

Do paralympic track and field athletes have low energy availability?

Os atletas do atletismo paralímpico tem baixa energia disponível?

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Abstract – One of the greatest challenges when working with athletes is to achieve the energy demands for physiological processes and exercise expenditure. The aim of this study was to assess the energy availability (EA) of Paralympic track and field athletes (sprinters). Seventeen athletes (9 male and 8 female) with visual impairment (VI, n=10), cerebral palsy (CP, n=4) and limb deficiency (LD, n=3) were assessed for energy intake (EI) (4-day food photographic record), energy expenditure with exercise (EEex) (motion sensor), and body composition (skinfolds method). Energy availability was estimated using the equation: $EA = (EI_{kcal} - EEex_{kcal}) / \text{fat-free mass (FFM)} / \text{day}$, and values $\leq 30\text{kcal/kgFFM/day}$ were considered as low energy availability (LEA). EEex varied from 130 to 477kcal/h and athletes trained in average for 3.2 hours per day. Mean EA for VI, LD and CP were 36 (2.19), 37 (1.90) and 38 (3.38) kcal/kgFFM/day, respectively. Most (82.3%) participants presented EA below $\geq 45\text{kcal/kgFFM/day}$, throughout the days, which are the recommended values for athletes without disability. Athletes should be encouraged to consume adequate EA to avoid consequences related to low energy availability. There is need of further research to identify cut-off values adequate for this population.

Key words: Athletes; Energy expenditure; Energy intake; Sports for persons with disabilities.

Resumo – Um dos maiores desafios ao trabalhar com atletas é alcançar as demandas de energia para os processos fisiológicos e despesas com exercícios. O objetivo deste estudo foi avaliar a disponibilidade de energia (EA) dos atletas paralímpico de atletismo (velocistas). Dezesete atletas (9 homens e 8 mulheres) com deficiência visual (VI, n=10), paralisia cerebral (CP, n=4) e deficiência motora (LD, n=3) foram avaliados quanto à ingestão de energia (EI) (4 dias de registro fotográfico dos alimentos), gasto de energia com exercício (EEex) (sensor de movimento) e composição corporal (método de dobras cutâneas). A disponibilidade de energia foi estimada usando a equação: $EA = (EI_{kcal} - EEex_{kcal}) / \text{massa livre de gordura (FFM)} / \text{dia}$ e, os valores $\leq 30\text{kcal/kgFFM/dia}$ foram considerados como baixa disponibilidade de energia (LEA). O EEex variou de 130 a 477kcal/h e os atletas treinaram em média por 3,2 horas por dia. A EA média para VI, LD e CP foi 36 (2,19), 37 (1,90) e 38 (3,38) kcal/kgFFM/dia, respectivamente. A maioria (82,3%) participantes apresentaram EA abaixo de $\geq 45\text{kcal/kgFFM/dia}$, ao longo dos dias, que são os valores recomendados para atletas sem deficiência. Os atletas devem ser encorajados a consumir EA adequada para evitar conseqüências relacionadas a baixa disponibilidade de energia. Há necessidade de pesquisas adicionais para identificar valores de corte adequados para essa população.

Palavras-chave: Atleta; Esportes para pessoas com deficiência; Gasto energético; Ingestão de energia.

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INTRODUCTION

Athletes' energy requirements represent the sufficient quantity of energy to cover the everyday demands of exercise, in addition to maintenance of health¹. Energy requirements are influenced by training periodization and the characteristics of daily training sessions, varying according to volume and intensity of exercise². As consequences of an insufficient energy supply, physiological aspects such as basal metabolic rate, menstrual function, bone health, protein synthesis, immunity and cardiovascular health can be negatively affected, causing a consequent decrease in athletic performance³.

Energy Availability (EA) has been suggested as the best strategy to identify if the energy consumed supplies enough energy for the remaining physiological processes, after the energy expenditure with exercise (EE_{ex}) is considered, and adjusted to fat free mass (FFM)^{2,3,4}.

Low Energy Availability (LEA) has been implicated in two syndromes related to athletes: the Female Athlete Triad (FAT) and the Relative Energy Deficiency in Sports (RED-S). FAT involves three inter-related components: energy availability, menstrual status and bone health. The most severe presentation of FAT is characterized by LEA with or without an eating disorder (ED), functional hypothalamic amenorrhea and low bone mineral density^{3,5}. RED-S proposes a wider spectrum of symptoms, involving many body systems, resulting in short-term and long-term compromise of optimal health and performance. Athletes who suffer from long-term LEA may develop nutrient deficiencies, chronic fatigue and increased risk of infections and illnesses. Physiological complications involve the cardiovascular, gastrointestinal, endocrine, reproductive, skeletal, renal and central nervous systems^{2,3}.

Studies^{1,3,6} assessed different components associated with the risk of FAT development, but few evaluated EA itself. Blauwet et al.⁷ draw attention to the lack of knowledge on the prevalence of low energy availability and components of FAT or REDs in athletes with disabilities. However, it is believed that due to the characteristics of each deficiency, there may be changes in energy requirements, bone health and menstrual dysfunction, which differ from able-bodied athletes^{7,8}. Considering the lack of knowledge in this area, the aim of this study was to evaluate EA in Paralympic athletes of the Brazilian national track & field team.

METHODOLOGICAL PROCEDURES

The Ethics Committee of the Federal University of São Paulo approved this study under appraisal #921.384/2014. All athletes were briefed on the objectives and procedure and signed an informed and written consent.

Subjects

Seventeen Paralympic track and field athletes (9 male and 8 female) of functional classes visual impairment (VI; n=10), cerebral palsy (CP; n=4)

and limb deficiency (LD; n=3), all sprinters with international experience, participated in this study. The LD athletes presented upper limb amputation (one bilateral hand amputation, one forearm level amputation and one hand amputation). In all cases, amputations did not represent more than 2.5% loss of body mass, according Osterkamp⁹. Two CP presented spasticity and two athetoid CP, with hemiplegia on the left side of the body. Eight VI athletes were blind and two had low vision.

Procedures

Data were collected during four consecutive days, during one of the Evaluation Weeks (EW) within the annual evaluation cycle of the High Performance Program of the Brazilian Paralympic Committee, conducted between the pre-competitive/competitive training periods. The program proposes one week (five consecutive days) of physical evaluation every three months along the year. Athletes were housed in a hotel, where they received three meals/days (self-service buffet) and snack-kits. The EW has an extensive routine of physical tests/assessments with the professional team (dietitian, physician, psychologist and physiotherapist) interspersed with training periods.

Athletes had their body mass/composition assessed in the first and last day of the EW and only athletes who were not controlling body mass/composition participated in the study.

Dietary energy intake

All information on food/beverage/supplement consumed or food remains was recorded on a digital worksheet and a photographic record was carried out by one of the researchers (DPJ) using a high-resolution digital camera. At the end of the day, photographs were loaded onto the researcher's computer. Athletes were instructed to inform if they had seconds, snacks, and all extra foods or supplements consumed along the day (e.g. candies, sport drinks, etc.).

The meals were held in the restaurant where the athletes ate their meals. The self-service buffet provided for breakfast: breads (whole and white), ham, cheese (mozzarella and parmesan), natural fruit juice, milk and fruits (3 types); for lunch and dinner: vegetables (six types: two raw leaves, two raw vegetables and one cooked or steamed vegetable), main dishes (white and brown rice, beans, two meat options, and pasta or tubers cooked as side dishes), and a dessert buffet (two types of sweets and two types of fruit). Athletes could serve themselves of any type of preparation at will. A standardized snack-kit composed by 1 sandwich (whole grain bread with 1 slice of yellow cheese and 1 slice of lean ham), 2 fruits and 200mL of processed fruit juice) was available to athletes in the intervals between meals and were consumed pre, during or post training.

Athletes were instructed to choose their usual foods and quantities. VI athletes had their meals served by the athlete-guides, as requested. Consumed amounts were converted to grams according to comparison

of consumption with standard photographic portions. EI (kcal/day) were calculated using the software Avanutri® version 4.0

Anthropometric and Body Composition Assessment

Body mass (kg) was assessed using an electronic scale (0.1kg accuracy) and height (cm) using a stadiometer (0.1cm accuracy). All athletes were assessed standing, with both feet together and head placed in Frankfort plane. Body skinfolds were assessed using Lange® skinfold callipers (accuracy of 1mm and constant pressure of 10g/mm²), on the right side of the body, with the exception of athletes with CP and LD, who were measured on the non-affected side.

To control for intra-evaluator variability, the skinfolds measurements were obtained from the mean of three repeated measurements, by the same anthropometrist who presents typical error measurement of 2.24%.

Skinfolds (triceps, subscapular, biceps, iliac crest, abdominal, thigh and calf) were measured according to the procedures proposed by the International Society for the Advancement of Kinanthropometry¹⁰, while the midaxillary and chest skinfolds according to Lohman¹¹. Body density was estimated by Jackson & Pollock^{12,13} equations, for men and women, respectively, and all converted to body fat percentage by Siri's equation¹⁴.

Energy Expenditure with Exercise

The EEex assessment was conducted using the Actical® (Mini-Mitter Co., Bend, OR, USA) multidirectional accelerometer which monitors the occurrence of movement through acceleration. The device measures acceleration from 0.005 to 2.0G, and has a frequency range between 0.5 to 3.0Hz, memory capacity of 32MB, dimensions of 29mm x 37mm x 11mm and weighs 22g. Athlete's height, body mass, gender and age were registered in the Actical®. During exercise, movement information was stored every 15 seconds and converted into 1-minute intervals for data analysis. The device was attached by an elastic band to the athlete's body, on the anterior axillary line, on the iliac crest, on the right side of the body, during the four of the evaluation. Athletes were instructed to use the device throughout the sports activities, being placed on Monday and removed on Friday. The devices were collected on the fifth day of the EW, after breakfast.

Training was composed of warm-up exercise (cardiovascular and 10 types of educational running), mobility activities, sprinter running (9.8m/s), and strength exercises, totalling 180 minutes of exercise per day (1 or 2 session).

Energy Availability

EA was calculated using the equation: $[EA = EI_{(kcal)} - EEex_{(kcal)} / FFM (kg)]$. EA cut-off values were: $\geq 45kcal/kgFFM/day$ - adequate EA; between 30 to 45kcal/kgFFM/day - reduced EA and values $\leq 30kcal/kgFFM/day$ - LEA^{2,3,4}.

Statistical Analysis

Data were processed using SPSS® software version 20.0. Data descriptive

analysis of is presented as mean and standard-deviation. The normality of the sample was tested by Shapiro-Wilk. Paired t tests were used to determine differences between genders. To compare the functional classes in relation to the study variables, the model of analysis of variance with a fixed factor was used, being considered significant differences when $p \leq 0.05$. To verify the difference between the days, the repeated measures of Variance Analysis Model, and the Bonferroni multiple comparisons method was used. Significance was established when $p \leq 0.05$. In addition, we calculated the effect-size (F) and confidence interval (95% CI).

RESULTS

The anthropometric, body composition and training characteristics of the athletes are summarized in Table 1, according to the functional classification.

Table 1. Characterization of the sample according to the functional classification

	VI	LD	CP
	(n=10)	(n=03)	(n=04)
	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	26 (6.17)	27 (8.50)	24 (7.54)
Hour of training (h/day)	3.0 (0.57)	3.6 (1.20)	3.4 (0.48)
Body Mass (kg)	62.0 (10.53)	59.9 (9.66)	63.9 (11.10)
Height (m)	1.68 (0.09)	1.69 (0.05)	1.75 (0.12)
Fat Free Mass (kg)	54.4 (11.38)	54.7 (8.22)	59.1 (11.64)
Sum Skinfolts (mm) ^a	91 (24.27)	62 (12.50)	64 (15.73)

SD=standard deviation; VI=visual impairment; LD=limb deficiency; CP=cerebral palsy; VI functional class: (11, 12 e 13); CP functional class: (36 and 38); LD functional class: (46 and 47); ^aSum Skinfolts (mm): triceps, subscapular, biceps, midaxillary, chest, iliac crest, abdominal, thigh and calf.

Table 2 shows the EI (kcal/day), EEEx (kcal/hour), and EA (kcal/kgFFM/day) according to athletes' functional classification. No difference was found between groups evaluated for EI ($p=0.281$), EEEx ($p=0.773$), and EA ($p=0.485$).

Table 2. Energy Intake (EI), Energy Expenditure with e Exercise (EEEx) and Energy Availability (EA), based on four-days data collection, according to the functional classification

		EI (kcal/day) ^a	EEEx (kcal/hour) ^b	EA (kcal/kgFFM/day) ^c
		Mean (SD)	Mean (SD)	Mean (SD)
VI	(n=10)	2262 (483.15)	314 (111.85)	36.3 (6.99)
LD	(n=3)	2359 (466.13)	324 (144.28)	37.2 (3.32)
CP	(n=4)	2518 (192.52)	293 (71.92)	38.6 (6.46)

SD=standard deviation; VI=visual impairment; LD=limb deficiency; CP=cerebral palsy; ^aEI=Energy Intake; ^bEEEx=Energy Expenditure with Exercise; ^cEA=Energy Availability; Comparison of means between groups for the EI ($p=0.281$); for the EEEx ($p=0.773$) and for the EA ($p=0.485$); Comparison of means between male and female ($p=0.845$).

There was no difference ($p=0.845$) in EA between male and female athletes. The values of EI (kcal/day) and EEex (kcal/hour) were lower among female athletes than among male athletes in all functional classes. No difference was found in EI (kcal/day) between days ($p=0.791$) according to functional classification and between groups ($p=0.541$).

Table 3 shows EA values (kcal/kgFFM/day) between evaluated days. No difference was found ($p=0.524$) between the evaluated days and between the groups ($p=0.761$).

Table 3. Energy Availability (kcal/kgFFM/day) according to functional classification and gender

	Day 1	Day 2	Day 3	Day 4
	35	30	34	35
Male (n=4)	39	52	45	52
	31	42	30	36
	32	25	27	38
VI	40	39	46	43
	56	67	33	38
Female (n=6)	25	30	39	34
	27	34	30	35
	40	34	35	23
	33	29	25	35
Total (n=10) ^a	36 (8.83)	38 (12.66)	34 (7.02)	37 (7.47)
LD	36	31	27	46
Male (n=2)	36	47	35	46
Female (n=1)	34	29	48	30
Total (n=3) ^a	35 (1.16)	35 (9.94)	37 (10.5)	41 (9.23)
	34	34	33	43
CP	41	36	34	39
Male (n=3)	29	29	37	36
Female (n=1)	46	57	43	46
Total (n=4) ^a	37 (7.15)	39 (12.3)	37 (4.10)	41 (4.55)

^aData presented as mean (standard deviation); VI=visual impairment; LD=limb deficiency; CP=cerebral palsy; Comparison of EA (kcal/kgFFM/day) between days ($p=0.524$); Comparison of EA (kcal/kgFFM/day) between groups ($p=0.761$).

Four parathletes presented adequate EA in at least two days. A reduced EA was observed in 70.5%, 52.9%, 91.6% and 70.5% for days 1, 2, 3 and 4, respectively. LEA was present for 17.6%, 33.3%, 33.3% and 8.3% of athletes for days 1, 2, 3 and 4, respectively. No athlete consumed EA below 30kcal/kgFFM/day for more than 2 days.

DISCUSSION

This is a pioneer study in the assessment of EA in a Paralympic track & field population. EA assessment is particularly challenging when working with parathletes, as all the methods for estimating the EA components require maximal care to be as accurate as possible, and the available possibilities have limitations for the studied population, depending on the functional classification. For example, FFM may be altered as a result of the deficiency, such as in the case of LD and CP, compromising the determination of FFM and, consequently, EA⁷.

Van de Vliet et al.¹⁵ suggest the use of the sum of skinfolds for the longitudinal monitoring of athletes with disabilities, avoiding the use of non-specific predictive equations for this population. However, the FFM (kg) estimation is fundamental for the determination of EA. The use of predictive equations such as Jackson and Pollock^{12,13}, even though non-specific for this population has been used in other studies^{16,17}. Furthermore, we adopted Jackson and Pollock equations considering that the assessed athletes were athletes VI, who are physiologically similar to athletes without disability, only LD athletes whose deficiency represented less than 2.5% of body mass, and only CP athletes, who belong to functional classes with low body commitment. The more physiologically closer to an able-body condition, the less critical is the use of these equations⁸.

There is a fair amount of information on EEex in athletes without disability, however, for parathletes, there is scarce information because of the difficulty in accurately determining EEex. Multidirectional accelerometers are being used to assess EEex, which can detect movements in more than one plane and, therefore, and are considered as more accurate¹⁸, and may be a good alternative for this population⁸, interfering minimally in the athletes' routine training. However, there may be an underestimation of the exercise according to the positioning of the instrument in the body, as well as the type of exercise performed¹⁹. Esliger and Tremblay²⁰ demonstrated a greater reliability (CV=0.5%) intra-instrument when compared the Actical[®] to other accelerometers in population without disability. Brazeau et al.²¹, investigated the validity and reliability of Actical[®] to evaluate EEex, compared to the double-labelled water technique, and results showed that the Actical[®] is reliable for the evaluation of EEex, with little imprecision, underestimating EEex to -244 kcal/d. However, there is no validity and reliability information on Paralympic athletes. No studies with a similar sample to our study were found, and the majority of studies on EEex of parathletes are conducted with subjects with spinal cord injury. Even among athletes without disability, there are few studies on sprinters. Therefore, our results should be considered with caution.

All methods to assess EI may present a bias due to memory, level of participation of responder, underreporting (intentional or not), and it is not different with para athletes. In this study, we chose to collect food data using a photographic record aiming to obtain more accurate information^{22,23}

and reducing the information bias on food consumption. Furthermore, for VI athletes, and some LD athletes, it was more comfortable to have the investigator taking the pictures than asking them to register what they ate. Food provided during the EW respect the typical Brazilian every-day food habits, therefore, athletes can eat what they are used to. Nevertheless, athletes encounter a greater variety of foods and that can lead to different food choices and to a greater amount ingested.

But the greatest challenge in this study is the very use of the cut-off values of EA for the Paralympic population, which were determined for athletes without disability. Paralympic athletes (such as athletes with CP, LD) may have a lower body muscle mass due to contraction disorders, as well as a different energy demand due to the deficiency⁸. In addition, these cut-off values have been proposed mainly for female athletes. Therefore, we can only infer that the values we observed represent a reduced EA in some of these athletes. On the other hand, athletes with VI do not have physiologic differences from athletes without disability; therefore, we suggest that the EA cut-off values can be appropriate for this specific group.

Although all the difficulties and limitations in assessing EA components in this group of athletes, some specific conditions during assessment of EEex and EI components in this study should be taken into consideration. During the EW, the food provided represents the typical Brazilian dishes. However, it is generally more varied and abundant than in the athletes' households, which can lead to different food choices. As far as training is concerned, their individualized training schedule is respected, but adapted to allow them to undergo other activities. Training was different from the athletes' usual training, due to lower intensity and/or duration of the activities, similar to the moment of the competition, since the objective of the period was the physical evaluation of the athletes. Considering their training schedule (monitored by trainers), the specific training sessions (speed race) are short, but the recovery periods between the specific exercises are long.

Considering that EEex was lower and available food more abundant than usual we hypothesized that EA would be adequate. However, for all groups mean EA was below 45kcal/kgFFM/day. Furthermore, LEA was detected for at least one day in 8 athletes, evidencing the need of constant attention to the adjustment of EI to EEex of these athletes. In studies with cyclists without disability²⁴ and soccer players⁶ LEA was identified in different moments of the periodization (pre-season, competition and post-season). Viner et al.²⁴ associated LEA to the conscious practice of cyclists to restrict energy consumption (kcal/day) to reduce/maintain body mass and body fat percentage, which is also common practice among runners²⁵.

In the present study, the lower EI (kcal/day) observed in some days, may be explained due to the difference in taste and variety of preparations. It is important to highlight that athlete-guides have an important role in athletes with VI's food choices, since they assist them in assembling and portioning the meals. These are subject to the interpretation of the athlete-

guide, since the quantities requested by the athlete VI may be inaccurate. This may have influenced EI and also the EA values found for these athletes. We found only one study which assessed track and field female athletes (n=25, including sprinters) which observed that 52% of the athletes were at LEA, 40% had amenorrhea and 32% had a history of stress fractures and consequently the risk of RED-S²⁶. No study was found evaluating Paralympic athletes.

Although we cannot affirm that all athletes who presented EA below 30kcal/kgFFM/day in this study have LEA, as the cut-off values were not determined for the Paralympic population, we should be aware of them and aim to manage EI and EE_{ex} constantly, following changes in the periodization and training dynamics, FFM adjustments, and changes in diet, since this decrease may adversely affect health and performance, when EI (kcal/day) is not being adjusted to EE_{ex}.

We highlight that the EA values in our study refer to a specific assessment period, and cannot be extrapolated to athletes' usual training. Another aspect to be considered is the size of the sample, as they represent the elite of Paralympic track and field athletes, and there is still the subdivision according to functional classification and sex, which may have influenced the power to detect differences between groups or between days for assessment of EA.

CONCLUSION

Like any other athlete, Paralympic athletes who have high exercise EE_{ex} and restrict EI or are not able to adjust their daily EI do changes in EE_{ex} volumes should be followed-up carefully because they are at risk of developing LEA and its consequences. Although no cut-off values to determine LEA in Paralympic athletes have been proposed, we hope our results arouse awareness and motivate the development of studies to improve knowledge about EA and its components in this population, in order to avoid implications related to FAT and RED-S.

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