Predictive equations for resting metabolic rate are not appropriate to use in Brazilian male adolescent football athletes

Taillan M. Oliveira¹, Paula A. Penna-Franca¹, Christian H. Dias-Silva¹, Victor Z. Bittencourt¹, Fabio F. L. C. Cahuê¹, Sidnei J. Fonseca-Junior¹,², Anna Paola T. R. Pierucci¹*

¹ Graduate Program in Nutrition, Laboratory of Food Development for Special Health Purpose and Education (DAFEE), Nutrition Institute Josué de Castro (INJC), Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil, ² Colégio de Aplicação, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil

* appierucci@gmail.com

Abstract

High accuracy in estimating energy expenditure is essential for enhancing sports performance. The resting metabolic rate (RMR), as a primary component of total energy expenditure (TEE), is commonly estimated using predictive equations. However, these references may not be applicable to adolescent athletes. The purpose of this cross-sectional study was to analyse the differences between predicted RMR in relation to energy expenditure measured by indirect calorimetry (IC) among 45 Brazilian male adolescent football athletes. Indirect calorimetry (IC) and anthropometric (bioimpedance) measurements were recorded at a single visit to the laboratory after fasting overnight. The mean age was 15.6 ± 1.14 years, body mass was 63.05 ± 7.8 kg, and height was 172 ± 7.5 cm. The RMR values predicted by equations proposed by the Food and Agriculture Organization (FAO) (United Nations), Henry and Rees (HR), Harris Benedict (HB), and Cunningham (CUN) were compared with IC RMR values, by correlation analysis. The FAO and HR predictive equations yielded different values from IC (IC: 1716.26 ± 202.58, HR: 1864.87 ± 147.78, FAO: 1854.28 ± 130.19, p = 0.001). A moderate correlation of 0.504 was found between the results of HB and IC. In the survival-agreement model, the CUN equation showed low disagreement with the IC RMR, with error values between 200 and 300 kcal/day. The results showed that HB and CUN yielded similar values as IC, with the CUN equation showing low disagreement with IC; hence, adolescent athletes should undergo evaluation with precise laboratory methods to ensure that accurate information about RMR is recorded.

1. Introduction

To ensure optimal control of body composition and maximal sports performance, it is essential to balance energy intake with energy expenditure. Estimating the total daily energy expenditure (TEE) can be challenging for nutritionists because athletes’ nutritional goals and requirements are not static over the training year [1].
Daily TEE is composed of basal or resting metabolic rate (BMR or RMR), which refers to the energy cost of essential life processes (60–75% of the TEE), diet-induced thermogenesis (the energy expended to digest, absorb, and convert food, ~10%), and the energy expended during physical activities (activity energy expenditure, ~15–30%) [2, 3]. Although there are objective methods for measuring the TEE, such as doubly labeled water and indirect calorimetry (IC), these can be impracticable because of the high cost of the equipment and related maintenance. Thus, in practical field approaches, the TEE is generally estimated subjectively using predictive RMR equations.

Some of the equations proposed in the literature [4–7] are commonly used to estimate athletes’ RMR. These equations were mainly developed in studies carried out in North America [4, 5], while in some studies, the nationality of the participants has not been stated [6, 7]. Moreover, all of the studies included children, adults, and older populations and did not analyse adolescents exclusively [4–7]. As a result, the estimations of athletes’ RMR produced by these equations have questionable reliability. For several adolescent athletes, estimating the RMR is important to determine weight and height gain as well as for maintaining health and suitable body composition for the said modality [1].

Body composition is an important parameter for football players, who start their competitive careers in adolescence, and from that early age, they are subjected to constant and prolonged physical exhaustion. Football is an endurance sport [8], characterized by intermittent activity with bursts of intense effort [9]. The players’ activities during a match include standing, walking, jogging, cruising, sprinting, and backing, and the time spent on each of those activities depends on the player’s field position [10]. Athletes may compete two or three times a week, and the number of games played impacts their response to training [11], including energy demands. Thus, it is important to estimate the RMR correctly because it is the main variable for estimating the TEE.

In current clinical practice, predictive equations are widely used for estimating the RMR of adolescent athletes [1]. Previous studies have shown that RMR equations may not produce accurate results for this population, and there is no agreement between studies on the most suitable equation [12]. To date, no study has evaluated the accuracy of predictive equations in estimating the RMR in Brazilian adolescent football players. We hypothesized that predictive equations and IC, which is considered the gold standard for estimating the RMR, yield different RMR values [13]. Therefore, the aim of this study was to investigate the suitability of four predictive equations for evaluating the RMR of adolescent football players in Brazil using IC as the standard method.

2. Methods

In all, 45 male players from the under-15 and under-17 categories of a first division team in the Rio de Janeiro State Association Football Championship participated in this cross-sectional study. The inclusion criteria were training load of at least 4 hours for 5 days each per week, engaged in practice for at least 1 year prior to recruitment, and competed in at least one official national championship season. After club approval and meeting with the coaching committee, a meeting was held with the athletes for recruitment. The participants and their parents or legal guardians were informed about the experimental procedures and possible risks associated with the study, and informed consent was obtained in writing. The participants completed the testing procedures on a single day. Four athletes were evaluated per day for 3 weeks at the Nutrition Evaluation Laboratory of the Federal University of Rio de Janeiro. The football players underwent anthropometric, body composition, and indirect calorimetry measurements after fasting for 8 hours and 24 hours of rest from training. The study was approved by the Research Ethics Committee of the Clementino Fraga Filho University Hospital, Rio de Janeiro Federal University, Brazil (CAAE 58179716.3.0000.5257).
**Anthropometric and body composition measures**

Body mass was assessed using a digital scale platform without an anthropometric ruler, Fili-zola® brand, accurate to 0.05 kg and 150 kg. Height was measured using an Alturexata® portable stadiometer, with a bilateral scale in millimeters (resolution of 1 mm), and field of use of 0.35 to 2.13 m. The participants were asked to remain barefoot for the measurements [14]. The body mass index (BMI) was calculated. Body fat percentage, body mass, fat-free mass (FFM), and fat mass (FM) were measured by bioimpedance (Byodinamics® 450) [15]. The participants were instructed to avoid consuming alcohol or caffeine on the day prior to the test, to not engage in exercise, to observe 8 hours of fasting, and avoid using diuretic medications. The participants were asked to lie down in a relaxed manner, in the supine position, barefoot without any metal adornment, with the hands leaning away from the body, and legs hip-distance apart.

**Indirect calorimetry measures**

IC was carried out as per Compher’s [16] protocol. The participants were instructed to avoid consuming any thermogenic food, supplements, stimulants, sleep or appetite inhibitors, analgesics, or other substances known to affect RMR 1 day before the test. In addition, they were instructed not to take part in any physical practice on the day prior to the test and fast for 8 h before giving the measurements. On arrival to the laboratory, the participants were interviewed individually by a specialised nutritionist, and adherence to the RMR measurement protocol was confirmed. For IC, the Vmax Encore 29 System (VIASYS Healthcare Inc., Yorba Linda, CA) calorimeter was used. The measurements were taken in the morning, with the athletes in the supine position. A maximum of four participants were examined per day. Oxygen consumption (VO$_2$) and carbon dioxide production (VCO$_2$) values were collected by canopy and checked continuously for 30 min. For calculation purposes, the first 10 minutes were discarded to ensure data homogeneity. The VO$_2$ and VCO$_2$ values were used in the equation proposed by Weir [17] [Eq 1].

Equations:

\[
RMR \text{ kcal/day} = (3.9 \times VO_2(\text{ml/min}) + 1.1 \times VCO_2(\text{ml/min})) \times 1440 \quad \text{(Eq 1)}
\]

**Predictive RMR equations**

The following predictive equations were used:

\[
\begin{align*}
\text{Harris & Benedict (1919)} & : 66.4730 + (13.7516 \times W) + (5.0033 \times H) - (6.7550 \times A) \quad \text{(Eq 2)} \\
\text{Cunningham (1980)} & : 581.6 + 21.6 \times \text{FFM} \quad \text{(Eq 3)} \\
\text{Henry & Rees (1991)} & : (0.084 \times W + 2.122) \times 239 \quad \text{(Eq 4)} \\
\text{FAO (2004)} & : 17.686 \times W + 658.2 \quad \text{(Eq 5)}
\end{align*}
\]

Legend: weight (W), height (H), age (A), fat-free mass (FFM)

**Statistical analyses**

The Statistical Program for Social Sciences, version 20.0 (SPSS, Chicago, IL, USA) was used for statistical analyses. The methods were compared by difference analysis, correlation, degree of agreement, and survival-agreement. Additionally, IC data were also compared against age, anthropometric, and body composition variables to determine associations among these
parameters. The Kolmogorov-Smirnov test was used to establish data normality, and the results were expressed as mean and standard deviation. Repeated measures one-way ANOVA was applied to compare mean RMR values between predictive equations and IC at 95% significance (p < 0.05). Pearson’s correlation was used to compare the values from predictive equations; IC values, and the variables of weight, height, age, BMI, FM, and FFM. The coefficients of correlation were considered strong (r > 0.8), moderate (r < 0.8 and >0.5), or weak (r < 0.5). Additionally, the Bland–Altman plot [18] and survival agreement [19] were used to ascertain the degree of agreement between the aforementioned methods.

3. Results

The characteristics of the participants are shown in Table 1. The RMR predicted by the HB and CUN equations was not different from the IC RMR values, but values obtained from the HR and FAO equations were statistically different (IC × FAO p = 0.0002, IC × HR p = 0.0001) from IC RMR values (Fig 1). Moderate correlations were found between the RMR values from the equations and IC, with a high correlation to the values from the HB equation (Fig 2).

The Bland–Altman scatter plots in Fig 3, which compare data at an individual level, showed a significant difference between IC RMR and predicted RMR values. The differences and confidence intervals (95% CI) between the predicted values and IC values were, respectively, 138.02 ± 182.07 and 84.82–191.22 for FAO, 44.41 ± 176.11 and -7.04–95.87 for HB, 148.61 ± 186.24 and 94.20–203.02 for HR, and 12.25 ± 181.29 and -40.72–65.22 for CUN. The values obtained from CUN and HB were closer to the IC RMR values than those obtained from the other equations.

The agreement-survival results plotted in Fig 4 show a lack of agreement between the RMR values obtained from the equations and IC, with a variation of 200 to 400 kcal between them. On comparing the RMR values from IC and the equations, the CUN equation showed lower variation than the others, of 200 to 300 kcal/day, while for the other equations, the discrepancy was 300 to 400 kcal/day, at a disagreement level of 0.2 (20%) [19] (Fig 4).

The Pearson correlations between the body composition variables and IC values were determined. Except for height (r = 0.493) and body mass (r = 0.446), all variables showed moderate correlations to IC values (age: r = 0.282; BMI: r = 0.130; FM: r = 0.396; FFM: r = 0.396).

4. Discussion

We aimed to comparatively analyse the suitability of RMR prediction equations and RMR measured by IC in adolescent male football athletes. Our main finding was that the equations yielded RMR values with variations of 200 to 400 kcal from the IC RMR values. The HB and CUN equations showed moderate agreement compared to the FAO and HR equations. These

| Table 1. Age and body characteristics of male adolescent soccer players (n = 45). |
|-------------------------------|------------------|
| Variable                      | Mean ± SD        |
| Age (years)                   | 15.69±1.41       |
| Height (cm)                   | 173.00±7.53      |
| Body mass (kg)                | 67.63±7.36       |
| BMI (kg/m²)                   | 22.32±1.61       |
| Fat mass (kg)                 | 21.35±4.98       |
| Fat mass (%)                  | 14.53±4.06       |
| Fat-free mass (kg)            | 53.10±5.95       |
| Fat-free mass (%)             | 78.26±4.99       |

https://doi.org/10.1371/journal.pone.0244970.t001
results are in line with previous findings about differences between values obtained from IC and prediction equations [20–22].

The RMR is the main variable used to calculate daily TEE, so accurate calculation is a crucial requirement [1]. The equations investigated in this study yielded similar coefficients of variation (7.02–7.92%), which were lower than that yielded by IC (11.80%). This indicates that the equations have minimal capacity of detecting differences among athletes and each athlete’s actual energy individualised needs as compared to IC. Furthermore, sports training demands different levels of physical exertion and predicted energy expenditure [23]. In football, a variation of 1000–2000 kcal [24] in energy expenditure may be expected depending on the player’s position during a game. Individualised nutritional counselling is an essential tool in training programs for high-performance football players. Differences of 200–400 kcal in the predicted RMR can lead to weight gain or loss and to changes in body composition [1]. Besides, it can impact an athlete’s daily energy availability [20] and be detrimental to his/her sports performance, recovery, and overall health [25–27].

Although the HB and CUN equations returned better values, the results cannot be considered accurate. Studies conducted with athletes of different modalities have shown that the RMR prediction equations proposed by FAO and HR did not agree with IC RMR values [12, 23]. Loureiro et al. [27] investigated this in modern pentathlon athletes using the same statistical procedures as used in the current study and found similar results as the current study. Cherian et al. [12] also found the CUN and HB equations to be the best for predicting the RMR in a small sample of adolescent Indian football players. It is also important to note the differences between the characteristics of the study sample in the present study and of the populations on which the equation studies were based on [12, 23, 27].

Bland–Altman plots were used to present the degree of association between the values obtained from IC and the predictive equations [17], while survival-agreement plots were used to quantify the average overestimation or underestimation margin of each predictive equation [18]. The Bland–Altman plots showed that the equations did not agree with IC, with HB showing the best graphical association. However, studies using the same graphical demonstrations found acceptable results with the CUN equation, contrary to our data [12, 23, 27–29]. The survival-agreement plots showed that the accepted discordance proportion of 0.2 (20%) [19] induced an underestimation of 200 kcal in RMR estimation for both the HB and CUN equations.
Correlations between IC and anthropometric parameters were weak or moderate. Sagayama et al. [30] examined whether body composition estimated by bioimpedance influenced the RMR values; they found that weight and body mass were not significantly associated with RMR data, similar to our study. In general, the use of predictive equations to assess athletes’ RMR is criticized because their body composition interferes with the results since the equations were proposed for non-athlete populations [31].

Our study evaluated whether the equations presented differences between their means in a way that the variation could impair the assessment of a group of athletes. It also verified the agreement between the methods at both the individual and group levels. Finally, we evaluated the disagreement between the methods to verify the margin of error that a practitioner in clinical practice would have to consider when choosing any of the methods.

**Limitations**

Evaluating FM in adolescent athletes is a challenge in nutritional monitoring [32]. Studies aimed at determining the most accurate methods for assessing body composition in athletes
are still ongoing and there is a gap in the knowledge [33, 34], moreover, the four-compartment model is too complex to be used in day-to-day sports activities [35, 36].

Another possible limitation of this study is that nutrient intake was not assessed. Although the athletes were interviewed on food and supplement consumption to ensure RMR protocol compliance, the data were not analysed as nutrient intake. According to Madzima et al. [37], protein and carbohydrate ingestion prior to analysis by IC can influence RMR measurements.

5. Conclusion

In summary, this study evaluated differences between the predicted and IC RMR values. The present results conform with previous findings in the literature on athletes and diverse sports modalities, showing that the use of equations to predict RMR has practical limitations. The predictive equations tested in this study showed differences of 200–400 kcal from the IC RMR values. Therefore, when using predictive equations, the athletes’ energy balance as well as maintenance of body composition, physical performance, and recovery may be compromised. Athletes should undergo RMR evaluation with precise laboratory methods to obtain appropriate dietary prescriptions.
Novelty statement

The energy needs of football adolescent athletes can be incorrectly estimated using RMR equations. The difference between the RMR values from IC and predictive equations was up to 400 kcal.

Practical applications

When choosing a predictive equation to determine an athlete’s RMR, the nutritionist must consider its margin of error and field applicability.

Supporting information

S1 File.

(DOCX)

Acknowledgments

All technical support for the evaluations was provided by the Laboratory of Food Development for Special Health Purpose and Education (LabDAFEE) and the Nutritional Assessment Laboratory (LANUTRI).

Author Contributions

Conceptualization: Taillan M. Oliveira, Christian H. Dias-Silva, Victor Z. Bittencourt, Anna Paola T. R. Pierucci.

Data curation: Taillan M. Oliveira, Paula A. Penna-Franca, Christian H. Dias-Silva, Victor Z. Bittencourt.

Formal analysis: Taillan M. Oliveira, Paula A. Penna-Franca, Christian H. Dias-Silva.

Investigation: Taillan M. Oliveira, Christian H. Dias-Silva, Victor Z. Bittencourt.
Methodology: Taillan M. Oliveira, Paula A. Penna-Franca, Fabio F. L. C. Cahuê, Sidnei J. Fonseca-Junior, Anna Paola T. R. Pierucci.

Project administration: Anna Paola T. R. Pierucci.

Resources: Christian H. Dias-Silva.

Writing – original draft: Taillan M. Oliveira, Paula A. Penna-Franca, Victor Z. Bittencourt, Fabio F. L. C. Cahuê, Sidnei J. Fonseca-Junior, Anna Paola T. R. Pierucci.

Writing – review & editing: Taillan M. Oliveira, Paula A. Penna-Franca, Christian H. Dias-Silva, Fabio F. L. C. Cahuê, Sidnei J. Fonseca-Junior, Anna Paola T. R. Pierucci.

References
1. Thomas DT, Erdman KA, Burke LM. American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. Med Sci Sports Exerc. 2016; 48(3):543–68. https://doi.org/10.1249/MSS.0000000000000852 PMID: 26891166
2. Ravussin E, Bogardus C. Relationship of genetics, age, and physical fitness to daily energy expenditure and fuel utilization. Am J Clin Nutr. 1989; 49(5 Suppl):968–75.
3. Westerterp KR. Physical activity and physical activity induced energy expenditure in humans: measurement, determinants, and effects. Front Physiol. 2013; 4:90. https://doi.org/10.3389/fphys.2013.00090 PMID: 23637685
4. Harris JA & Benedict FG. A biometric study of human basal metabolism. Proc Natl Acad Sci 1918; 4 (12):370–373. https://doi.org/10.1073/pnas.4.12.370 PMID: 16576330
5. Cunningham JJ. A reanalysis of the factors influencing basal metabolic rate in normal adults. Am J Clin Nutr 1980; 33:2372–2374. https://doi.org/10.1093/ajcn/33.11.2372 PMID: 7435418
6. Henry CJK. & Rees DG. New predictive equations for the estimation of basal metabolic rate in tropical peoples. Eur J Clin Nutr 1991; 45:177–185. PMID: 1824042
7. Food and Agriculture Organization of the United Nations. Human energy requirements: Report of a Joint FAO/WHO/UNU Expert Consultation, 2004.
8. Hoff J & Helgerud J. Endurance and strength training for soccer players physiological concentrations. Sports Med 2004; 34(3):165–180. https://doi.org/10.2165/00007256-200434030-00003 PMID: 14987126
9. Stalen T, Chamari K, Castagna C, & Wisla U. Physiology of soccer. Sports Med 2005; 35(6):501–536. https://doi.org/10.2165/00007256-200535060-00004 PMID: 15974635
10. Strayer J, Hansen L, & Klausen K. Physiological profile and activity pattern of young soccer players during match play. Med Sci Sports Exerc 2004; 36(1):168–174. https://doi.org/10.1249/01.MSS.0000106187.05259.96 PMID: 14707784
11. Mohr Magni, et al. "Muscle damage, inflammatory, immune and performance responses to three football games in 1 week in competitive male players." European journal of applied physiology 116.1 (2016): 179–193. https://doi.org/10.1007/s00421-015-3245-2 PMID: 26377004
12. Cherian KS, Shahkar F, Sainoji A, Balakrishna N, and Yagnambhatt VR. Resting metabolic rate of Indian Junior Soccer players: Testing agreement between measured versus selected predictive equations. Am J Hum Biol 2018; 30(1): e23066. https://doi.org/10.1002/ajhb.23066 PMID: 28963803
13. Haugen Heather A., Chan Lintgak-Neander, and Li Fanny. Indirect calorimetry: a practical guide for clinicians. Nutrition in Clinical Practice 22.4 (2007): 377–388. https://doi.org/10.1177/0115426507022004377 PMID: 17644692
14. Stewart A, Marfell-Jones M, Olds T, and Ridder DH. International Society for Advancement of Kinanthropometry. International standards for anthropometric assessment. Lower Hutt, New Zealand: ISAK 2011; 50–3.
15. Gonçalves Vivian Siqueira Santos, et al. Predictive capacity of different bioelectrical impedance analysis devices, with and without protocol, in the evaluation of adolescents. Jornal de pediatria 89.6 (2013): 567–574.
16. Compher Charlene, et al. Best practice methods to apply to measurement of resting metabolic rate in adults: a systematic review. Journal of the American Dietetic Association 106.6 (2006): 881–903. https://doi.org/10.1016/j.jada.2006.02.009 PMID: 16720129
17. Weir JBD. New methods for calculating metabolic rate with special reference to protein metabolism. J. Physiol. (Lond.) 1949; 109:1–9. https://doi.org/10.1113/jphysiol.1949.sp004363 PMID: 15394301
18. Bland JM, & Altman DG. Measuring agreement in method comparison studies. Stat Methods Med Res 1999; 8:135–160. https://doi.org/10.1177/09622802990800204 PMID: 10501650
19. Luiz R R, Costa AJL, Kale PL, and Werneck GL. Assessment of agreement of a quantitative variable: a new graphical approach. J Clin Epidemiol 2003; 56:963–967. https://doi.org/10.1016/s0895-4356(03)00164-1 PMID: 14568627
20. Schofield KL. Thorpe K, and Sims ST. Resting metabolic rate prediction equations and the validity to assess energy deficiency in the athlete population. Exp Physiol 2019, 104.4: 469–475. https://doi.org/10.1113/EP087512 PMID: 30758869
21. Jagim AR, Camic CL, Kisiolek J, Luedke J, Erickson J, Jones MT, et al. The accuracy of resting metabolic rate prediction equations in athletes. J Strength Cond Res 2017; 1. https://doi.org/10.1519/JSC.0000000000002111 PMID: 26829334
22. ten Haaf T, and Weijs PJM. Resting energy expenditure prediction in recreational athletes of 18–35 years: Confirmation of Cunningham equation and an improved weight-based alternative. Plos One 2014; 9(10):1–8. https://doi.org/10.1371/journal.pone.0108460 PMID: 25275434
23. Speakman JR, and Selman C. Physical activity and resting metabolic rate. Proc Nutr Soc 2003; 62 (3):621–634. https://doi.org/10.1079/PNS2003282 PMID: 14692598
24. Dunford Marie. Sports nutrition: A practice manual for professionals. American Dietetic Association, 2006.
25. Logue Danielle M., et al. Low Energy Availability in Athletes 2020: An Updated Narrative Review of Prevalence, Risk, Within-Day Energy Balance, Knowledge, and Impact on Sports Performance. Nutrients 12.3 (2020): 835.
26. Rankin Janet Walberg. Weight loss and gain in athletes. Current sports medicine reports 1.4 (2002): 208–213. https://doi.org/10.1249/00149619-20020800-00004 PMID: 12831697
27. Loureiro LL, Fonseca Junior S, Castro N, dos Passos RB, Porto CPM, and Pierucci APTR. Basal Metabolic Rate of Adolescent Modern Pentathlon Athletes: Agreement between Indirect Calorimetry and Predictive Equations and the Correlation with Body Parameters. Plos One 2015; 10:12. https://doi.org/10.1371/journal.pone.0142859 PMID: 26569101
28. Kim JH, Kim MH, Kim GS, Park JS and Kim FK. Accuracy of predictive equations for resting metabolic rate in Korean athletic and non-athletic adolescents. Nutr res Pract 2015; 9:4: 370–378. https://doi.org/10.4162/nrp.2015.9.4.370 PMID: 26244075
29. Tinsley GM, Austin JG, and Lane MM. Resting metabolic rate in muscular physiques athletes: validity of existing methods and development of new prediction equations. Appl Physiol Nutr Metab 2018; 44:4: 397–406. https://doi.org/10.1139/apnm-2018-0412 PMID: 30240568
30. Sagayama H, Yoshimura E, Yamada Y, Ichikawa M, Ebine N, Hiraki Y, et al. Effects of rapid weight loss and regain on body composition and energy expenditure. Appl Physiol Nutr Metab 2014; 39:21–27. https://doi.org/10.1139/apnm-2013-0096 PMID: 24383503
31. Koshimizu T, Matsu shima Y, Yokota Y, Yanagisawa K, Nagai S, Okamura K, et al. Basal metabolic rate and body composition of elite Japanese male athletes. J Med Invest 2012; 59.3.4: 253–260 https://doi.org/10.2152/jmi.59.253 PMID: 23037196
32. Müller L, Hildebrandt C, and Raschner C. The role of a relative age effect in the 7th International Children's Winter Games 2016 and the influence of biological maturity status on selection. J Sports Sci Med 2017; 16:195–202. PMID: 28630572
33. Aragon AA, Schoenfeld BJ, Wildman R, Kleiner S, van Dusseldorp T, Taylor L, et al. International society of sports nutrition position stand: diets and body composition. J Int Soc Sports Nutr 2017; 14(1):16. https://doi.org/10.1186/s12970-017-0174-y PMID: 28630601
34. Re A. H. N., Cattuzzo M. T., Santos F. M. C., & Monteiro C. B. M. Anthropometric characteristics, field test scores and match-related technical performance in youth indoor soccer players with different playing status. International Journal of Performance Analysis in Sport 2014; 14:482–492.
35. Fonseca-Junior SJ, Oliveira AJ, Loureiro L L, Pierucci APTR. Validity of skinfold equations, against dual-energy Xray absorptiometry, in predicting body composition in adolescent pentathletes, Ped Exerc Sci. 2017; 29(2):285–293. https://doi.org/10.1123/pes.2016-0101 PMID: 27705535
36. Kendall KL, Fukuda DH, Hyde PN, Smith-Ryan AE, Moon J, Stout J. Estimating fat-free mass in elite-level male rowers: a four-compartment model validation of laboratory and field methods. J. Sports Sci 2017; 35(7):624–633. https://doi.org/10.1080/02640414.2016.1183802 PMID: 27159216
37. Madzima TA, Panton LB, Fretti SK, Kinsey AW, and Ormsbee MJ. Night-time consumption of protein or carbohydrate results in increased morning resting energy expenditure in active college-aged men. Br J Nutr 2014; 111:71–77. https://doi.org/10.1017/S000711451300192X PMID: 23768612