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Allometric Scaling of Agility and Power Performance in Basketball Players

Carlos Ewerton Palheta, Fabrício João Milan, André Luiz A. Soares, Caio Garbo Miguel, Carine Collet, Felipe Goedert Mendes, Michel Milistetd & Humberto Moreira Carvalho[1]

Abstract

The selection of NBA players usually takes place through the NBA Draft. Assessment of players entering in the draft is made in the NBA pre-draft combine, where each athlete performs a battery of tests composed by body size and basketball-specific agility and power performance. Physiological performance is influenced by body dimensions, and in basketball size is highly valued. Thus, interpretation of performance needs to account appropriately for the influence of body size on performance. In this study we examined the influence of the body dimensions of the NBA Draft Combine test battery performance. Also we examined the validity of the ratio standards or allometric scaling to partition the influence of body dimensions on performance. The performance in the pre-draft assessment of the NBA among 405 athletes from 2010 to 2017 was considered. Players were aged 17.8 to 28.0 years (21.5 ± 1.46 years). Data was extracted from the NBA's Draft Combine website (https://stats.nba.com/draft/combine/). Correlations between adjusted scores against the size indicator were performed to examine the validity of the partition models. Substantial correlations between athletes´ performance with body size descriptors were observed. Substantial negative correlations were observed between ratio standard adjusted performance and each size descriptor. Allometric adjusted performance presented no correlation with body size descriptors. Based on the performance of highly selected basketball players, the interpretation of basketball players needs to account appropriately for the influence of body dimensions using allometric scaling. Thus, ratio standards should not be used to account for the influence of body dimensions.

Keywords: national basketball association**;** elite; body size; modelling **.**

Introduction

Basketball is a multifaceted team sport with movement patterns that involve high-intensity short-term activities, such as sprinting, jumping and cutting (Abdelkrim et al., 2010; Stojanović et al., 2017). These actions are important for player's performance (Abdelkrim, El Fazaa and El Ati, 2007), mostly dependent on anaerobic metabolism (Castagna, Manzi, Impellizzeri, Weston and Alvarez, 2010). Maximal short term efforts are influenced by body size (Nevill, Bate and Holder, 2005). Body dimensions are highly valued in basketball, and a large variation is observed among basketball players, even at a highly selected level such as NBA players (Drinkwater, Pyne and Mckenna, 2008).

In general, the selection of NBA players takes place through the NBA Draft. The pre-draft combine is an event where prospects (i.e., candidate players to be chosen by an NBA team) are assessed, and future performance predictions are projected (Berri, Brook and Fenn, 2011). The pre-draft combine measurements include body dimensions, functional capacities tests (agility, speed and jump) and technical basketball specific tests. The performance of players in NBA pre-draft combine may add information relevant to the selection decisions of teams. However, the variability of body size among basketball players, among other complex environmental factors, can often mislead the accuracy and interpretation of results of the more traditional physiological tests used in talent selection (Abbott, Button, Pepping and Collins, 2005; Pearson, Naughton and Torode, 2006).

It has been longtime established in exercise physiology that the interpretation of functional capacities performance needs to account for variation in body dimensions (Nevill, Ramsbottom and Williams, 1992; Winter, 2006). Functional capacities performance interpretation needs to account for variation from different sources of variation, in particular body dimensions (Nevill, Ramsbottom and Williams, 1992). Different statistical methods can be used to adjust the body size when functional performance is tested, in particular ratio standard (i.e., watts by kilogram or liter per minute per kilogram) or allometric scaling method (based on power functions) (Jaric, Radosavljevic-Jaric and Johansson, 2002).

The use of ratio standards is generalized in exercise testing, both in research and applied contexts, despite the pitfalls of its use have been clearly demonstrated (Nevill et

1 Department of Physical Education, Federal University of Santa Catarina, Florianópolis, SC, Brazil. Corresponding author: Humberto M. Carvalho. Departamento de Educação Física, Centro de Desportos, Universidade Federal de Santa Catarina. Campus Reitor João David Ferreira Lima, 88040-900 Florianópolis. Florianópolis, Santa Catarina, Brasil. E-mail: hmoreiracarvalho@gmail.com

al., 2005; Tanner, 1949). In particular, the use of ratio standards tends to overestimate the performance of individuals with smaller sizes and underestimate the performance of larger individuals (Vanderburgh and Katch, 1996). Alternatively, allometric scaling may provide an alternative to account for size differences on individuals´ performance. The method, based on the power function model ($Y= aX^{-b}+\epsilon$), was proposed to describe the relationship between the physiological performance variable (Y) and body size variable (X), assuming that both the variables and errors are assumed to be proportional (Nevill, Holder and Alan, 1995).

The validation of the models used to control body dimensions should be done by inspection of the residual of the models with the respective size descriptor (Tanner, 1949). Also the respective correlation between residuals and size descriptor will be useful to check the assumptions of derived estimates independency of the individuals' body size descriptor, as well as homoscedasticity of residuals in the models (Nevill et al., 1995; Tanner, 1949). If the model (ratio standards or allometric scaling) was successful in partitioning the influence of body size, the correlation between the residuals and the size descriptor should approach zero, i.e., there should be little or no residual size correlation (Jaric et al., 2002; Nevill et al., 1992). Correlation coefficients that do not approach zero would suggest that the partition model was not efficient in rendering performance outputs independent of body size (Nevill et al., 1992). Considering the preceding observations, in the present study we examined the influence of body dimensions on the performance of professional basketball players entering the NBA Draft (assessed in the pre-draft combine test battery). Furthermore, we examined the validity of the ratio standards and allometric scaling to appropriately partition the influence of size on performance and allow for a meaningful interpretation in the applied case of selection in basketball.

Methods

Data

The performance of 405 athletes at the NBA pre-draft combine from 2010 to 2017 was considered in this study. Players were aged 17.8 to 28.0 years (21.5 ± 1.46 years). Data is available at the official NBA's Draft Combine website (https://stats.nba.com/draft/combine/).

Nba Pre-Draft Combine Testing

The NBA's Draft Combine testing comprises five physical fitness tests: (i) lane agility drill, (ii) shuttle run, (iii) three quarter sprint, (iv) standing vertical leap, (v) max vertical leap.

The lane agility drill which is based on a regular three second area within the NBA court, where the athlete sprints forward for 5.8m, then proceed with defensive shuffle movement across the free-throw line, followed by a backpedaling until the baseline (5.8m) and defensive shuffle to the starting point (to complete the test players completed the inverse path).

The shuttle run is a test of speed, body control and the ability to change direction (agility), as well as reaction time that uses the marking of the standard NBA basketball court (9,76m). The player starts by straddling the middle line. When indicated by the measuring system, the player runs either to the right or left direction, and places his foot on or over the sideline of the key. He then runs 16 yards back to the opposite line, then finally turns and finishes by running back through the start/finish line. The score is the best time of three trials.

The three quarter sprint have aim to determine running speed over 3/4 court distance (75 feet, 22.86 meters), using marked basketball court with 4 cones, the athlete performs a maximum sprint in 3/4 of a basketball from the baseline until the final line marking.

The standing vertical leap is a countermovement jump executed from a stationary position with arm swing to propel the body upwards generating additional propulsion.

The max vertical leap is a test where the athlete stands away from the instrument, and leaps vertically as high as possible using both arms and legs to assist in projecting the body upwards.

Statistical Analysis

Initially we examined the correlation between performance indicators and body size descriptors (stature and body mass). Both ratio standard and power functions, derived via log transformed linear regression of both dependent and independent variables, were derived. Validity of the models were inspected by visual inspection of residual plots against body size descriptors and correlations between scaled performance with body size. Non-zero correlations indicate spurious correlation (Carvalho et al., 2012). Linear regression models were derived using *lm* function on R statistical language (R Core Team, 2018).

Results

Descriptive statistics of candidate players performing in the NBA pre-draft combine between 2010 to 2017 are summarized in Table 1. In Table 2 are summarized the correlations between the performance and body dimensions (body mass and stature). Overall, there were substantial correlations between performance descriptors and body dimensions.

Table 1
Descriptive statistics

	Mean	Standards deviation	Minimum	Maximum	Amplitude
Age (years)	21.5	1.46	17.8	28.0	10.2
Body mass (kg)	97.4	11.03	67.70	136.90	69.20
Stature (cm)	196.92	8.31	173.40	216.50	43.10
Lane Agility (s)	11.35	0.56	10.10	13.40	3.30
Shuttle Run (s)	3.08	0.17	2.60	3.70	1.10
Three Quarter Sprint (s)	3.31	0.13	3.00	3.80	0.80
Standing Vertical Leap (cm)	75.27	7.93	57.20	96.50	39.30
Max Vertical Leap (cm)	89.43	9.26	63.50	113.00	49.50

Table 2
Correlations between performances and body dimensions (95% confidence intervals)

	Lane Agility	Shuttle Run	Three Quarter Sprint	Standing Vertical Leap	Max Vertical Leap
Body mass	0.42 (0.36 to 0.52)	0.18 (0.05 to 0.29)	0.46 (0.36 to 0.51)	-0.24 (-0.36 to -0.18)	-0.39 (-0.52 to -0.36)
Stature	0.40 (0.33 to 0.49)	0.17 (0.05 to 0.29)	0.47 (0.35 to 0.51)	-0.25 (-0.33 to -0.15)	-0.41 (-0.50 to -0.34)

The allometric exponents resulting from the application of the equation between performance of the basketball players entering in the NBA pre-draft combine and body dimensions are summarized in Table 2. Allometric size exponents ranged between -1.04 to 0.48.

Table 3
Allometric exponents

	Lane Agility	Shuttle Run	Three Quarter Sprint	Standing Vertical Leap	Max Vertical Leap
Body mass	0.19 (0.15 to 0.23)	0.09 (0.03 to 0.15)	0.14 (0.12 to 0.18)	-0.26 (-0.34 to -0.17)	-0.41 (-0.49 to -0.32)
Stature	0.48 (0.38 to 0.58)	0.23 (0.07 to 0.39)	0.38 (0.31 to 0.47)	-0.61 (-0.84 to -0.36)	-1.04 (-1.25 to -0.81)

Validation of ratio standards and allometric scaling to partition size influence on performance are presented in Figure 2 and Figure 3 for body mass and stature as size descriptors, respectively. Substantially moderate to very large spurious correlations were present between ratio standard scaled performance and its respective size descriptor. This implies that ratio standards failed to remove body size influence on performance. The correlations value between allometric scaled performance and size descriptors were all near to zero with exception of allometric scaled shuttle run for stature (r=0.11, 95% confidence interval -0.01 to 0.23), implying that allometric scaling models were successful partitioning body dimensions´ influence on performance

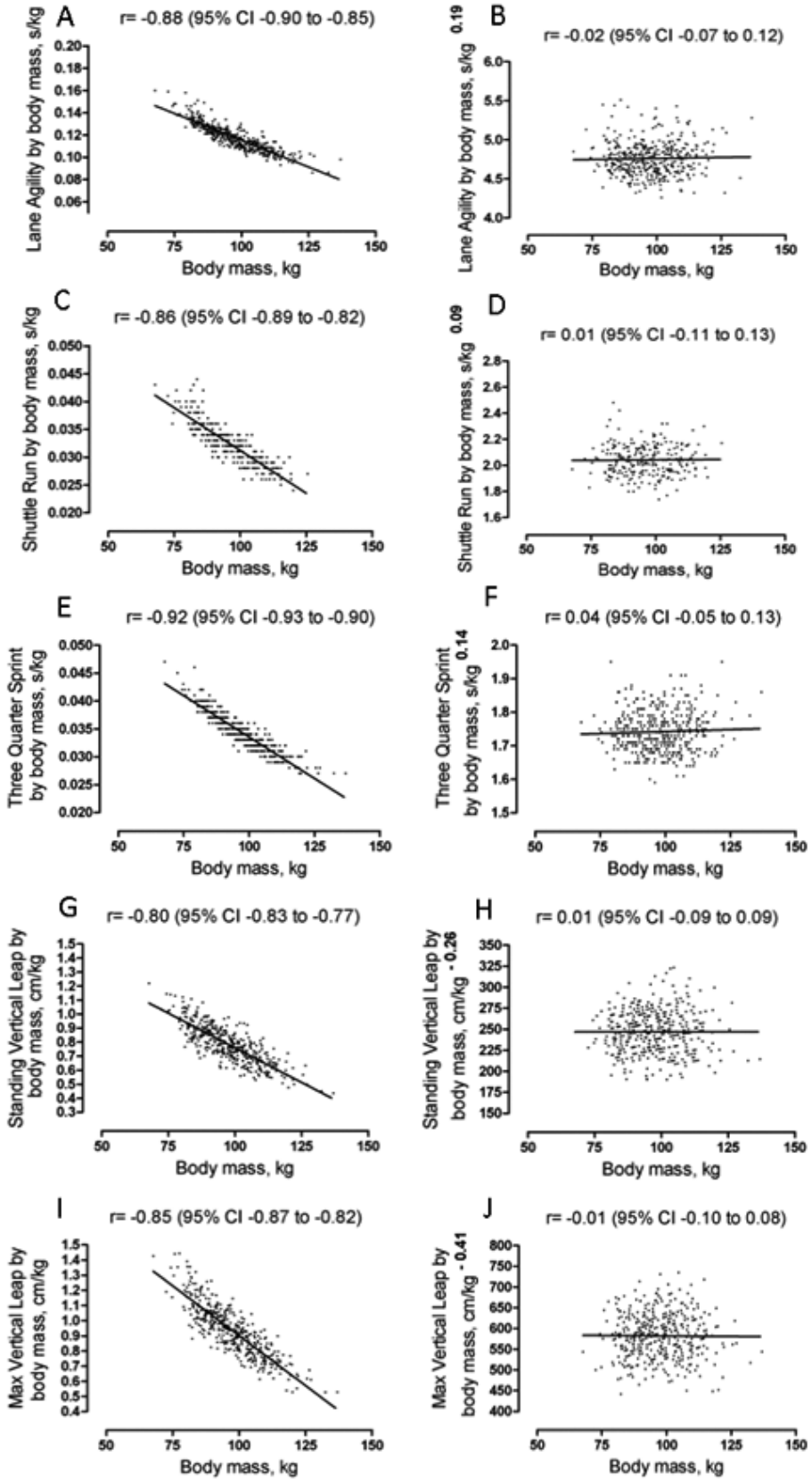

Figure 1. Ratio standards and allometric scalling considering body mass as body dimension

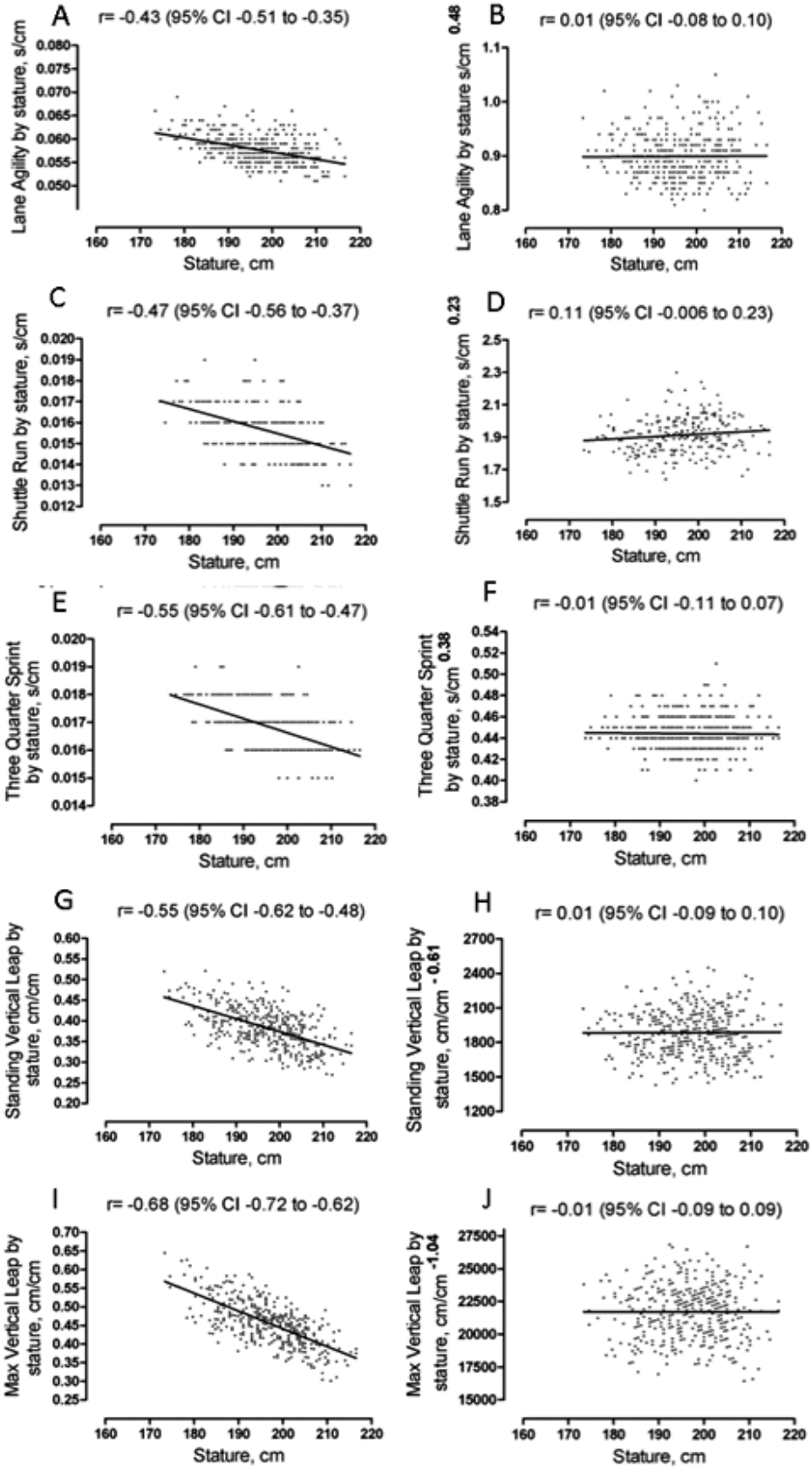

Figure 2. Ratio standards and allometric scalling considering stature as body dimension

Discussion

The present study examined the influence of the body dimensions of the NBA Draft Combine test battery. Also it was considered the validity of ratio standards or allometric scaling to partition the influence of body size on the athletic performance of professional basketball players´ candidate to enter in the NBA. Body dimensions were substantially related to performance in the NBA pre-draft combine tests, where smaller players tended to have better performance.

In the NBA Draft Combine the physical tests reflect results related to muscle strength (agility, speed, and jump). Under these conditions comparisons of the absolute result allow the effect of body dimensions such as stature and body mass (Jaric et al., 2002). Commonly ratio standards are used in practical, albeit its pitfall, to remove the effect of these dimensions (Nevill et al., 2005). The present study results add to the body of knowledge discouraging the use of standard ratios (Carvalho et al., 2011; Carvalho et al., 2012, Carvalho et al. 2013; Jaric et al., 2002; Nevil et al 1992; Nevill et al., 1995; Tanner, 1949). In the present case of running and jump performance, i.e. performance with rapid movements (Markovic and Jaric, 2004), ratio standard scaled performance was extremely ineffective removing the influence of size on performance.

The use of allometric exponents, obtained from the linear relationship of the logarithmic transformed variables, showed to be efficient in removing the effects of body dimensions in the NBA Draft Combine test performance. Particularly considering the importance and variability among basketball players, in the present data comprising between 178.4 and 219.1 cm for stature. The use of allometric models is recommended to normalize data, allowing to identify disproportionality due to the influence of factors related to body size (Carvalho et al., 2012; Nevill et al., 2005). The magnitude of the size exponents was smaller than suggested by theoretical proposed geometric or biological similarity exponents (McMahon, 1984; Jaric, Mirkov and Markovic, 2005). The lower exponents for both size descriptors are consistent with observations in performance with rapid movements, where influence of body mass is reduced compared to long-term maximal efforts [e.g. maximal oxygen uptake testing (Nevil et al., 2003)], maximal short-term efforts cycling [e.g. wingate anaerobic test (Carvalho et al., 2011] or isokinetic testing (Carvalho et al., 2012; Jaric et al., 2002). Even though the discussion on the ideal method for adjusting the effect of body dimensions on tests that reflect muscle strength (Jaric et al., 2002), the use of the allometric scale proves to be the most adequate to highlight more reliable results.

The results of the present study affirm the influence of body dimensions on player selection in basketball (Drinkwater et al., 2008) and have application of important practices in the selection of players in the battery of NBA Draft Combine tests. Thus, it will help NBA teams in the process of player's selection, decrease odds of failure during draft. So, this can benefit the team performance in the next years. Despite all this, we assume the limitations for only considerate the physical tests and no other variable as technical, tactical, and psychological information's. Furthermore, there are differences between basketball position players in specific physical demands.

In summary, there was a substantial negative influence of body dimensions on the results achieved by players in the NBA's Draft Combine testing battery (i.e., smaller players had better performances). Therefore, it may be more insightful to interpret players test performance accounting appropriately for size differences, likely allowing for better decisions on prediction of players´ future performance. For this allometric scaling is an appropriate modeling approach, whereas commonly used ratio standards should not be used at all.

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Modelos alométricos del rendimiento de agilidad y potencia de jugadores de baloncesto

Resumen

La selección de jugadores de la NBA generalmente ocurre a través del Draft de la NBA. En la evaluación pre-draft, cada atleta realiza una batería de pruebas para evaluación de dimensiones corporales, habilidades específicas de baloncesto, y rendimiento de potencia. El rendimiento fisiológico es influenciado por las dimensiones corporales y, en el baloncesto, el tamaño corporal es altamente valorado. En este estudio, examinamos la influencia de las dimensiones corporales en la batería de pruebas de la NBA Draft Combine. También examinamos la validez de los patrones de razón o escala alométrica para dividir la influencia de las dimensiones corporales en el desempeño. El desempeño en la evaluación preliminar de la NBA de 405 atletas de 2010 a 2017 fue considerado. Los datos se extrajeron del sitio web de la Combinación de NBA (https://stats.nba.com/draft/combine/). Se realizaron correcciones entre las puntuaciones ajustadas contra el indicador de tamaño para examinar la validez de los modelos de partición. Se observaron correlaciones sustanciales entre el desempeño de los atletas con los descriptores de tamaño corporal. Se observaron correlaciones negativas sustanciales entre el rendimiento ajustado al índice de razón y cada descriptor de tamaño. El desempeño alométrico ajustado no presentó correla-

ción con los descriptores de tamaño corporal. Con base en el rendimiento de jugadores de baloncesto, la interpretación de los jugadores de baloncesto debe responder adecuadamente a la influencia de las dimensiones corporales usando la escala alométrica. Así, los patrones de razón no deben ser usados para explicar la influencia de las dimensiones corporales.

Palabras-clave: national basketball association**;** elite; talla corporal; modelado.

Modelação alométrica do desempenho de agilidade e potência em jogadores de basquetebol

A seleção de jogadores da NBA geralmente acontece através do Draft da NBA. Na avaliação pré-draft, cada atleta realiza uma bateria de testes para avaliação de dimensões corporais, habilidades específicas de basquete, e desempenho de potência. O desempenho fisiológico é influenciado pelas dimensões corporais e, no basquete, o tamanho corporal é altamente valorizado. Neste estudo, examinamos a influência das dimensões corporais na bateria de testes da NBA Draft Combine. Também examinamos a validade dos padrões de razão ou escala alométrica para dividir a influência das dimensões corporais no desempenho. O desempenho na avaliação preliminar da NBA de 405 atletas de 2010 a 2017 foi considerado. Os dados foram extraídos do site da Draft Combine da NBA (https://stats.nba.com/draft/combine/). Correlações entre os escores ajustados contra o indicador de tamanho foram realizadas para examinar a validade dos modelos de partição. Correlações substanciais entre o desempenho dos atletas com os descritores de tamanho corporal foram observadas. Correlações negativas substanciais foram observadas entre o desempenho ajustado ao índice de razão e cada descritor de tamanho. O desempenho alométrico ajustado não apresentou correlação com os descritores de tamanho corporal. Com base no desempenho de jogadores de basquete, a interpretação dos jogadores de basquete precisa responder adequadamente à influência das dimensões corporais usando a escala alométrica. Assim, os padrões de razão não devem ser usados para explicar a influência das dimensões corporais.

Palavras-chave: national basketball association**;** elite; tamanho corporal; modelação.

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