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Maximal Fat Oxidation During Running: A Reliability and Thermo-Metabolism Pilot Study

Research Brief

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Abstract
Introduction: We investigated the reliability of a novel Fat_{max} protocol on a treadmill, and if exercising at Fat_{max} in the cold would increase fat oxidation and energy expenditure.
Methods: On separate days, five participants performed two identical Fat_{max} tests. They then exercised at Fat_{max}, in cold (~0°C) and thermoneutral (~22°C) environments for 30 min.
Results: Excellent reliability (ICC >.9) was found for the Fat_{max} protocol, and a non-significant increase in fat utilization was observed during cold exercise at Fat_{max}.
Conclusions: Our novel Fat_{max} protocol on a treadmill is reliable and its impact on fat utilization in the cold should be further studied.

Key Words: Substrates Oxidation, Running, Temperature

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Introduction

As rates of obesity and metabolic disorders continue to rise across the globe, understanding mechanisms governing lipid turnover is foundational in developing effective exercise interventions. Measures of fat oxidation (FO), such as maximal fat oxidation (MFO) and the intensity eliciting MFO, Fat_{max}, are considered metabolic health markers[1] and have been associated with insulin sensitivity[2], as well as physical performance[3,4]. Both MFO and Fat_{max} have very high levels of inter-individual variability with coefficients of variations >20% observed[5]. One study previously examined Fat_{max} reliability during a running protocol[6], despite its known higher MFO and Fat_{max} compared to cycling[7]. In this study, most participants (11/16) achieved Fat_{max} during the warm-up stage, set at 70% of lactate threshold (~40-50% $\dot{V}O_{2max}$ for their participants), with the first stage set at 100% lactate threshold (>60% $\dot{V}O_{2max}$ for their participants). Fat_{max} generally occurs within 23%-88% $\dot{V}O_{2max}$, while lactate threshold rarely occurs below 50% $\dot{V}O_{2max}$[8]. Investigating individual responses of Fat_{max} with sufficient stages both above and below lactate threshold is necessary to evaluate the reliability of running protocols.

Moreover, MFO and Fat_{max} were recently found to be greater in the cold (4.6°C) compared to warm (34.1°C) environments during graded treadmill running[9,10]. Whether greater FO rates in the cold are maintained or increased during prolonged exercise at Fat_{max}, potentially further promoting metabolic health, have yet to be explored. Altogether, the purpose of this pilot study was to *i*) test a novel Fat_{max} protocol for reliability on a treadmill ergometer and *ii*) examine substrate oxidation rates during prolonged exercise at an individual's Fat_{max} intensity in both cold and thermoneutral ambient temperatures.

Methods

Participants

Five young recreationally active (exercising 3-5 times a week) and in excellent health ($\dot{V}O_{2max}$ 51.5 ± 1.93 ml•kg^{-1}•min^{-1}) male subjects took part in the study (Table 1) approved by the Laurentian University Research Ethics Board (LUREB) and in accordance with the Declaration of Helsinki. Participants provided written informed consent, were screened with a Get Active Questionnaire (GAQ), a health screening form, and recorded and repeated their diet 24hrs before each exercise session.

Protocol

An incremental maximal oxygen consumption ($\dot{V}O_{2max}$) test was performed on a treadmill, starting at 6km/h 0% incline and increasing 2 km·h^{-1} every 3 min until volitional exhaustion[6,12]. For the second and third session (Fat_{max} reliability sessions), participants performed identical Fat_{max} tests, in a 22°C lab, consisting of 3-min stages starting at 2.2 mph at a 1% incline. Speed was then increased to 2.7 mph, 3.4 mph, 4.0 mph, and finally 4.7 mph every three minutes, from which point the gradient was increased by 2% at each subsequent stage until an RER of 1.0 was reached. The Fat_{max} test was terminated once participants reached an RER of 1.0. The final two experimental sessions consisted of prolonged running at Fat_{max} intensities completed in either a thermoneutral (~22°C) or cold environment (~0°C), following a balanced design. Skin (iButtonLink Technology) and core temperature (Physitemp) were measured during both experimental trials. Cardiopulmonary variables (Ultima CPX, MGC Diagnostics) were continuously assessed during all trials. All sessions were separated by at least seven days and were performed at the same time of day.

Fat_{max} data

Data from the last minute of each Fat_{max} trial stage was averaged and graphed using a 2nd order polynomial curve. Absolute values of MFO and Fat_{max} were determined as the values corresponding to the peak of the curve. Fat_{max} stages were then determined as the stage closest to the peak of the curve. Oxidation rates of CHO and fat were calculated as previously described[11].

Statistical Analysis

One participant exhibited a carbohydrate dominant curve in his first trial, followed by a fat dominant curve in the second (Randell 2013). Although the participant reported similar dietary intake, sleep pattern, and lifestyle, this shift in substrate dominance was likely caused by external variables and their data was thereby removed from the analyses. Data is presented as means ± standard error (SE). Reliability of Fat_{max} and MFO were assessed via two-way mixed effects, absolute agreement, single measurement intraclass correlations (2,1) (ICCs). Reliability assessment between MFO at Fatmax and FO rates at the third min of experimental sessions was also conducted. Two-way RM ANOVA (factors: temperature [cold: CO; thermoneutral: TN] and time) was used to assess differences for rates of substrate oxidation, %$\dot{V}O_{2max}$, skin temperature and core temperature. All statistics were conducted using SPSS version 26.

Results

Table 1: Anthropometric Measures

Variable	Mean (SE)
Age (yrs)	21.5 ± 0.65
Height (cm)	185.5 ± 2.48
Body Mass (kg)	87.7 ± 8.65
Body Mass Index (kg•m^{-2})	25.3 ± 1.73
Body Fat (%)	17.4 ± 2.59
Fat Mass (kg)	15.7 ± 3.84
$\dot{V}O_{2max}$ (ml•kg^{-1}•min^{-1})	51.5 ± 1.93

Temperature

Skin temperature ($\bar{T}_{sk}$) during the CO condition was significantly lower than TN (P=.011), and decreased significantly over trial duration (P=<.001). No differences were found in T_c between TN and CO trials.

Reliability

Reliability assessment was found to be excellent for Fat_{max} with an ICC of 0.928 (95% CI [.454, .995]) and good for MFO with an ICC of 0.882 (95% CI [.237, .992]) (Fig. 1). Reliability of MFO compared to FO rates in the third minute of experimental trials was found to be good for TN with an ICC of .771 (95% CI [-.061, .983]) but only moderate for CO with an ICC of .597 (95% CI [-.153, .963]).

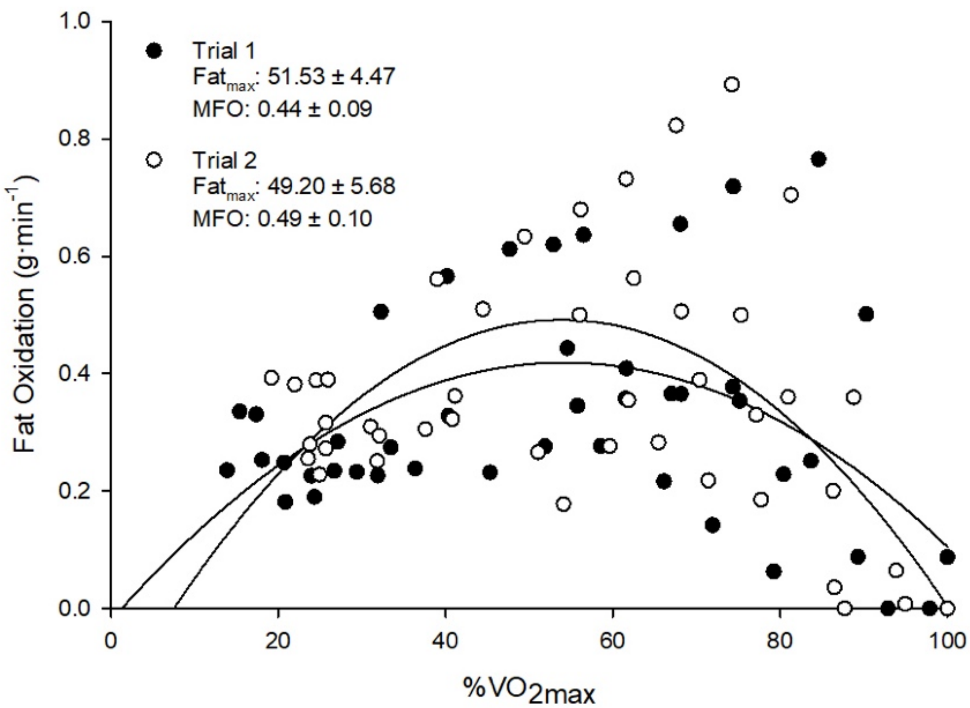

Figure 1: Scatter plot of Fat Oxidation vs $\%VO_{2max}$ for two identical Fat_{max} protocol trials on a treadmill.

Energy Metabolism

Fat oxidation rates significantly increased over time (P<.001). Neither fat nor CHO oxidation rates were different between conditions (Fat: CO=0.699 ± 0.02 g·min^{-1}, TN=0.612 ± 0.04 g·min^{-1}; P=.251; CHO: CO=1.32 ± 0.137 g·min^{-1}, TN=1.49 ± 0.133 g·min^{-1}; P=.071) (Fig. 2). Total energy expenditure from fat and CHO was not different between conditions (Fat: CO 201.8 ± 14.5 kcal, TN 180.4 ± 29.1 kcal; P=.536; CO 166.8 ± 47.9l kcal; P=.754; TN 189.47 ± 49.5 kcal) (Fig. 2). Total energy expenditure between the two trials was also not different (TN: 369.8 ± 62.3 kcal, CO: 368.6 ± 55.8 kcal; P=.909) (Fig. 2).

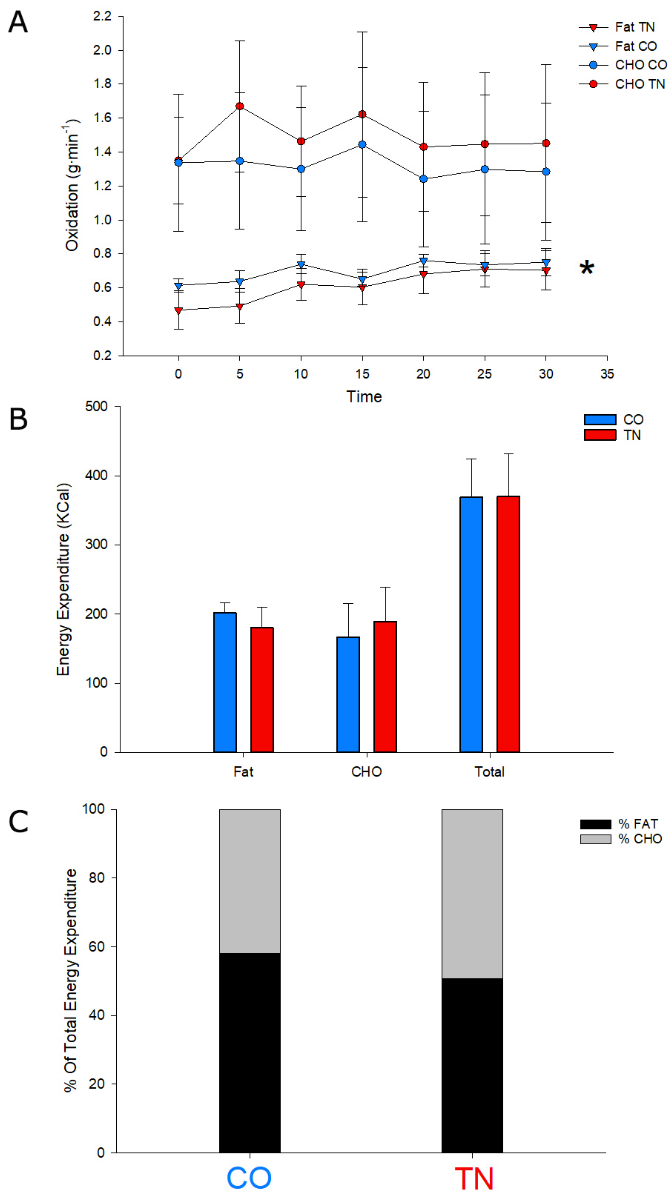

Figure 2: A) Substrate oxidation (g·min-1) over time, B) energy expenditure (kcal) from Fat, CHO and Total, and C) relative energy expenditure (%) coming from Fat or CHO, for both TN and CO conditions.

Discussion

This study was preliminary and cautious interpretation of the results is warranted. Our novel treadmill Fat_{max} protocol demonstrated acceptable reliability (ICC >.9)[13] and good reliability of MFO (ICC > .8) [13], which has not been previously reported[6,12,14]. While the present pilot study was not designed to examine different methodologies to measure, assess, or calculate Fat_{max}, our preliminary findings seem to indicate that graphical depiction and subsequent identification of the peak of the curve, without mathematical modelling and alteration, is a reliable method. Our study is also the first to examine changes of FO rates at Fat_{max} over prolonged exercise in both CO and TN conditions. When comparing MFO to FO rate of the third minute of prolonged exercise bouts (following an identical build up to our Fat_{max} trial), good reliability was observed for TN (ICC>.75) but only moderate for CO (ICC = .597). No significant differences were found between MFO and FO rates in the third minute of CO (p=.262), however FO rates did trend towards higher values in the third minute of CO compared to MFO (0.595 *vs.* 0.466 g·min-1), likely explaining the lower ICC. From this, it would seem that exercising at Fat_{max} is a reliable method for maximizing the utilization of fat in a thermoneutral environment and should be further studied to see if it further amplifies fat reliance in the cold, as previously observed[9,10]. In conclusion, the treadmill Fat_{max} protocol utilized in this study demonstrated high intra-individual reliability (ICC >.9) which could be beneficial for metabolic investigations and training designs for maximizing fat utilization. Exercising at Fat_{max} in the cold could further improve oxidation of fat compared to a thermoneutral environment.

Media-Friendly Summary

Humans have been shown to utilize two main forms of fuel to power exercise: carbohydrates and fats. Over the years, an individualized exercise intensity has been theorized to promote the maximal utilization of fat possible for the individual during exercise termed Fat_{max}. This marker has been associated with numerous health markers including insulin sensitivity and fitness. Our pilot study has possibly found the first reliable and valid protocol to determine Fat_{max} during running. We have also found that running at ones individual Fat_{max} intensity in the cold may promote even greater fat utilization when compared to a neutral environment.

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