Original Article (short paper)

Can the elite slalom kayaker's performance be correlated with anthropometric, nutritional, genetic, psychological as sleep traits?

Leonardo Henrique Dalcheco Messias[1], Homero Gustavo Ferrari1, João Bosco Pesquero[2], Marciane Milanski[1], Andrea Maculano Esteves[1], Marta Fuentes Rojas[1], Andressa Reginato[1], Kelly Cristina Malavazi-Piza[1], Elton Dias Silva[2], Fúlvia B. Manchado-Gobatto[1]

[1]*Universidade Estadual de Campinas, UNICAMP, School of Applied Sciences, Limeira, SP, Brazil;*
[2]*Universidade Federal de São Paulo, UNIFESP, São Paulo, SP, Brazil*

Abstract — Aims: The aims of this study were to investigate and characterize the anthropometric, nutritional, genetic, psychological and sleep variables of slalom kayakers, and to verify the correlation of these variables with the slalom kayakers' performance. **Methods:** Ten elite Brazilian team slalom kayakers participated of this study. Nutritional analysis was made by the Food Record (three days), 24 Hour Dietary Recall and Food Frequency Questionnaire. The ACE I/D, AGTMet235Thr, ACTN3R577X and BDKRB2+9/-9 were genotyped for genetic profile. The Profile of Mood States (POMS) and Sports Competition Anxiety Test (SCAT) were applied to investigate the psychological variables. The Pittsburgh Sleep Quality Index (PSQI), Epworth Sleep Scale (ESS) and Morningness-eveningness questionnaire (MEQ) were used for sleep traits analysis. Performance trials were performed on a white-water course with 24 gates, and finish time was considered as the variable related to performance. **Results:** Significant correlations were obtained between Performance Time Trial and %Fat (r=0.77), Energy (r=-0.75), Protein (r=-0.76), Carbohydrate (r=-0.72), Vitamin B6 (r=-0.87), Vitamin A (r=-0.82), Thiamine (r=-0.77), Riboflavin (r=-0.71), Magnesium (r=-0.86) and Phosphorus (r=-0.74) intake, besides the Fatigue mood domain (r=0.73) and the SCAT score (r=0.67). Athletes genotyped with the I, T, R and +9 alelle also presented better performances. **Conclusions:** In summary, the novel results provided by this study reinforce the necessity of considering several aspects during athlete development in order to achieve better performance in competitions.

Keywords: canoe slalom; exercise performance; elite athletes; simulated race; multifactorial analysis.

Introduction

In the last years, studies involving several approaches on the Olympic sport canoe slalom emerged. These investigations provided fundamental advances related to the metabolic demand during simulated race[1], energy production via aerobic and anaerobic sources throughout physiological evaluation [2,3,4,5] and physical development of slalom kayakers after training[6]. Apart from the metabolic/physiological relevance, other factors such as sleep traits, nutrition, genetic profile and psychological can significantly affect athletes' performance; however, literature involving these factors on canoe slalom is scarce[7].

Considering the natural environments on both artificial and natural white-water courses [7], slalom kayakers must constantly overcome obstacles that require great metabolic participation [1]. The high intensity efforts performed to negotiate gates may depend on the creatine-phosphate source and activity of enzymes from the glycolysis, mainly the hexokinase and phosphofructokinase, which catalyzes the beginning and irreversible glucose breakdown to provide adenosine triphosphate. However, inadequate intake of macronutrients, primarily carbohydrate, can affect the anaerobic power of myocytes to provide energy from glucose[8], which in turn may reflect on the slalom kayakers performance to negotiate gates. Other macronutrients and micronutrients may be key regulators for recovery during training and competition of slalom races due to their antioxidant activity, immunological function and energy replenishment[9]. Because these athletes may already compete at international level at age 15, and nutrient intake is particularly different between ages[10], this aspect claims for scientific basis for both the immediate as well as future performance and health of these athletes[11].

Along with the abovementioned perspective, recent scientific studies have concentrated on looking for the exact genes related to athletic performance[12], but sports that require both aerobic and anaerobic contribution are still restricted regarding genetic analysis[13]. Considering this information and that during canoe slalom races both aerobic and anaerobic metabolisms are relevant (aerobic – 45.2 %; anaerobic alatic – 24.9; anaerobic lactic – 29.0 %)[1], gene polymorphisms related to these metabolisms such as the angiotensin I-converting enzyme (*ACE*)[13], angiotensinogen (*AGT*)[14], α-actinin-3 (*ACTN3*)[15] and β-receptor of bradykinin (*BDKRB2*)[16] may have important roles in slalom kayakers' performance. Although the genetic profile of athletes from other nautical sports has been achieved[17], there is a lack of information about this context in canoe slalom athletes.

Apart from the metabolic/physiological aspects, a relationship between psychological aspects and slalom kayakers' performance has been discussed[18]. However, no evidence regarding the mood states and anxiety of these athletes is available. Since canoe slalom courses are not perfectly similar[19], athletes must negotiate a series of gates during the race with no previous practice on such course; this procedure is not allowed. In this

sense, both mood states and anxiety may be key points to achieve better performance during races, since these factors may affect the decision of planning the negotiation of gates during races. Along with these factors, the sleep traits such as the sleepiness, sleep quality and chronotype can provide an important role on both physical as well as cognitive aspects[20], which in turn are required during slalom competition; however, no information involving this perspective was published so far.

Thus, the aims of this study were: a) to investigate and characterize the anthropometric, nutritional, genetic, psychological and sleep variables of slalom kayakers; and b) to verify the correlation of anthropometric, nutritional, genetic, psychological and sleep variables with kayakers performance.

Methods

Subjects

Ten male elite Brazilian team slalom kayakers participated of this study. All slalom kayakers have been training and competing in high level (national and international) for ±5 years, and in preparation for an international championship. Considering the total sample, four athletes compete in K1 discipline, four in the C1 and four in C2. The researchers did not interfere in the athletes' training. Participants were asked to adhere to the same dietary and sleep behaviors duration experimental procedures. Athletes and parents provided written, informed consent authorizing the athletes' participation in this study. All experiments were approved by the Faculty of Medical Sciences Ethics Committee (n° 02160812.9.0000.5404) and were conducted according to the ethical standards of Helsinki.

Experimental Design

All analysis was undertaken in order to answer the study aims. In addition, for each study area an expertise researcher was responsible for the data analysis. Regarding the anthropometric analyses, we measured several anthropometric parameters including the somatotype, which may give a greater overview of this issue. Dietary assessment was accomplished using the 24-Hour Dietary Recall, Food Frequency Questionnaire and Food Record (over three days), enabling the assessment of food/beverage habits and nutrient intake. Regarding genetic profiling, athletes were genotyped for the *ACE* I/D, *AGT* Met235Thr, *ACTN3*R577X and *BDKRB2*+9/-9. For psychological analysis, POMS and SCAT questionnaires were applied to investigate the slalom kayakers mood states and anxiety. Concerning the sleep characteristics analyses, the MEQ, PSQI and ESS questionnaires were completed to assess chronotype, sleep quality and sleepiness, respectively. Performance trial was conducted on a white-water course with 24 gates, and time was considered as the variable related to performance. The anthropometric, nutritional, psychological and sleep variables were correlated with the performance time trial in order to investigate the relationship between these parameters.

Anthropometric measurements

Anthropometric analyses were accomplished according to the guidance of American College of Sports Medicine (ACSM) and the International Standards for Anthropometric Assessment (ISAK). The anthropometric measurements were made in the morning, at the same time (8 a.m.) by an experienced and trained researcher. Several anthropometric measurements such as body mass, height, sitting height, lower extremity length and wingspan were determined. Body mass index (BMI) was calculated as body mass divided by height in meters squared. Nine skinfolds (chest, triceps, biceps, supraspinale, subscapular, axillary, abdominal, thigh, and lower leg) were measured and used to estimate fat percent and lean mass. Fat mass was determined as body mass minus lean mass. The somatotype was analyzed using the somatochart[21].

Nutritional analysis

Dietary intake of the athletes was assessed using the Frequency Questionnaire (FQ) and Food Record (FR) (over three days). The FQ was administered only on the first day of collection and athletes completed the questionnaire after training with a nutritionist. This questionnaire was able to assess the daily, weekly or monthly frequency of nineteen Brazilian food groups (fruits, vegetables, legumes, milk and dairy products, meat, eggs, sausages, fish, seafood, cereal and breads, sweets, candies, soft drinks, juices, artificial juices, snacks, chips and alcohol). The results were expressed as the sum of the number of athletes in each predetermined frequency (1-2 times/day, 2-4 times/day, 2-3 times/week, 1-2 times/week, 1-2 times/month, rarely, and never). The FR was assessed by the analysis of dietary intake over three non-consecutive days, including one day of the weekend (Saturday or Sunday), which were also completed by athletes. Foods were described in household measures and subsequently converted to grams (g) or milliliters (mL). The calculation of the total energy expenditure of athletes was based on the equation Estimated Energy Requirements (EER) established by the Dietary Reference Intakes (DRI). The carbohydrate, protein and dietary lipids adequacy was made based on the recommendations of the American Dietetic Association, Dietitians of Canada and American College of Sports Medicine. The consumption average over three days of macronutrients and micronutrients was quantified using the Brazilian Table of Food Composition (TACO) and Diet PRO version 5i software for nutritional assessment and prescription diets. Interpretation of the adequacy probability of micronutrients was performed according to the Estimated Average Requirement (EAR) values, except for sodium, potassium manganese and fibers, which were analyzed according to the recommendations of the Recommended Daily Allowance (RDA). It was not possible to consider the EAR values for iron as we lacked sufficient data for the calculation, such as interpersonal variation. Thus, we used the adaptation range (70%- 130%) established in 1993 by Gibson [22] for calculation of these minerals and fibers.

Genetic profile

DNA samples were extracted via the reaction of ammonium acetate and isopropanol from the epithelial cells of the oral mucosa. *ACTN3*R577X (rs.1815739) and *AGT* Met235Thr (rs.699) were genotyped using fluorescence-based TaqMan® SNP Genotyping Assays (Applied Biosystems, Foster City, CA, USA). Flanking primer sets and allele specific probes were used in a Polymerase Chain Reaction (PCR) mastermix containing ampliTaq DNA polymerase Gold (Applied Biosystems, Foster City, CA, USA) in a reaction volume of 20 µl. PCR required 10 minutes of heat activation (95°C) followed by 50 cycles of 15s each at 95°C and 1 minute at 60°C. Amplification was accomplished with PCR equipment Real Time ABI 7500 (Applied Biosystems).

ACE insertion or deletion (I/D) was identified by a polymerase chain reaction (PCR) using a sense primer (5′-CTG GAG ACC ACT CCC ATC CTT TCT-3′) and an antisense primer (5′-GAT GTG GCC ATC ACA TTC GTC AGA T-3′). PCR resulted in 490 bp (I/I) and 190 bp (D/D) analyzed on a 2% agarose gel stained with SYBR® Safe DNA gel stain (Invitrogen). *BDKRB2* presence or absence (+9/-9) was identified by PCR using a sense primer (5′-AGT CGC TCC CTG GTA CTG C-3′) and an antisense primer (5′-TCC AGC TCT GGC TTC TGG-3′). PCR resulted in 89 bp (+9/+9) and 80 bp (-9/-9) fragment analyzed on a 4% agarose gel stained with SYBR® Safe DNA gel stain (Invitrogen).

Psychological aspects

The short form of the POMS[23] was applied. This questionnaire is composed by 36 questions addressing six mood domains (Tension, Depression, Angry, Vigor, Fatigue and Confusion). Athletes were asked to answer the questions using a scale ranging from 0 (absence) to 4 (extreme). Six questions were related to each mood state and the sum of the answers resulted in the final specific score for each one.

The SCAT[24] was applied to address the slalom kayakers' anxiety level. Fifteen affirmative questions rated from 1: Hardly ever to 3: Often compose this questionnaire. Two questions were omitted from scoring, five were considered as controls and ten were used for the final score calculation. According to the final score, the athletes were considered to display Low (≤10), Regular (11-19) and High (≥20) levels of anxiety.

Sleep characteristics

Three questionnaires were applied to assess the sleep characteristics of the slalom kayakers. All questionnaire results were analyzed by a researcher with expertise in this area. The Pittsburgh Sleep Quality Index (PSQI)[25] consists of 19 questions divided into seven subcategories, including sleep quality, latency, duration, efficiency, disturbance, use of sleep medication and daytime dysfunction. The sum of the 7 component scores results in the global PSQI score, which may range from 0 to 21. The lower PSQI score indicates higher sleep quality. On the other hand, the higher PSQI score may indicate severe difficulties in all eight components, which reflect poorer sleep quality[25].

Data associated with sleepiness were obtained by the application of the Epworth Sleep Scale (ESS). This questionnaire is composed by eight items related to daytime sleepiness and the capability to stay alert and awake in several moments of the day[26]. The athletes answered every question using a scale of 0 to 3, with every answer and follow score: "would never doze" (0), "slight chance of dozing" (1), "moderate chance of dozing" (2) and "high chance of dozing" (3). The sum of the answers score refers to the ESS final score. Athletes with scores ≥10 were considered as individuals with excessive daytime sleepiness[26].

The Morningness-Eveningness questionnaire (MEQ)[27] was completed in order to identify the athletes' chronotype. The MEQ contains 19 questions related to daily activities and sleep time. Each question is composed by four answers with values ranging from 1 to 4. Based on the sum of answer values, individuals are classified into Definitively Evening (DE = 16-30), Moderately Evening (ME = 31-41), Neither (NE = 42-58), Moderately Morning (MM = 59-69) and Definitively Morning (DM = 70-86)[27].

Performance trial

The slalom kayakers performed the performance trial on a white-water course where national and international competitions regularly take place (Itaipu, PR, Brazil; length- 430m; width-8-25m; mean depth-120m). Before the trial, the kayakers warmed up for five minutes in low intensity training. The course had 24 gates (six against and 18 with the current) to be negotiated by the athletes. Each elite athlete used their own equipment, including boat and paddle. Equipment model, length, width and mass complied with the International Canoe Federation regulations. Trial time was considered as the variable related to performance.

Statistical analysis

Statistical analysis was carried out using a statistical software package (STATISTICA 7.0, Statsoft, OK, USA). Mean and standard deviation were calculated for all studied variables. Homogeneity and normality were confirmed using the Levene and Shapiro-Wilk tests, respectively. A Pearson product moment correlation was applied to the relationship analysis. Confidence intervals were also calculated for relationships analysis (Pearson product moment correlation) and mean with $\alpha=0.05$ ($\sigma/\sqrt{n}$). In all cases, statistical significance was set at $P < 0.05$.

Results

The anthropometric results of the slalom kayakers are presented in **Table 1**. Only three athletes were younger than 18 (mean=18±2; range=15-22). Mesomorphic somatotype was predominant among the evaluated kayakers (Endomorphic-2.6±0.5; Mesomorphic-4.3±0.7; Ectomorphic-2.5±0.6). Mean sitting height,

lower extremity length and wingspan were equal to 88.6±4.0 cm (range=85.4-93.7), 83.7±5.0 cm (range=77.3-91.1) and 177.0 ± 8.9 (range=167.5-189.5), respectively. The sum of skinfold was low for most cases (mean=57.7±13.2; range=40.0-78.0), which resulted in low fat mass (mean=15.5±2.7; range=8.6-11.6) and high lean mass (mean=51.4±11.2; range=33.1-65.3).

Table 1. Anthropometric measurements of the slalom kayakers.

	Mean	Range	CI (α=0.05)*
Body mass (kg)	66.9 ± 8.9	53.3 – 79.7	60.5 – 73.3
Height (cm)	172.0 ± 9.0	159.0 – 184.1	166.9 – 178.1
Fat (%)	10.2 ± 1.0	8.6 – 11.6	9.4 – 10.9

*Upper and lower confidence limits of confidence interval for mean.

According to the FQ, 80% of athletes drank 1.5/2.0 l of water on a daily basis. All athletes denied the use of dietary supplements. More than half (60%) reported fruit and candy intake two-three times a week. The highest intake of vegetables, greens and legumes was reported at two-three times a week (50 %, 70 % and 50 %, respectively). All athletes reported the cereal intake at two-three times a week. For milk (and dairry), meat, built-food and egg, the highest intake was stated at one-two times a week (60 %, 70 %, 80 % and 40 %, respectively). The processed juice intake was reported by 70 % at one-two times a week while only 10 % reported fresh juice intake at the same frequency. Less than half of the athletes (40 %) reported soft drink intake at two-three times a week. Snacks and junk foods were consumed by 40 % and 50 % of the athletes one-two times a week.

Regarding macronutrient intake (**Figure 1a**), while 50 % and 60 % of athletes were compliant with the recommendation of protein and fat, most athletes consumed less energy and carbohydrate. Athletes were also inside the inappropriate classification for some vitamins (**Figure 1b**). In regard of some minerals, the kayakers presented higher or lower than the recommended (**Figures 1c and 1d**).

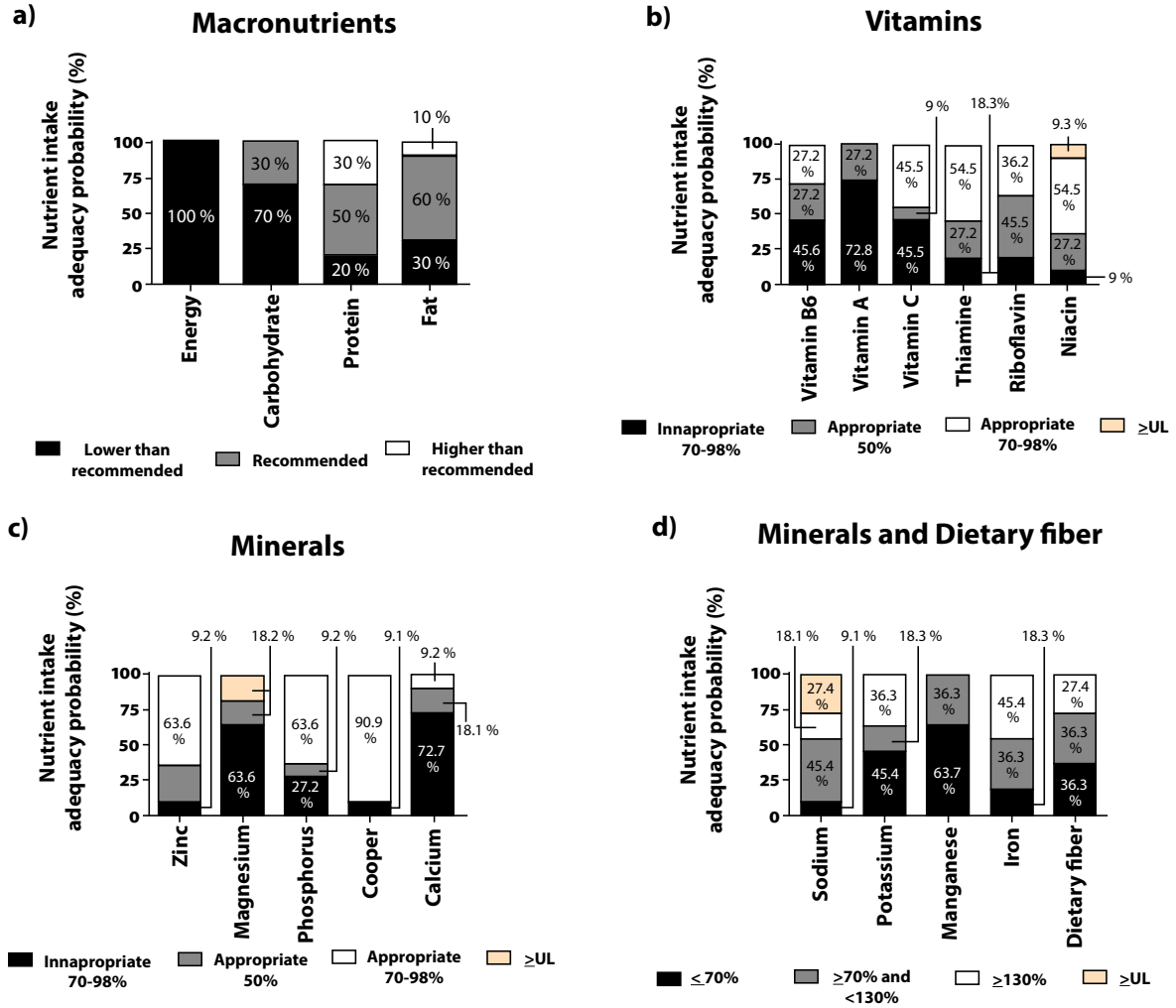

Figure 1. Athletes' food intake valuation; **a)** Daily energy and macronutrient consumption, obtained over three days and compared with the American Dietetic Association, Dietitians of Canada and American College of Sports Medicine; **b)** Vitamin intake adequacy probability according to the dietary record over three days; **c)** and **d)** Minerals intake adequacy probability according to the dietary record over 3 days and fiber food consumption obtained over 3 days. All columns represent the percentage of athletes in each classification.

Considering the genetic profile, 70 % of the athletes were genotyped with the I allele (i.e ID plus II) for *ACE* protein (**Figure 2a**). In relation to the *AGT* protein, only 20 % do not express it (**Figure 2b**). Similarly, 10 % and 20 % of the slalom kayakers do not express the *ACTN3* (**Figure 2c**) and *BDKRB2* (**Figure 2d**), respectively.

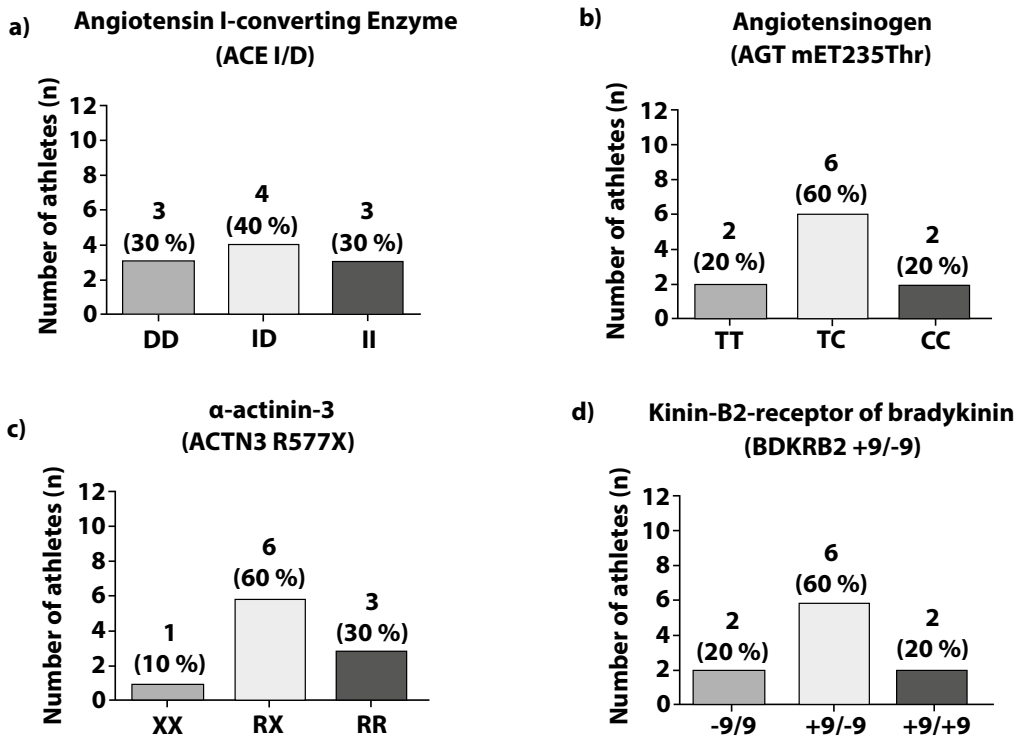

Figure 2. Slalom kayakers genetic profile; a) Gene polymorphisms of angiotensin I-converting enzyme (ACE). DD, ID and II indicate expression absence, less expression and high expression, respectively; b) Gene polymorphisms of angiotensinogen (AGT). TT, TC and CC indicate expression absence, less expression and high expression, respectively; c) Gene polymorphisms of α-actninin-3 (ACTN3). XX, RX and RR indicate expression absence, less expression and high expression, respectively; d) Gene polymorphisms of kinin-B2-receptor of bradykinin (BDKRB2). -9/-9, +9/-9 and +9/+9 indicate expression absence, less expression and high expression, respectively.

The psychological results are shown in **Table 2**. According to POMS, vigor was more pronounced than the other mood states within the athlete sample. Additionally, six athletes were considered to be "Regular" and six showed high anxiety levels from the SCAT results.

Table 2. Profile of Mood States (POMS) and Sports Competition Anxiety Test (SCAT) results of the slalom kayakers.

	Mean ± SD	**Range**	**CI (α=0.05)***
Profile of Mood States (POMS)			
Tension	7.7 ± 2.5	4 - 14	5.8 – 9.5
Depression	2.1 ± 1.7	0 - 6	0.8 – 3.3
Angry	3.3 ± 2.6	0 - 8	1.4 – 5.1
Vigor	17.2 ± 3.2	13 - 23	14.4 – 19.5
Fatigue	3.6 ± 1.9	1 - 7	2.2 – 4.9
Confusion	6.8 ± 2.7	2 - 12	4.9 – 8.6
Sports Competition Anxiety Test (SCAT)			
Score	18.8 ± 3.1	12 - 22	16.5 – 21.0

*Upper and lower confidence limits of confidence interval for mean.

Regarding the athletes' chronotypes, **Table 3** shows that eight slalom kayakers (75 %) were inside the "Neither" classification, one in "Moderately Morning" (16.6 %) and one inside the "Definitively Morning" classification (8.4 %). None of the athletes were classified as "Definitively Evening" or "Moderately Evening". With regard to sleep quality, nine athletes had sleep latency less or equal than 30 min. None of the slalom kayakers displayed sleep efficiency and Global Scores of less than 84 %. In relation to sleepiness, only two athletes had a score above ten (16.6 %) (**Table 3**).

Table 3. Pittsburgh Sleep Quality Index (PSQI) and Epworth Sleep Scale (ESS) results of the slalom kayakers.

	Mean ± SD	Range	CI (α=0.05)*
Pittsburgh Sleep Quality Index (PSQI)			
Sleep latency (min)	24.4 ± 25.4	10 - 50	4.8 – 43.9
Sleep efficiency (%)	94.4 ± 3.7	87 - 100	91.5 – 97.3
Global score	4.0 ± 2.0	1 - 7	2.4 – 5.5
Epworth Sleep Scale (ESS)			
Sleepiness	7.2 ± 2.8	3 - 12	5.2 – 10.0

*Upper and lower confidence limits of confidence interval for mean.

Athletes performed the performance trial in 108.1 ± 16.6 s. Significant and positive relationships were obtained between the performance time trial and anthropometric and psychological parameters (**Table 4**). In addition, significant negative relationships were also visualized between the kayakers' performance and some macronutrients, minerals and dietary fiber. Better performances were given by athletes with II for *ACE* (DD=130.0±5.1 s; ID=99.5±9.7 s; II= 97.6±6.6 s), TC for *AGT* (TT=133.0±0.0 s; TC=100.8±12.2 s; CC=105.0±12.7 s), RR for *ACTN3* (XX=96.0 s; RX=117.1±15.7 s; RR=94.0±2.0 s) and +9/-9 for *BDKRB2* (-9/-9=110.0±19.7 s; +9/-9= 106.7±18.4 s; +9/+9=109.5±6.3 s).

Table 4. Relationship between the anthropometric, nutritional, psychological and sleep variables with the performance time trial.

	Performance Time Trial		
	r	P	CI (α=0.05)*
Antropometric			
Body mass	0.23	0.507	-0.47 - 0.75
Height	0.29	0.402	-0.42 - 0.78
% Fat	0.77	0.008	0.27 - 0.94
Nutritional			
Energy	-0.75	0.029	0.17 - 0.94
Protein	-0.76	0.026	0.25 - 0.95
Carbohydrate	-0.72	0.041	0.17 - 0.93
Fat	-0.49	0.208	-0.20 - 0.86
Vitamin B6	-0.87	0.004	0.49 - 0.97
Vitamin A	-0.82	0.012	0.34 - 0.96
Vitamin C	-0.62	0.100	-0.08 - 0.91
Thiamine	-0.77	0.024	0.22 - 0.95
Riboflavin	-0.71	0.048	0.09 - 0.93
Niacin	-0.52	0.177	-0.22 - 0.88
Zinc	-0.35	0.390	-0.41 - 0.82
Magnesium	-0.86	0.005	0.46 - 0.97
Phosphorus	-0.74	0.032	0.15 - 0.94
Cooper	-0.36	0.370	-0.40 - 0.83
Calcium	-0.62	0.097	-0.08 - 0.92
Sodium	-0.54	0.158	-0.19 - 0.89
Potassium	-0.29	0.484	-0.46 - 0.80
Manganese	-0.60	0.108	-0.11 - 0.90
Iron	-0.61	0.112	-0.09 - 0.91
Dietary fiber	-0.83	0.010	0.37 - 0.96
Psychological			
Tension	0.06	0.851	-0.59 - 0.66
Depression	0.32	0.360	-0.39 - 0.79
Angry	0.23	0.504	-0.46 - 0.76
Vigor	0.49	0.147	-0.20 - 0.86
Fatigue	0.73	0.015	0.19 - 0.93
Confusion	0.34	0.325	-0.37 - 0.80
SCAT Score	0.67	0.030	0.07 - 0.91
Sleep			
Sleep latency	0.21	0.570	-0.48 - 0.74
Sleep efficiency	0.37	0.315	-0.34 - 0.81
Sleepiness	0.40	0.284	-0.31 - 0.82

*Upper and lower confidence limits of Pearson correlation coefficient.

#Significant correlation (P<0.05).

Discussion

The present study provided a novel and impactful characterization of anthropometric, nutritional, genetic, psychological

and sleep variables of elite slalom kayakers. In addition, significant relationships were obtained between these variables and athletes' performances, showing the necessity of considering multidisciplinary factors during training and competition in order to achieve better performance.

Contemporary research showed that performance time has improved in recent years, leading to modifications in the morphological profile of slalom paddles[28]. Conversely, compared with the US national team of 1983[29], Brazilian athletes evaluated in our study showed similar anthropometric results, mainly in fat percentage (10.4 and 10.3, respectively). Considering this similarity, fat percentage possibly has an important role in elite kayakers' performance. Our results support this, since fat percentage was significantly correlated with performance (r=0.77; *P*=0.08). Additionally, our results confirmed previous reports that slalom kayakers are predominantly mesomorphic[28,29]. Thus, it is possible to suggest the canoe slalom anthropometric requirement is specific, characterized by low fat percentage and large circumferences of the upper limbs, but it seems not to be dependent on the canoe slalom disciplines (i.e K1, C1 and C2), given that a low variance was observed in the anthropometric results.

Directly related to the anthropometric profile, nutritional traits have important roles in body composition and performance. According to our nutritional results, while all athletes reported lower energy intakes, 70 % and 20 % respectively reported lower carbohydrate and protein intake than the recommended. Adequate energy, carbohydrate and protein intake must be properly considered during canoe slalom competition. While carbohydrates deliver glucose to the bloodstream, which can then be transferred to muscle during exercise and replenish glycogen content during rest, adequate protein intake facilitates muscle reconditioning after exercise[30]. In addition, we suggest that considerable attention must be given to these macronutrients during canoe slalom competitions. In these events, athletes must perform two races separated by ~1 hour[7]. Thus, between races carbohydrate and protein ingestion can directly influence slalom kayakers' recovery, and therefore, performance. In agreement with this, negative and significant relationships between the athlete's performance and energy, carbohydrate and protein intake were revealed , supporting the aforementioned statements.

Along with adequate macronutrient intake, vitamins and minerals are key regulators of health and performance due to their antioxidant activity, immunological function and energy supply[9]. While limited information exists about the relationship between vitamin A and exercise[31], studies described the relevance of adequate vitamin B6[32], magnesium[33], thiamine[34], riboflavin[35], calcium and phosphorus[36] intake on biological processes related to athletic performance. Considering the high blood lactate levels (8.29±2.43 mM) demonstrated by Messias et al.[3] after canoe slalom simulated trials and the importance of vitamins of B6 complex, thiamine, riboflavin in gluconeogenesis process involving the conversion of lactic acid to glucose in the liver[32,34,35], inadequate intake of this vitamin may influence energetic replenishment after a race. In agreement with this, significant and negative relationships between slalom kayakers' performance and the aforementioned vitamins/minerals were revealed. On the other hand, despite studies described the relevance of vitamin C, niacin, zinc, calcium, sodium, potassium, manganese and iron during exercise[9,37-41], we did not obtain significant correlations between these vitamins/mineral and performance.

Regarding genetic traits, the *ACE* insertion/deletion (I/D) has been related to both aerobic and anaerobic metabolisms. We found that 70 % of the slalom kayakers studied have the I allele, which is related to improvement in endurance sports by means of lower *ACE* serum and tissue activity[12]. Despite Zamparo, Tomadini, Didone, Grazzina, Rejc, Capelli[1] demonstrating that anaerobic metabolism is predominant during canoe slalom races, the high *ACE* insertion in the Brazilian athletes evaluated in our study may indicate that the aerobic component is also important for performance improvement in this sport, which was confirmed by the better performance of athletes genotyped as II or ID (97.6±6.6 s; 99.5±9.7 s, respectively) when compared with athletes genotyped as DD (130.0±5.1 s). Moreover, athletes who only have the arginine residue replacement (R) in the premature stop codon (X) encoding the α-actinin-3 (*ACTN3*) protein (which is related to powerful muscle contraction due to its expression in glycolytic type IIX fibers)[13] also demonstrated better performance, confirming the anaerobic relevance during canoe slalom races proposed by other studies[1,3].

In regard of *AGT* and *BDKRB2* genes, slalom kayakers genotyped with the C and +9 alleles (80 % and 70 %, respectively) performed better than other athletes. The role of *AGT* and *BDKRB2* in the renin-agiotensin-aldosterone system is well established, which is also related to the *ACE* activity[14-16]. In fact, we believe that the expression of *ACE*, *AGT* and *BDKRB2* genes in elite slalom kayakers is not random, since aerobic metabolism is not solely important for energy replenishment improvement after races, but also for improving the volume of anaerobic training sessions, which are necessary for performance improvement.

The psychological traits of the slalom kayakers are of particular interest in science[18]. Thus, despite the fact that the mean SCAT result was inside the "Regular" classification (19.1 ± 0.8), 50 % of the athletes showed a high final score (21.1 ± 0.4), demonstrating considerable anxiety. Moreover, since significant and positive correlations were obtained between the SCAT final scores and kayakers' performance, the anxiety levels of these athletes should be considered to improve their performance. Conversely, the mean vigor results were higher than other mood states , suggesting positive psychological preparation for training and competition. However, significant correlation was not found between this mood state and kayakers' performance. Considering the important role of psychological factors in slalom kayakers' performance[18], and that the POMS and SCAT provided different conclusions, we reaffirm the previous suggestion of Messias, Reis, Ferrari, Manchado-Gobatto[7], in that slalom kayakers' training and periodization should not be limited to coaches but should also include sports psychologists in order to improve athletic performance.

Another variable that is directly related to psychological disorders is sleep quality. Low sleep latency, efficiency and global scores were obtained from the PSQI, indicating high sleep quality. Additionally, only three athletes reported ESS scores ≥10, demonstrating that 75% of the Brazilian kayakers evaluated

in our study do not suffer from excessive sleepiness in active or passive situations. These results provide relevant information for improving slalom kayakers' performance, since poor sleep quality may affect physical and cognitive aspects in training and competition[20]. Interestingly, the MEQ results showed that most of the athletes were classified as the "Neither" chronotype. This analysis is also interesting for coaches, once better results may be achieved when training sessions are designed considering biological rhythm and chronotype[20]. Despite this importance, significant corrections were not observed between sleep traits and kayakers' performance.

Conclusion

This study provided novel results regarding the relationship between slalom kayakers' performance and aspects that could directly influence this performance, including anthropometric factors, nutrition, genetics, psychology and sleep. Additionally, the tools used in this study (i.e. equipment and questionnaires) are cost-effective and their application is easily undertaken by a multidisciplinary team. Regarding the anthropometric measurements, significant but positive correlation between fat percentage and performance was observed; coaches and athletes must be aware of this factor. The macronutrients intake as energy and protein were significantly and negatively correlated with the performance; such perspective is extended to micronutrients intake for vitamins B6 and C, besides thiamine, riboflavin, magnesium, phosphorus and dietary fiber. With relation to psychological factors, we obtained significant but positive relationship between fatigue and performance; coaches must carefully consider such factor during training and competition. Although the importance of sleep traits to athlete's development, we do not observe significant relationship between any parameter of this nature with the kayaker's performance. Overall, we highlight that slalom kayak training should not be limited to athletic coaching alone, but should also include a multidisciplinary team coaching in order to achieve better performance in competitions.

REFERENCES

1. Zamparo P, Tomadini S, Didone F, Grazzina F, Rejc E, Capelli C. Bioenergetics of a slalom kayak (k1) competition. Int J Sport Med. 2006;27:546-552.
2. Messias LH, Ferrari HG, Reis IG, Scariot PP, Manchado-Gobatto FB. Critical velocity and anaerobic paddling capacity determined by different mathematical models and number of predictive trials in canoe slalom. J Sport Sci Med. 2015;14:188-193.
3. Messias LH, Ferrari HG, Sousa FA, Dos Reis IG, Serra CS, Gobatto CA, Manchado-Gobatto FB. All-out Test in Tethered Canoe System can Determine Anaerobic Parameters of Elite Kayakers. Int J Sport Med. 2015; 36:803-808.
4. Ferrari HG, Messias LHD, Reis IGM, Gobatto CA, Sousa FAB, Serra CS, Manchado-Gobatto FB. Aerobic evaluation in elite slalom kayakers using a tethered canoe system: a new proposal. Int J Sport Phys Perf. 2017; 12:864-871.
5. Messias LHD, Sousa FAB, Reis IGM, Ferrari HG, Gobatto CA, Serra CS, Papoti M, Manchado-Gobatto FB. Novel paddle stroke analysis for elite slalom kayakers: relationship with force parameters. Plos One. 2018; 13:e0192835.
6. Manchado-Gobatto FB, Vieira NA, Messias LHD, Ferrari HG, Borin JP, Andrade VC, Terezani DR. Anaerobic threshold and critical velocity parameters determined by specific tests of canoe slalom:Effects of monitored training. Sci Sport. 2014; 29:55-58.
7. Messias LHD, Reis IM, Ferrari HG, Manchado-Gobatto FB. Physiological, psychological and biomechanical parameters applied in canoe slalom training: a review. Int J Perf Anal Sport. 2014;14:24-41.
8. McMurray RG, Proctor CR, Wilson WL. Effect of caloric deficit and dietary manipulation on aerobic and anaerobic exercise. Int J Sports Med. 1991;12:167-72.
9. Lukaski HC. Vitamin and mineral status: effects on physical performance. Nutrition. 2004;20:632-644.
10. Petrie HJ, Stover EA, Horswill CA. Nutritional concerns for the child and adolescent competitor. Nutrition. 2004;20:620-631.
11. Brotherhood JR. Nutrition and sports performance. Sports Med. 1984;1:350-89.
12. Ma F, Yang Y, Li X, Zhou F, Gao C, Li M, Gao L. The association of sport performance with ACE and ACTN3 genetic polymorphisms: a systematic review and meta-analysis. Plos One. 2013;8:e54685.
13. Eynon N, Banting LK, Ruiz JR, Cieszczyk P, Dyatlov DA, Maciejewska-Karlowska A, Sawczuk M, Pushkarev VP, Kulikov LM, Pushkarev ED, Femia P, Stepto NK, Bishop DJ, Lucia A. ACTN3 R577X polymorphism and team-sport performance: a study involving three European cohorts. J Sci Med Sport. 2014;17:102-106.
14. Gomez-Gallego F, Santiago C, Gonzalez-Freire M, Yvert T, Muniesa CA, Serratosa L, Altmae S, Ruiz JR, Lucia A. The C allele of the AGT Met235Thr polymorphism is associated with power sports performance. App Phys Nut Met. 2009;34:1108-1111.
15. Norman B, Esbjornsson M, Rundqvist H, Osterlund T, Glenmark B, Jansson E. ACTN3 genotype and modulation of skeletal muscle response to exercise in human subjects. J Appl Physiol. 2014;116:1197-1203.
16. Alves CR, Alves GB, Pereira AC, Trombetta IC, Dias RG, Mota GF, Fernandes T, Krieger JE, Negrao CE, Oliveira EM. Vascular reactivity and ACE activity response to exercise training are modulated by the +9/-9 bradykinin B(2) receptor gene functional polymorphism. Phys Gen. 2013;45:487-492.
17. Scanavini D, Bernardi F, Castoldi E, Conconi F, Mazzoni G. Increased frequency of the homozygous II ACE genotype in Italian Olympic endurance athletes. Eur J Hum Gen. 2002;10:576-577.
18. Macintyre T, Moran A, Jennings DJ. Is controllability of imagery related to canoe-slalom performance? Percept Mot Skills. 2002;94:1245-1250.
19. Nibali M, Hopkins WG, Drinkwater E. Variability and predictability of elite competitive salom-kayak performance. Eur J Sport Sci. 2011;11:125-130.
20. Silva A, Queiroz SS, Winckler C, Vital R, Sousa RA, Fagundes V, Tufik S, Mello MT. Sleep quality evaluation, chronotype,

sleepiness and anxiety of Paralympic Brazilian athletes: Beijing 2008 Paralympic Games. Br J Sports Med. 2012;46:150-154.
21. Heath BH, Carter JEL. A modified somatotype method. Am J Phys Ant. 1967;27:17.
22. Gibson RS. Nutritional assessment: a laboratory manual: New York: Oxford University; 1993.
23. Shacham S. A shortened version of the Profile of Mood States. J Pers Ass. 1983;47:305-306.
24. Martens R. Sport Competition Anxiety Test. Champaign, IL: Human Kinetics; 1977.
25. Buysse DJ, Reynolds CF, 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: A New Instrument for Psychiatric Practice and Research. Psych Res. 1988;28:193-213.
26. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. Sleep. 1991;14:540-545.
27. Horne JA, Ostberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. Int J Chron. 1976;4:97-110.
28. Ridge BR, Broad E, Kerr DA, Ackland TR. Morphological characteristics of Olympic slalom canoe and kayak paddlers. Eur J Sport Sci. 2007;7:107-113.
29. Vaccaro P, Gray PR. Physiological Characteristics of World Class White-Water Slalom Paddlers. Res Q Exerc Sport. 1984;55:206-210.
30. Van Loon LJC. Is There a Need for Protein Ingestion During Exercise? Sport Med. 2014;44:105-111.
31. Siqueira JR, Gabriel RC, Zucolotto V, Silva AC, Dantas NO, Gasparotto LH. Electrodeposition of catalytic and magnetic gold nanoparticles on dendrimer-carbon nanotube layer-by-layer films. Phys Chem Chem Phys. 2012;14:14340-14343.
32. Manore MM. Vitamin B6 and exercise. Int J Sport Nut. 1994;4:89-103.
33. Chen HY, Cheng FC, Pan HC, Hsu JC, Wang MF. Magnesium enhances exercise performance via increasing glucose availability in the blood, muscle, and brain during exercise. Plos One. 2014;9:e85486.
34. Choi SK, Baek SH, Choi SW. The effects of endurance training and thiamine supplementation on anti-fatigue during exercise. J Exer Nut Bioch. 2013;17:189-198.
35. Sato A, Shimoyama Y, Ishikawa T, Murayama N. Dietary thiamin and riboflavin intake and blood thiamin and riboflavin concentrations in college swimmers undergoing intensive training. Int J Sport Nut Exer Met. 2011;21:195-204.
36. Karakukcu C, Polat Y, Torun YA, Pac AK. The effects of acute and regular exercise on calcium, phosphorus and trace elements in young amateur boxers. Clin Lab. 2013;59:557-562.
37. Buratti P, Gammella E, Rybinska I, Cairo G, Recalcati S. Recent Advances in Iron Metabolism: Relevance for Health, Exercise, and Performance. Med Sci Sport Exer. 2015;47:1596-1604.
38. Chenoweth LM, Smith JR, Ferguson CS, Downey AE, Harms CA. The effects of antioxidant vitamin supplementation on expiratory flow rates at rest and during exercise. Eur J Appl Physiol. 2015;115:2049-2058.
39. Haakonssen EC, Ross ML, Knight EJ, Cato LE, Nana A, Wluka AE, Cicuttini FM, Wang BH, Jenkins DG, Burke LM. The effects of a calcium-rich pre-exercise meal on biomarkers of calcium homeostasis in competitive female cyclists: a randomised crossover trial. Plos One. 2015;10:e0123302.
40. Micheletti A, Rossi R, Rufini S. Zinc status in athletes: relation to diet and exercise. Sports Med. 2001;31:577-582.
41. Plaisance EP, Mestek ML, Mahurin AJ, Taylor JK, Moncada-Jimenez J, Grandjean PW. Postprandial triglyceride responses to aerobic exercise and extended-release niacin. Am J Clin Nut. 2008;88:30-37.

Acknowledgments

We would like to thank the coaches and athletes from the Brazilian canoe slalom team and colleagues of our and other laboratories for the collaboration.

Corresponding author

Fúlvia de Barros Manchado-Gobatto.
Address: School of Applied Sciences, University of Campinas.
Pedro Zaccaria Street, 1.300, Jardim Santa Luiza,
Postal Code 13484-350 – Limeira, São Paulo, Brazil.
Email: fbmanchado@yahoo.com.br.

Manuscript received on April 28, 2018
Manuscript accepted on May 28, 2018