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ENERGY BALANCE AND MACRONUTRIENT INTAKE DURING SEASON TRAININGS: INFLUENCE ON ANTHROPOMETRIC AND LIPID PROFILES IN PROFESSIONAL ATHLETES

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ABSTRACT

This study evaluated energetic balance and macronutrient intake at competitive training and transition training and their impact on anthropometric and lipid profiles in sixteen professional male athletes. Dietary data, body composition measurements and lipid profile were obtained at the end of both season trainings. Despite increased carbohydrate supplementation during exercise and higher caloric intake at competitive training (+10%, *P* =0.01), total daily energy expenditure was higher than caloric intake (79%, P<0.001). These results show negative energy balance at competitive training. However, total daily energy expenditure and caloric intake were similar at transition training (*P* =0.35). Higher intake of carbohydrate, fat, and protein were observed at competitive training (+13%, *P* =0.001 for all), although caloric intake was below the requirements during this period. Body mass (+2%, *P* =0.05), body fat percentage (+56%, *P* =0.01), fat mass (+57%, *P* =0.01), and waist and hip circumferences (+10%, *P* =0.004) were higher at transition training, as well as total and LDL-cholesterols (+14%, *P* =0.001). Endurance athletes showed negative energy balance at competitive training and maintained similar caloric intake at transition training despite decreased total daily energy expenditure, which might have contributed to changes in anthropometric and lipid profiles. These findings emphasize the importance of nutritional counseling for professional athletes during different season trainings.

Key words: Diet. Endurance Exercise. Calorie. Energy Expenditure. Performance.

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RESUMO

Balanço energético e ingestão de macronutrientes durante periodos de treinamento: influência nos perfis antropométrico e lipídico em atletas profissionais

Este estudo avaliou o balanço energético e a ingestão de macronutrientes nos treinamentos competitivo e de transição do treinamento e o seu impacto nos perfis antropométrico e lipídico de dezesseis atletas profissionais. Dados da dieta, medidas da composição corporal e perfil lipídico foram obtidos no final de ambos os treinamentos físico. Apesar do aumento da suplementação de carboidrato durante exercício e maior ingestão calórica no treinamento competitivo (+10%, *P* =0,01), o gasto energético diário total foi maior do que a ingestão calórica (79%, P<0,001), mostrando balanço energético negativo no treinamento competitivo. Entretanto, o gasto energético diário total e ingestão colórica foram similares no treinamento de transição (*P* =0,35). Maior ingestão de carboidrato, lipídio e proteína foram observados no treinamento competitivo (+13%, *P* =0,001), embora a ingestão calórica tenha sido abaixo da recomendada. Massa corporal (+2%, *P* =0,05), percentual de gordura corporal (+56%, *P* =0,01), massa de gordura (+57%, *P* =0,01), e circunferências de cintura e quadril (+10%, *P* =0,004) foram maiores no treinamento de transição, assim como o cholesterol total e LDL-c (+14%, *P* =0,001). Atletas de resistência apresentaram balanço energético negativo no treinamento competitivo e mantiveram ingestão calórica similar no treinamento de transição, apesar da diminuição do gasto energético, o que provavelmente contribuiu para as mudanças nos perfis antropométrico e lipídico. Esses achados ressaltam a importância do aconselhamento nutricional para atletas nos diferentes períodos do treinamento.

Palavras-chave: Dieta. Exercício de Resistência. Caloria. Gasto Energético. Rendimento.

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INTRODUCTION

The nutritional status of professional athletes is as important as their rigorous training plan, because it can influence the athletes' performance (Rodriguez et al., 2009).

Therefore, the consensus among nutrition sports specialists is to establish energy balance as a key priority for athletes (Rodriguez et al., 2009).

However, meeting the energy balance can be a difficult task because athletes, especially endurance athletes, normally show an increased energy expenditure (Rodriguez et al., 2009) and a total daily energy expenditure (TDEE) as high as 8,000 calories during competitive training (CT) period (Noakes, 2006).

This period of training is part of one year training periodization and is characterized by high-volume and high-intensity exercises, as a means of achieving ones' best performance of endurance athletes.

On the other hand, the transition training (TT) that follows CT is identified by significant decline in both volume and intensity of exercise for proper athletes' recovery (Bompa et al., 2009).

Insufficient energy intake and, consequently negative energy balance has been already demonstrated in endurance athletes only for a short period of time of increased energetic demand (one week of high-volume vs. one week of low-volume training) (Drenowatz et al., 2012).

Consequently, food intake adjustment is fundamental to reach energy balance during different training periods and supplementation during exercise emerges as the most common strategies for promoting energy balance in periods of high intensity and prolonged exercises.

Carbohydrate intake must be introduced (Burke et al., 2011, Rodriguez et al., 2009) but may not be enough during CT of professional athletes.

In this context, it is of extreme importance a dietary plan to satisfy the high energetic demand during more intense training (CT) or to adjust their energy intake during low intense and volume training (TT) to prevent disequilibrium in energy balance. Furthermore, energy imbalance in both CT and TT could eventually lead to anthropometric and lipid profile changes in athletes.

Previous studies have demonstrated that the type and amount of dietary lipids (Lukaski et al., 1984) influence plasma lipid concentrations as does exercise cessation (Thompson et al., 1984) in endurance athletes.

To our knowledge, there is no study evaluating energy balance in the most distinct season trainings of professional athletes.

In this context, we investigated the energy balance and macronutrient intake along with carbohydrate supplementation in endurance athletes and their effect on anthropometric and lipid profiles at both CT and TT.

MATERIALS AND METHODS

Population

This observational prospective study was conducted in 16 healthy professional male endurance athletes (national top 10: two road Cyclists, 6 long distance Runners, and 8 Rowers; n =16; 20 to 36 years of age) who were engaged in competitions for at least four years (mean = 8 ± 1 years).

Of note, this study composes a large study which the first part has been recently published (Azevedo et al., 2014).

The athletes were evaluated at the end of the most distinct season trainings: at CT (at their highest level of performance) and at TT (at the end of their active recovery).

The training sessions were self-reported by the athletes. They performed the following trainings during CT: Cyclists - 6 days.week^{-1}, 6 sessions.week^{-1}, 850 km.week^{-1}; Runners - 7 days.week^{-1}, 12 sessions.week^{-1}, 187 km.week^{-1}; and Rowers - 6 days.week^{-1}, 9 sessions.week^{-1}, 154 km.week^{-1}. Despite different volumes of training (km.week^{-1}) there was no significant difference in the time spent on exercise training for each sport modality (Cyclists, 5.0 ± 0.05; Runners, 4.5 ± 0.02; and Rowers, 4.8 ± 0.03 h; *P* =0.67).

During TT, cyclists interrupted cycling and rowers reduced their volume of training (km.week^{-1}) by 10%. Additionally, cyclists and rowers started running during this phase.

Runners maintained the same sport modality with a reduction of 50% in their training volume (km.week^{-1}). The average hours of training during TT were of 2.2 ± 0.2. The present study (# 0021/10) complies with the Declaration of Helsinki and was approved

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by the Institutional Ethics Committee. Each athlete signed a written informed consent at the beginning of the assessments.

Study Protocol

All evaluations were performed at the same week, within 3 days. Athletes fasted for a minimum of 12 hours and exercise was restraint for 48 hours before evaluations.

The athletes underwent venipuncture to obtain blood samples for lipid analysis and ate a small snack afterwards. Height was assessed by a wall-mounted stadiometer (0.1 cm) and body mass assessed with individuals wearing shorts only (0.01 kg - Filizola Personal 200 #1459, Campo Grande, MS-Brazil).

Body composition was obtained by using the skinfold method (Lange Skinfold Caliper – Cambridge, Maryland-USA) and calculated as previously reported (Azevedo et al., 2014).

Each skinfold was assessed 3 times by one expert technician and the final value was averaged between the two most similar values.

Dietary Intake and Supplementation Assessments

A sports and cardiovascular nutrition specialist assessed athletes' dietary intake using a 3-day food record (Thompson et al., 2010) at the end of each season trainings (CT and TT).

The dietitian asked them to report their food daily intake considering two weekdays and one weekend day.

Energy and nutrient intakes from dietary assessment were calculated by using a nutrition software program (NutWin® Software, version 1.5) (de Oliveira et al., 2015) and dietary supplement use was evaluated at the day of athletes' diet assessment. Macronutrients intake was calculated and compared to The American College of Sports Medicine recommendations (Rodriguez et al., 2009).

Energy Expenditure

Resting metabolic rate was calculated by the Cunningham equation, and non-exercise activity thermogenesis was estimated as 5% of resting metabolic rate (Cunningham, 1980).

Exercise energy expenditure (EEE) in both CT and TT was estimated as follows:

Competitive Training - all calculations were based in VO_{2peak}, ventilatory thresholds and training hours evaluated after CT.

EEE = (100%VO_{2peak} ($l.h^{-1}$) x 5 x 30%TTH at CT) + (mean %VO_{2peak} ($l.h^{-1}$) between AT and RCP x 5 x 70%TTH at CT)

Transition Training - all calculation were based in VO_{2peak}, ventilatory thresholds and training hours evaluated after TT.

EEE = (mean %VO_{2peak} ($l.h^{-1}$) between AT and RCP x 5 x TTH at TT)
VO_{2peak} = peak oxygen consumption; TTH = total training hours; CT = competitive training; AT = anaerobic threshold; RCP = respiratory compensation point; TT = transition training.

We subtracted resting metabolic rate from the EEE according to the number of training hours. The reference of one liter of $O_2.min^{-1}$ = 5 $kcal.min^{-1}$ was used for calculation.

TDEE was calculated by summing resting metabolic rate, non-exercise activity thermogenesis, and EEE.

VO_{2peak} was evaluated by progressive exercise testing using a ramp protocol up to exhaustion and measuring the oxygen and carbon dioxide outputs as previously described (Azevedo et al., 2011).

Each athlete performed the tests using specific ergometers according to their sport modality (Cycle - Ergoline GmbH, ViaSprint 150P Analog – Palm Springs, CA, EUA; Treadmill - Inbramed Millennium ATL - Inbrasport – Porto Alegre, Brazil, and Indoor rowing ergometer, Concept 2 PM4, model D - Vermont, USA).

We asked athletes to fast from caffeinated beverages on the day of the test. The ventilatory thresholds (AT and RCP) were independently determined by two experts; a third investigator arbitrated when there was no concordance.

Maximal respiratory exchange ratio (RER) $>$ 1.10 and/or oxygen consumption plateau were used as criteria for attainment of maximal exercise test (Doherty et al., 2003).

Laboratory tests

Total serum cholesterol (automated enzymatic colorimetric method), HDL-C

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(automated homogeneous enzymatic colorimetric method), and triglycerides levels (automated enzymatic colorimetric method) were measured and LDL-C was calculated (Friedewald et al., 1972).

Statistical analysis

The data was reported as mean ± standard error. The *Students' t-test* for paired data was used to test the difference in all variables in the competitive and transition trainings.

The one-way ANOVA was used to compare the time spent on exercise training according to sport modalities. Statistical significance was set at $P \leq 0.05$.

RESULTS

Table 1 shows anthropometric data, VO_{2peak}, and blood lipids at the end of CT and TT. Body mass, body fat and fat mass were higher at TT whereas lean mass tended towards reduction at the end of this training period. In addition, waist and hip circumferences were higher at TT.

As expected, VO_{2peak} was lower at TT which indicates a reduced maximal cardiopulmonary capacity due to the decrease in load training. Total and LDL cholesterols presented higher values at TT, although HDL-C and triglycerides were similar in both season trainings.

Table 1 - Anthropometric variables, maximal cardiopulmonary capacity and blood lipids in all athletes at the end of trainings.

	CT	TT	P value
Body Mass (kg)	73.5 ± 3	74.8 ± 3	0.05
Body Fat (%)	9 ± 1	14 ± 3	0.01
Fat Mass (kg)	7 ± 1	11 ± 3	0.01
Lean Mass (kg)	66 ± 2	64 ± 2	0.06
Waist Circumference (cm)	78.4 ± 1	80.4 ± 1	0.01
Hip Circumference (cm)	94.8 ± 1	96.5 ± 2	0.01
Waist/Hip Ratio	0.83 ± 0.01	0.83 ± 0.01	0.33
VO_2 peak ($mL.kg^{-1}.min^{-1}$)	73 ± 2	66 ± 2	0.0004
VO_2 peak ($L.min^{-1}$)	5.3 ± 0.1	4.9 ± 0.1	0.004
Cholesterol			
Total ($mg.dL^{-1}$)	167 ± 8	184 ± 8	0.004
HDL-C ($mg.dL^{-1}$)	51 ± 2	52 ± 2	0.62
LDL-C ($mg.dL^{-1}$)	101 ± 7	115 ± 8	0.001
Triglycerides ($mg.dL^{-1}$)	83 ± 8	84 ± 9	0.94

Legends: Values are presented as mean ± SE. CT=competition training; TT=transition training; VO_2=oxygen consumption; HDL-C=high density lipoprotein-cholesterol; LDL-C=low density lipoprotein-cholesterol.

Resting metabolic rate tended toward higher values at CT (1,953 ± 40 vs. 1,903 ± 41 kcal, P =0.06). Figure 1 shows values of TDEE and caloric intake in both trainings. TDEE was higher at CT (8,476 ± 354 vs. 4,585 ± 254 $kcal.d^{-1}$, P <0.001).

Although caloric intake was higher at CT (4,741 ± 303 vs. 4,316 ± 287 $kcal.d^{-1}$, P =0.01), the values were similar when supplementation was not taken into account at competitive and transition season trainings, respectively (4,229 ± 307 vs. 4,228 ± 267 $kcal.d^{-1}$, P =0.9).

TDEE was greater than caloric intake at CT (8,476 ± 354 vs. 4,741 ± 303 $kcal.d^{-1}$, P <0.001) which shows that energy balance was not properly achieved at this training. However, TDEE and caloric intake were similar at TT (4,585 ± 254 vs. 4,316 ± 287 $kcal.d^{-1}$, P =0.35).

Carbohydrate, fat, and protein intakes were higher at CT (Table 2).

Although caloric intake was below the expected energy requirement for CT, the amount of carbohydrate and protein intake were according to the American College of Sports Medicine recommendations in both season trainings.

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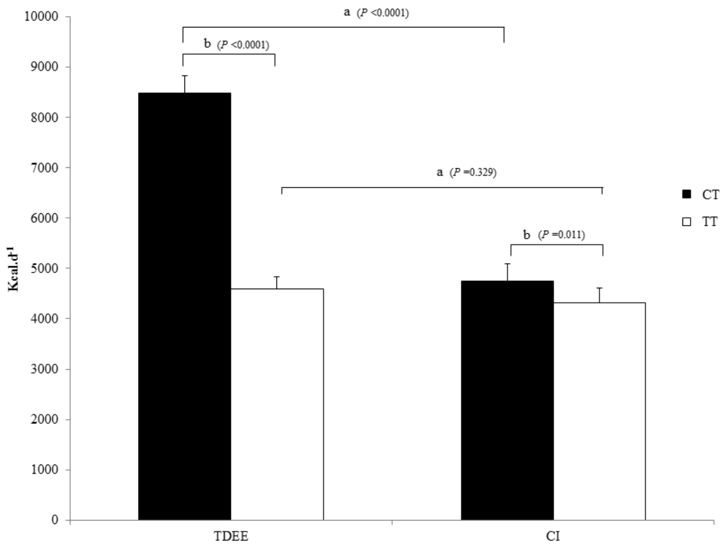

Legends: [a] indicates energy balance in both trainings (CT and TT) and [b] indicates the difference in TDEE and CI between the trainings.

Figure 1 - Differences in total daily energy expenditure (TDEE) and caloric intake (CI) during competitive training (CT) and transition training (TT) in professional male endurance athletes.

Table 2 - Daily macronutrients intake and carbohydrate supplementation in all athletes at the end of trainings.

	Competitive Training	Transition Training	P value	Sports nutrition recommendations
CHO intake (g.kg^{-1})	9.9 ± 0.8	8.8 ± 0.7	0.001	5-11
Fat intake (g.kg^{-1})	1.8 ± 0.1	1.6 ± 0.1	0.001	0.4-1.1
Protein intake (g.kg^{-1})	1.7 ± 0.1	1.5 ± 0.1	0.001	1.2-1.7
CHO supplementation (g.h exercise^{-1})	28 ± 3	13 ± 4	0.01	30-60

Legends: Values are presented as means ± SE. CHO=carbohydrate. Recommendations are based on the American College of Sports Medicine/American Dietetic Association´s “Nutrition and Athletic Performance”, 2009.

The intake of fat was higher at CT, and it was above current recommended daily intake of this nutrient for professional athletes during both trainings. Carbohydrate supplementation use was higher at CT.

However, it is important to mention that one subject did not quantify CHO supplementation at CT, because he based his intake on “the sensation of fatigue”. In the remaining group, seven individuals consumed at least 30 g.h exercise^{-1} of carbohydrate but none reached the upper limit of the recommended amount of 60 g.h exercise^{-1} for prolonged and high-intensity exercise.

Considering the whole study population, six subjects (38%) consumed carbohydrate supplement below the lower limit recommended by the American College of Sports Medicine in both season.

DISCUSSION

The present study highlights that professional endurance athletes fulfilled the energy balance at TT but were not able to satisfy this balance at CT. There was no macronutrient intake below American College of Sports Medicine recommendations; even during negative energy balance at CT.

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Furthermore, CHO supplementation use during exercise training should be higher at CT, although athletes doubled its consumption at this period. Specially, the lipid and anthropometric profiles changed unfavorably at TT.

Despite higher caloric intake at CT, energy consumption was far below the athletes' energy requirements during this period. High energetic demands have been demonstrated in professional athletes and our athletes presented TDEE compatible with that of endurance athletes (Noakes, 2006).

The caloric intake difference between the two trainings was the result of an increased amount of macronutrient intake and a higher carbohydrate supplementation during exercise at CT.

The macronutrient analysis showed a higher intake of CHO, fat, and protein at CT. Although TDEE was much higher than caloric intake, CHO and protein intakes were within Sports Nutrition recommendations (5-11 $g.kg^{-1}$ and 1.2-1.7 $g.kg^{-1}$, respectively) in contrast to fat intake, which was higher than recommended (0.4-1.1 $g.kg^{-1}$).

It strengthens previous statements (Rodriguez et al., 2009) that caloric intake is one of the most important variables when evaluating athletes' energy balance. It appears that the general recommendations for macronutrient underestimate macronutrient requirements when energetic demand is higher than 4,000 $kcal.d^{-1}$, which seems to be common in professional endurance athletes (Noakes, 2006, Rodriguez et al., 2009).

Although carbohydrate supplementation increased at CT, 38% of the athletes consumed it below the recommended amount by the American College of Sports Medicine (Rodriguez et al., 2009).

Noteworthy to mention that energy balance difference would persist with a negative value, even if all athletes (including missing data) had consumed the recommended amount of CHO supplementation during exercise.

Negative energy balance was previously reported in endurance athletes only with one week of a high-volume of training (Drenowatz et al., 2012).

In our investigation, we found a negative energy balance with a longer period of CT. Thus, independently of the duration of high-volume and high-intensity training, the energy needs of athletes are not met during high-energy expenditures.

We could question: how is it possible for athletes to maintain their athletic performance when presenting negative energy balance? Stubbs et al. (Stubbs et al., 2002) demonstrated that lean men were able to tolerate a considerable negative energy balance induced by exercise without invoking compensatory increases in caloric intake.

Despite being beyond the scope of the present study, it is interesting to mention that shortly after a prolonged and intense exercise there is a suppression effect on *ad libitum* energy intake (Loucks et al., 2011) and it seems to be regulated by hormones (King et al., 2010; King et al., 2009).

The drive for hunger is stimulated by the orexigenic hormone ghrelin whereas satiety is stimulated by anorexigenic hormones including peptide YY (PYY), glucagon-like peptide 1 (GLP-1) and pancreatic polypeptide (PP).

A recent meta-analysis showed that hunger scores and concentration of ghrelin were no higher after exercise than after rest, but PYY, GLP-1 e PP were significant increased for 2-9 h post-exercise (Schubert et al., 2014).

We have examined professional athletes with a very high TDEE and found that they seemed to replicate the lack of compensatory response of appetite to exercise, which may facilitate the development of a negative energy balance (Edwards et al., 1993; Fudge et al., 2006).

The negative energy balance associated with body mass loss during high-intensity exercise could compromise immune system function, leading to a greater susceptibility to infectious diseases, which could eventually harm athletic performance (Imai et al., 2002).

Our athletes did not report any drop in their performance or any immune disease. At this point, we could speculate that professional athletes may tolerate negative energy balance for a period of time without impairing their performance or health.

On the contrary, athletes were able to maintain an adequate caloric ingestion during TT. Moreover, their body weight changed at the end of this training and it was accompanied by an increased body fat and fat mass. Curiously enough, a higher body fat was

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observed when energy balance was adequate, which is probably related with the dramatic drop in TDEE at TT.

The perceived anthropometric change at this period was probably the result of both reduced hours of exercise training and exercise intensity. Important to notice that despite having a normal range of body fat at TT, the increase of 56 % happened during a relative short period of time of low training load. This reduced training load might explain the trend toward decreased muscle mass because the athletes moved from a phase marked by higher physical demand, which is the CT.

Interestingly, total and LDL-cholesterols increased at TT although fat intake decreased in this training period. However, it is important to note that fat intake was still above what is recommended for professional athletes.

Also essential is the fact that waist and hip circumferences increased along with body mass at TT. At this point, we can speculate that lower volume and exercise intensity leading to anthropometric changes and high fat intake at TT might have an important influence on cholesterol levels (Arnarson et al., 2014).

Previous study demonstrated that long-term detraining in endurance athletes decreased HDL-C, increased LDL-C, body mass index and fat mass, although caloric intake had been reduced during this phase (Petibois et al., 2004).

In our study, athletes were not detrained, but the decreasing in EEE at TT compared with hard endurance training may be related to the lipid profile change. Based on this, we could speculate that lipid profile in athletes is closely dependent on volume and intensity of training (Banfi et al., 2012).

Despite the athletes were within the normal range of LDL-C in both season trainings, special attention should be given to those who stop exercising for a long-term period.

The fact that active individuals in a sedentary routine do not decrease their food intake to match the reduced energy expenditure has already been addressed (Blundell et al., 2003). Consequently, athletes get themselves into a positive energy balance accompanied by body mass gain, which could lead to dyslipidemia.

In conclusion, our findings reinforce the importance of nutritional counseling during different season trainings of professional endurance athletes to balance their energy needs and to adjust carbohydrate during exercise.

This strategy may also prevent decreasing in performance of professional athletes.

Study limitations

First, food underreporting could be a limitation of our study because we do not have a standard method for assessing nutritional intake and it has been a frequent problem already reported (Bingham, 1991, Bothwell et al., 2009).

Although underreporting is always a challenge in studies involving caloric intake analyses, in our study body composition changes seem to be a result of both, the type of training and the negative energy balance. In order to minimize underreporting we used a 3-day food records evaluation.

We assumed that 3-day food intake records would be representative of a training period because our athletes usually have a diet with little variation. Actually, they kept a diet routine with the same macronutrient intake in both season trainings. Second, the inclusion of only male athletes limited the present findings to this gender.

Third, our study presents a small sample size of elite athletes and finally, we believe that the inclusion of different sports modalities may not influence our findings because the athletes of each sport had similar hours of training which was the main variable used to calculate their EEE.

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Conflict of Interest

None declared.

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