 2 min warm-up at 3 km/h and started the test at 4 km/h. The speed was increased by 1.0 km/h every 6 min until the fat oxidation level was decreased to 0 with a npRQ value of 1.01 (Achten et al., 2002). The interval duration in the Fatmax test was selected based on a previous study (Perez-Martin et al., 2001).

Calculation of fat and carbohydrate oxidation

Breath-by-breath data were averaged in 10 s increments for the maximal cardiopulmonary test, and 60 s average values were used to calculate substrate oxidation in the Fatmax test. Substrate oxidation was calculated using the deviation from the stoichiometric equation (Frayn, 1983). Protein oxidation throughout the test was accepted as negligible. Fat and carbohydrate oxidation rates were calculated as follows:

$$\begin{aligned} \text{Fat oxidation rate (g/min)} &= 1.67 \times \dot{V}O_2 - 1.67 \times \dot{V}CO_2 \\ \text{Carbohydrate oxidation rate (g/min)} &= 4.55 \times \dot{V}CO_2 - 3.21 \times \dot{V}O_2 \end{aligned}$$

By using the last 2 min average data, fat and carbohydrate oxidation rates were calculated for each stage, and the stage with the highest level of fat oxidation was recognized as Fatmax. In addition, the MFO rates were calculated with three different approaches in the Fatmax stage: (1) highest level of fat oxidation in the Fatmax stage (individual MFO rate), (2) 6 min average of fat oxidation in the Fatmax stage, and (3) last 2 min average of fat oxidation in the Fatmax stage. MacRae et al. (1995) proposed reference values to define the steady state level of gas exchange variables. In their study, during the 6 min progressive exercise, $\dot{V}O_2$, $\dot{V}CO_2$, and $\dot{V}E$ were measured for the 5th and 6th min. In this period, $\dot{V}O_2$ and $\dot{V}CO_2$ varied by less than 0.1 L/min, and $\dot{V}E$ varied by less than 0.5 L/min even at the highest (60–70% of the peak $\dot{V}O_2$) exercise intensities (MacRae et al., 1995). The difference between the 6th min and previous min $\dot{V}O_2$, $\dot{V}CO_2$, and $\dot{V}E$ values were calcu-

lated and compared with the reference values established by MacRae et al. (1995).

Statistical analysis

The results are presented as the mean \pm SEM. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS for Windows Version 22.0, USA). The normality of values was assessed with the Shapiro-Wilk test. ANOVA with repeated measures was performed to evaluate the differences in the mean values of fat oxidation rates for each min during the 6 min interval. The equality of variances between the differences was assessed with Mauchly's test of sphericity. Regarding the violation of sphericity, the Greenhouse-Geisser correction was applied. In the case of any significant differences in the test of within-subject effects, post-hoc comparisons using Bonferroni's method were performed to determine pairwise differences. Wilcoxon signed rank test was used to analyze the differences between the 6th min and previous min with reference values of 100 mL/min for $\dot{V}O_2$ and $\dot{V}CO_2$ and 0.5 L/min for $\dot{V}E$ as reported in the study by MacRae et al. (1995). Statistical significance was set at $p < 0.05$.

Results

The physical characteristics of the participants are shown in Table 1. The cardiopulmonary and metabolic responses of the participants to the Fatmax test are given in Table 2. The mean values of the variables in Table 2 (6 min average) were obtained in the stage where the MFO was determined. The number of participants who achieved Fatmax in the 1st, 2nd, and 3rd stages was 22, 9, and 3, respectively. Only a single participant's Fatmax was observed in the 4th stage.

Table 2. Performance characteristics of the participants during the Fatmax test in the stage where the fat oxidation rate was maximal. Values are the 6 min averages of the Fatmax stage and given as the mean \pm SEM

Variables	Fatmax stage
Fat oxidation rate, g/min	0.32 \pm 0.02
Carbohydrate oxidation rate, g/min	0.66 \pm 0.06
Contribution of fat to energy production, %	57.68 \pm 2.38
Contribution of carbohydrates to energy production, %	42.32 \pm 2.38
Exercise intensity, % $\dot{V}O_{2peak}$	39.81 \pm 1.17
Heart rate, bpm	106 \pm 3
Respiratory exchange ratio	0.83 \pm 0.01
Energy expenditure, kcal/h	330.7 \pm 13.6
Speed, km/h	4.51 \pm 0.13

The number of participants who underwent the Fatmax test until the 3rd (6 km/h), 4th (7 km/h), and 5th

stages (8 km/h) was 3, 13, and 18, respectively. Only a single participant's Fatmax test lasted until the 6th stage (9 km/h). The cardiopulmonary and metabolic responses of the participants for each of the stages are given in Table 3.

The change in $\dot{V}O_2$ values throughout the Fatmax stage was lower than the previously established reference value of 100 mL/min (MacRae et al., 1995). Moreover, the difference between the values in the 6th min and 2nd, 3rd, 4th, and 5th min was significantly lower than 100 mL/min (70.01 \pm 15.56, 51.09 \pm 8.92, 49.13 \pm 6.05, and 36.98 \pm 3.62 mL/min for the 2nd, 3rd, 4th, and 5th min, respectively; $p < 0.05$) (Figure 1).

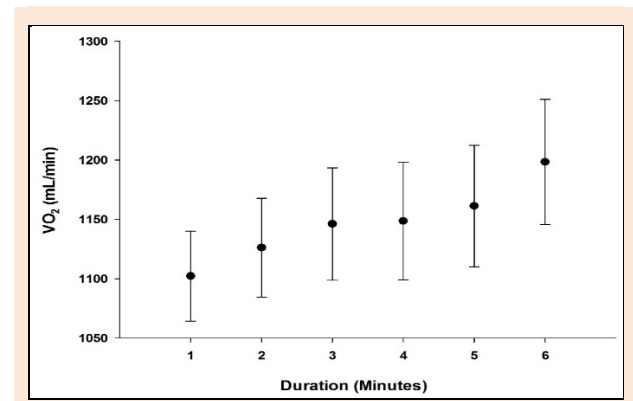


Figure 1. Average $\dot{V}O_2$ values for every min throughout the Fatmax stage.

Similar to $\dot{V}O_2$, the change in $\dot{V}CO_2$ values throughout the Fatmax stage was lower than the reference value of 100 mL/min (MacRae et al., 1995). In addition, the difference between the values in the 6th min and 3rd, 4th, and 5th min was significantly lower than 100 mL/min (71.55 \pm 9.15, 61.67 \pm 6.51, and 40.36 \pm 4.13 mL/min for the 3rd, 4th, and 5th min, respectively; $p < 0.05$) (Figure 2).

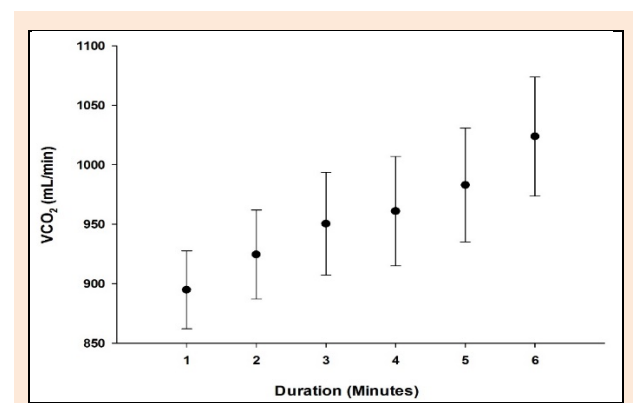


Figure 2. Average $\dot{V}CO_2$ values for every min throughout the Fatmax stage.

Table 3. Metabolic and cardiac responses of the participants for each completed stage. Values are the 6 min averages of each stage and given as the mean \pm SEM.

Stage (speed, km/h)	$\dot{V}O_2$ (mL/min)	$\dot{V}CO_2$ (mL/min)	Respiratory exchange ratio	Heart rate (bpm)
1 (4 km/h)	1039.83 \pm 26.55	853.98 \pm 21.32	0.82 \pm 0.01	102 \pm 2
2 (5 km/h)	1175.24 \pm 30.21	1002.55 \pm 25.77	0.85 \pm 0.01	107 \pm 2
3 (6 km/h)	1459.99 \pm 40.34	1314.61 \pm 39.91	0.90 \pm 0.01	120 \pm 2
4 (7 km/h)	1917.92 \pm 54.03	1876.26 \pm 57.79	0.98 \pm 0.01	144 \pm 2
5 (8 km/h)	2225.47 \pm 63.09	2216.75 \pm 64.59	1.00 \pm 0.01	158 \pm 3
6 (9 km/h)	2916.8	2881.3	0.99	194

In contrast to the consistency of the $\dot{V}O_2$ and $\dot{V}CO_2$ values throughout the Fatmax stage, the change in $\dot{V}E$ was higher than the previously established reference value (MacRae et al., 1995) (Figure 3).

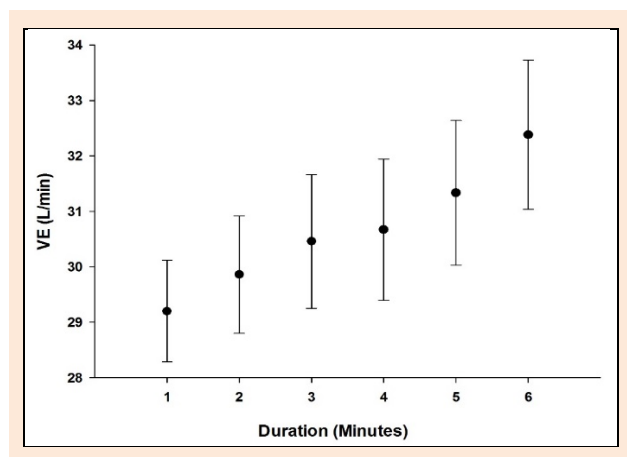


Figure 3. Average $\dot{V}E$ values for every min throughout the Fatmax stage.

The change in the respiratory exchange ratio (RER) throughout the Fatmax stage is shown in Figure 4. The RER was continuously increased from the 1st min (0.81 ± 0.01) to the 6th min (0.85 ± 0.01) (Figure 4).

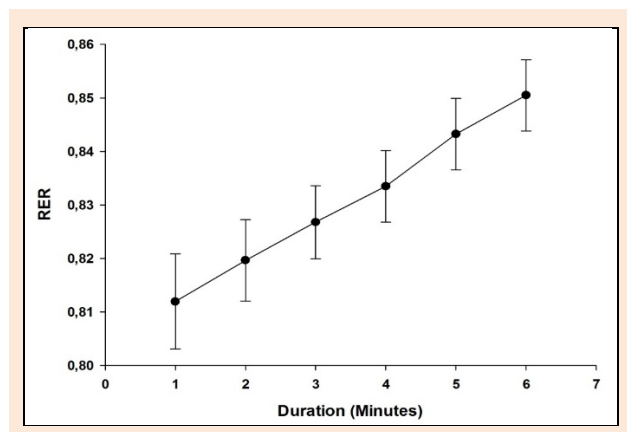


Figure 4. Average respiratory exchange ratio (RER) values for every min throughout the Fatmax stage.

An evaluation of the fat oxidation rate per min revealed that the average value of the 4th min was significantly lower than that of the 2nd and 3rd min (0.31 ± 0.01 , 0.34 ± 0.02 , and 0.33 ± 0.02 g/min for the 4th, 2nd, and 3rd min fat oxidation rates respectively; $p < 0.01$). In addition, the 5th and 6th min fat oxidation rates were significantly lower than the rates of the 1st, 2nd, 3rd, and 4th min (0.30 ± 0.01 and 0.29 ± 0.01 g/min for the 5th and 6th min, respectively, vs. 0.35 ± 0.02 , 0.34 ± 0.02 , 0.33 ± 0.02 , and 0.31 ± 0.01 g/min for the 1st, 2nd, 3rd, and 4th min, respectively; $p < 0.01$). The difference was approximately 17% between the 1st and 6th min fat oxidation rates (Figure 5).

Most of the participants had MFO rates in the 1st min of the stage (16/35 participants), and the MFO rates of the remaining participants were observed in the 2nd, 3rd, and

4th min (7/35, 4/35, and 8/35 participants, respectively). None of the participants had MFO rates in the 5th or 6th min (Figure 6).

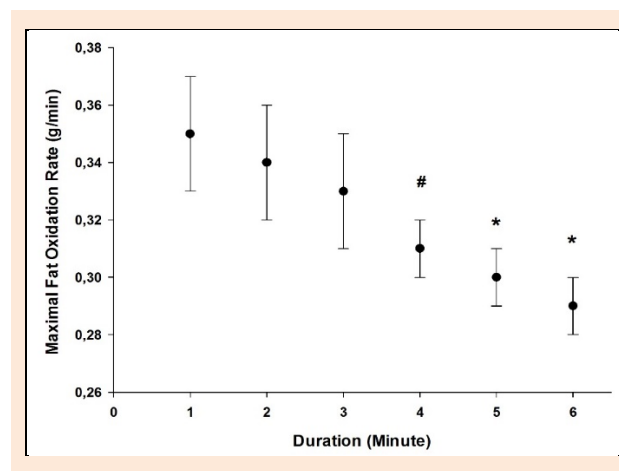


Figure 5. Changes in the maximal fat oxidation (MFO) rate over time. *: significantly lower than the 1st, 2nd, 3rd, and 4th min values ($p < 0.01$) #: significantly lower than the 2nd and 3rd min values ($p < 0.01$).

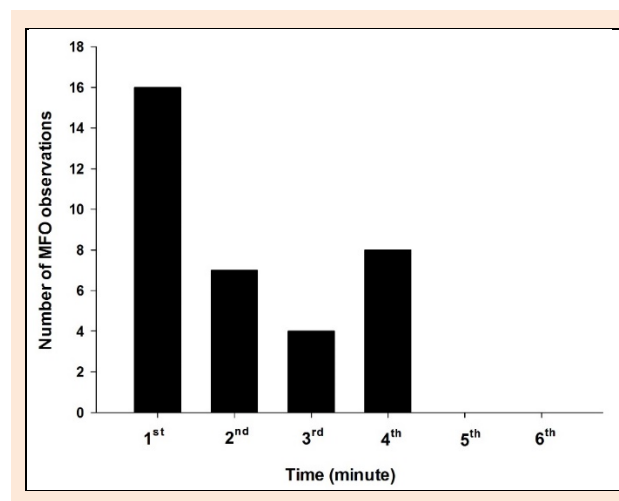


Figure 6. Frequency distribution of the number of participants who reached their individual maximal fat oxidation (MFO) rate with respect to the time in the Fatmax stage.

The MFO rates with respect to the individual maximal values, stage average values (average of 6 min), and last 2 min average values were 0.36 ± 0.02 , 0.32 ± 0.02 , and 0.30 ± 0.01 , respectively. The MFO rate that was calculated from the mean of the measurements taken during the last 2 min of the 6 min stage was significantly lower than that calculated from the individual maximal values ($p < 0.05$) (Figure 7).

Discussion

This study demonstrated that the selection of the last 2 min data for further metabolic analysis in a graded exercise test with 6 min intervals involving young, sedentary, and overweight men could result in the underestimation of the MFO rate. Furthermore, the results showed that participants had MFO rates at different times in the Fatmax stage due to inter-individual variations. Therefore, if the steady state is

reached early in the Fatmax test, then it is recommended to select the individual's highest fat oxidation rate rather than the average over a time period.

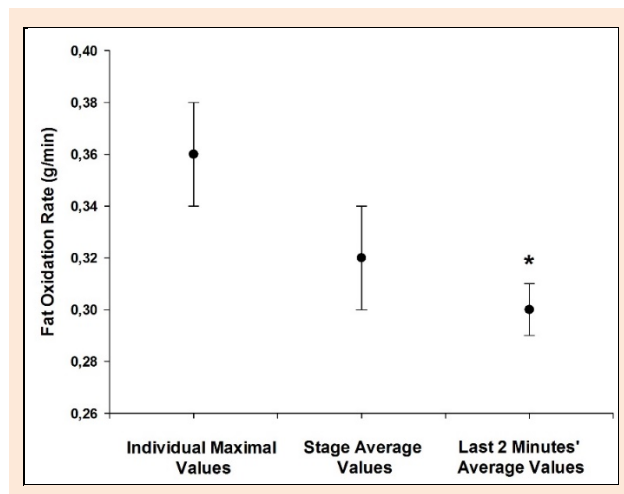


Figure 7. Comparison of fat oxidation rates calculated from the individual maximal, stage average, and last 2 min average values of the 6 min stage. *: significantly different from the individual maximal value ($p < 0.05$).

Changes in gas exchange variables throughout the Fatmax stage

Interestingly, most of the studies that used 6 min intervals have referred to the study by MacRae et al. for their data analysis. MacRae et al. stated a precondition for the measurement of gas exchange variables ($\dot{V}E$, $\dot{V}O_2$, and $\dot{V}CO_2$) during the 5th and 6th min of the graded test, suggesting that $\dot{V}O_2$ and $\dot{V}CO_2$ should vary less than 100 mL/min and that $\dot{V}E$ should vary less than 0.5 L/min. However, our data revealed that $\dot{V}O_2$ and $\dot{V}CO_2$ had a similar amount of variation not only between the 5th and 6th min but also throughout the whole stage (Figure 1 and 2). On the other hand, the difference in $\dot{V}E$ was well above 0.5 L/min, which was measured as an average of 1–3 L/min throughout the stage (Figure 3). This variation may be attributed to slight changes in the respiratory frequency and tidal volume during exercise. Nevertheless, the selected reference value of 0.5 L/min (variation in the ventilation per min) might be too narrow for graded exercise tests.

MFO intensity and self-determined pace

The participants that were recruited in our study were sedentary, overweight individuals. Their peak oxygen uptake values and MFO rates (35.0 ± 0.7 mL/kg/min and 0.32 ± 0.02 g/min, respectively) were similar to those of other studies (Bogdanis et al., 2008; Nordby et al., 2015). Most of the participants' MFO rates were observed in the first and second stages with an average speed of 4.51 ± 0.13 km/h. A similar observation was made by Chrzanowski-Smith et al. In their study, most of the participants' peak fat oxidation rates were recorded in the first stage of the graded test (Chrzanowski-Smith et al., 2018). In a study by Loftin et al., the energy expenditure on walking a mile for adult normal-weight walkers and overweight walkers was compared. They found that the preferred walking speed for normal weight walkers was 2.94 ± 0.08 mi/h (4.70 ± 0.13

km/h), whereas the preferred walking speed for overweight walkers was 2.97 ± 0.08 mi/h (4.75 ± 0.13 km/h) (Loftin et al., 2010). In addition, Browning et al. compared the preferred walking speeds of class II obese and normal-weight men and women. Their male normal-weight participants were fitter than our participants (48.6 ± 4.4 mL/min/kg for $\dot{V}O_{2max}$); their preferred speed was 1.41 ± 0.03 m/s (5.08 ± 0.11 km/h), and their speed of minimum energy cost per distance was 1.38 ± 0.01 m/s (4.99 ± 0.04 km/h) (Browning et al., 2005). In a study in which the effect of body weight on the basic spatial and temporal gait measures of healthy lean and obese women walking at their self-selected pace was evaluated, the mean velocity was reported as 1.08 ± 0.20 m/s (3.89 ± 0.72 km/h) for lean women and 1.12 ± 0.20 m/s (4.03 ± 0.72 km/h) for class I obese women (Błaszczuk et al., 2011). Therefore, regardless of gender and physical properties, it is possible to conclude that the preferred walking speed of sedentary individuals is between 4–5 km/h, which is consistent with our results (4.51 ± 0.13 km/h). With increasing workload, the oxidation rate of fat could be reduced. This reduction might begin instantaneously with the application of the load or might occur later in the stage. The walking speed of the subjects who reached their MFO rate may be closely similar to the preferred speed of sedentary individuals (Błaszczuk et al., 2011; Browning et al., 2006; Loftin et al., 2010). Therefore, the participants' MFO rate might decrease when the speed exceeds their metabolically adapted self-preferred speed.

Comparison of three different MFO rates obtained in the Fatmax stage

Previously, investigators have used protocols with different time intervals to calculate substrate oxidation. Although a “short” graded exercise test with 3 min stages is acceptable for the assessment of Fatmax in well-trained athletes (Achten 2002), the interval duration in our study was set at 6 min to ensure that steady states were reached for the gas exchange variables (Dandanell et al., 2016). In our study, the $\dot{V}O_2$ and $\dot{V}CO_2$ values fluctuated in a relatively narrow band in the Fatmax stage. The amount of fluctuation (difference between the end and beginning of the Fatmax stage) was 92.92 ± 23.45 mL/min and 125.51 ± 21.84 mL/min for $\dot{V}O_2$ and $\dot{V}CO_2$, respectively. In addition, although our protocol started from 4 km/h, the participants walked at 3 km/h for 2 min to warm up. Therefore, metabolic adaptation when priming with 3 km/h might be different compared with that when starting from rest. Our participants (young, sedentary, and overweight men) reached a steady state before the last 2 min of the 6 min Fatmax stage.

According to our findings, the MFO rate was decreased throughout the 6 min Fatmax stage (Figure 5). As stated previously, most of the MFO rates were observed in the first 4 min in the Fatmax stage (Figure 6).

When the 1st and 6th min fat oxidation rates were compared, the 1st min rate was 0.35 ± 0.02 g/min, whereas the 6th min rate was 0.29 ± 0.01 g/min. Throughout the stage, both oxygen uptake and carbon dioxide production were increased; however, the increase in $\dot{V}O_2$ was around 8%, whereas $\dot{V}CO_2$ was increased by around 12%. This

difference led to the decrease in the MFO rate from the 1st min to the 6th min (Figure 5). Individually determined MFO rates were approximately 17% and 11% higher than the stage average and average values, respectively, calculated using the last 2 min data (Figure 7). Although these three different MFO rate calculation methods gave different results, all values were based on the same stage. In other words, neither of these values changed the prescribed exercise intensity at Fatmax. Nevertheless, a correctly calculated fat oxidation rate is important to elucidate the methodological approaches among different research groups. Furthermore, a correctly calculated MFO rate is vital for evaluating the effect of any kind of intervention at Fatmax. Miscalculations might lead to erroneous conclusions. Our data showed that selecting the average of the last 2 min data, as preferred by different investigators, could risk underestimating the MFO rate when subjects reached the steady state earlier in the Fatmax stage (Bordenave et al., 2008; Isacco et al., 2015; Schwindling et al., 2014) (Figure 7). Different averaging approaches might yield different fat oxidation rates, and gas exchange kinetics should be evaluated before making any decisions.

Conclusion

This study demonstrated that the calculation of the fat oxidation rate by averaging the last portion of the Fatmax stage data may cause the underestimation of the MFO rate, which probably occurs earlier in the Fatmax stage. Furthermore, individual MFO rates might be observed at different times in the Fatmax stage. Therefore, selecting an individual's MFO rate rather than the average over a time period might give better results. The acceptance of an individual's maximal or average fat oxidation rate in the Fatmax stage does not change the prescribed training intensity. Nevertheless, the use of the average of the last 2 min to calculate the fat oxidation rate could risk underestimating the actual MFO rate. The selection of an appropriate fat oxidation rate is important for evaluating pre- and post-training effects.

Acknowledgements

The experiments comply with the current laws of the country in which they were performed. The authors have no conflicts of interests to declare.

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Key points

- Taking the average of the last 2 min to calculate the fat oxidation rate could risk underestimating the actual MFO rate.
- Individual maximal fat oxidation rates might be observed at different times in the Fatmax stage.
- Selecting an individual's maximal fat oxidation rate rather than the average over a time period might give better results.

AUTHOR BIOGRAPHY



Kerem Tuncay ÖZGÜNEN

Employment

Çukurova University, Medical Faculty, Department of Physiology, Division of Sports Physiology, Adana, Turkey

Degree

PhD

Research interest

Exercise physiology, biological signals, exercise testing and prescription

E-mail: kozgunen@gmail.com



Çiğdem ÖZDEMİR

Employment

Çukurova University, Medical Faculty, Department of Physiology, Division of Sports Physiology, Adana, Turkey

Degree

MD

Research interest

Substrat oxidation and obesity, isokinetic exercise, sports injuries

E-mail: cozdemir@cu.edu.tr



Selcen KORKMAZ-ERYILMAZ

Employment

Cukurova University, School of Physical Education and Sports, Department of Coaching Education, Adana, Turkey

Degree

PhD

Research interest

Exercise physiology, strength and conditioning, exercise testing, sport performance, physical training and adaptations

E-mail: selcen_korkmaz@yahoo.com



Abdullah KILCI

Employment

Research Assistant at Cukurova University, School of Physical Education and Sports, Adana, Turkey



Degree

PhD Student

Research interest

Exercise Physiology, Soccer, Training Sciences, Substrate Oxidation

E-mail: abdullahkilci89@gmail.com

	<p>Özgür GÜNAŞTI Employment Research asistant at Çukurova University, Medical Faculty, Department of Physiology, Division of Sports Physiology, Adana, Turkey Degree MD, PhD Research interest Exercise physiology, obesity, exercise prescription, sports injuries E-mail: ogunasti@gmail.com</p>
	<p>Sanlı Sadi KURDAK Employment Çukurova University, Medical Faculty, Department of Physiology, Division of Sports Physiology, Adana, Turkey Degree MD Research interest Exercise physiology, obesity, exercise prescription, sports injuries E-mail: sskurdak@cu.edu.tr</p>

✉ **Kerem Tuncay Özgünen**
Çukurova University, Medical Faculty, Department of Physiology, Division of Sports Physiology, Adana, Turkey