STUDIA UBB EDUCATIO ARTIS GYMN., LXX, Special Issue 1, 2025, pp. 161-173
(RECOMMENDED CITATION)
DOI: 10.24193/subbeag.70.sp.iss.1.11

CRITICAL CONSIDERATIONS ON THE SINGLE VERTICAL JUMP TEST AS AN INDICATOR OF LOWER-LIMB POWER: PRELIMINARY FINDINGS

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ABSTRACT. *Introduction*: The vertical jump test (VJT) is widely used to estimate lower-limb power through predictive equations, but the theoretical validity of these models remains uncertain. *Objective:* This preliminary study aimed to compare three predictive equations (Lewis, Harman, Johnson & Bahamonde) for estimating average lower-limb power from VJT, focusing on discrepancies in outcomes and theoretical validity. *Material and Methods*: Five healthy male students (age 20.2 ± 0.2 years; height 178.6 ± 4.72 cm; body mass 73.0 ± 8.12 kg) performed countermovement jumps (CMJ) measured with the OptoJump system, with the best trial retained for analysis. Average power was calculated using the three predictive equations. Descriptive statistics (M ± SD) were computed, and differences between models were analyzed with the Friedman test. Effect size was quantified with Kendall's W. *Results*: Significant differences were found between formulas (χ^2 (2) = 10.000, p = 0.007, W = 0.67, large effect). The Johnson & Bahamonde model yielded the highest values, followed by Harman and Lewis. None of the equations demonstrated dimensional homogeneity. *Discussion:* Findings highlight systematic discrepancies between predictive models, raising concerns about their reliability in practice. The lack of dimensional consistency undermines the theoretical validity of these equations, despite their continued use in applied settings. Consequently, classification of athletes based solely on these formulas may be misleading. *Conclusions:* Predictive equations for estimating lower-limb power from vertical jumps produce inconsistent results and fail to satisfy dimensional homogeneity. Future approaches should integrate time-dependent variables to ensure biomechanical validity and reliability.

Keywords: vertical jump; lower-limb power; sport assessment; athletic performance; predictive models; countermovement jump

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INTRODUCTION

Vertical jumping is a fundamental motor skill that integrates multiple neuromuscular qualities into a single explosive action. For this reason, the vertical jump test (VJT) is widely used in sport and exercise science to assess lower-limb function (Öncen et al., 2018; Sánchez-Sixto et al., 2021; Cooper et al.;2020; Santa et al., 2025). It remains popular among coaches, physical education & sport teachers, strength and conditioning specialists, and researchers because it is simple, practical, and applicable in both performance and health contexts (Keir et al., 2003; Milo et al., 2017; Stupar et al., 2020; Graur & Șanta-Moldovan, 2024).

Historically, the first standardized procedure was introduced by Sargent (1921) and later redefined by Abalakov in the 1938 (Klavora, 2000). With advances in technology, instruments such as force platform, motion capture, and optical systems have provided more detailed biomechanical information (Yingling et al., 2018; Buscemi et al., 2019, Geantă & de Hillerin, 2023). However, in applied settings, jump height remains the most common outcome (Sánchez-Sixto et al., 2018). Recent studies highlight that jump performance is influenced by multiple biomechanical and morphological factors beyond simple jump height, such as limb alignment, body composition, and eccentric force capacity (Daugherty et al., 2021; Vaverka et al., 2016; Nishiumi et al., 2023).

To extend its utility, several predictive equations have been proposed to estimate lower limb power from jump height and basic anthropometric data (Fox & Mathews, 1974; Harman et al., 1991; Johnson & Bahamonde, 1996; Sayers et al., 1999). These models are still widely cited and even embedded in online calculators (Mackenzie, 2007). Their appeal lies in their simplicity, but important methodological issues remain.

First, the term power is often used inconsistently, referring to athletic performance, rather than its mechanical definition. Power is mechanically defined as the rate of doing work overtime (Knudson, 2009; Hall, 2021). Second, most equations exclude time as a variable, which leads to dimensional inconsistencies and undermines their validity (Nettles, 2022). Consequently, different formulas yield substantially different values, which may not reflect true mechanical power.

Several investigations support this critique, showing that predictive equations often fail to appropriately categorize athletes (Ache-Dias et al., 2016), produce inconsistent rankings (Lara-Sánchez et al., 2011), or confound body size with actual muscle power output (Markovic et al., 2014). Furthermore, comparative analyses demonstrate discrepancies between calculation methods for jump height (Xu et al., 2023) and emphasize that power predictions vary depending on the model and population studied (Canavan & Vescovi, 2004; Amonette et al., 2012; Gomez-Bruton et al., 2019; Duncan et al., 2013).

This gap between the popularity of VJT-based estimates and their biomechanical limitations requires critical examination. Few studies have directly predictive equations under controlled conditions (Canavan & Vescovi, 2004; Duncan, Lyons, & Nevill, 2008; Amonette et al., 2012; Wright et al., 2012), and even fewer addressed their theoretical inconsistencies (Markovic et al., 2014; Xu et al., 2023; Eythorsdottir et al., 2024).

The purpose of this preliminary investigation was to analyze three popular predictive equations – Lewis, Harman, and Johnson & Bahamonde, commonly used for estimating lower-limb power. The study focused on identifying discrepancies between the results provided by these formulas and evaluating whether they comply with the principle of dimensional homogeneity of measurement units.

MATERIAL AND METHODS

This study employed a preliminary, cross-sectional design with a within-subjects approach. Each participant completed a standardized CMJ protocol, and performance outcomes were analyzed using three predictive equations for power estimation. By this kind of design, will allow us for direct comparisons of methods while controlling for inter-individual variability.

Participants

Five healthy male students (age: 20.20 ± 0.20 years; height: 178.60 ± 4.72 cm; body mass: 73.00 ± 8.12 kg) volunteered to participate in this preliminary study. Subjects were physically active, accustomed to plyometric exercise, and free from musculoskeletal injuries of pain in the six months prior to testing. Inclusion criteria required participants to be engaged in regular sports practice, with previous experience in jump-based tasks. Exclusion criteria included any lower-limb injury, neuromuscular disorder, or current pain that could compromise safe performance. All participants were informed about the procedures and provided written consent. The research protocol was reviewed, registered, and approved by the institutional ethics committee (Registration number:210/16.04.2025). The study was con- ducted in accordance with the clarify guidelines and the ethical standards of the Declaration of Helsinki.

Instruments

For the anthropometry, the body height was measured to the nearest 0.1 cm using a wall mounted stadiometer (SECA, Germany). Body mass was recorded with an Omron digital scale (Omron Healthcare, Japan) to the nearest 0.1 kg. Although, for the jumping performance, the vertical height was assessed with the MicroGate OptoJump Next system (Microgate, n.d.).

Procedure

All tests were conducted on the same day under standardized conditions. Participants completed a general warm-up consisting of 5-7 minutes of light running and dynamic stretching, followed by mobility drills (leg swings, walking lunges, hip and ankle rotations) to increase muscle temperature and joint range of motion.

After general warm-up, a specific protocol was applied. The protocol is composed from 1-2 sets of repeated vertical jumps 15-s jump test) performed bilaterally with arm swing. Each set was separated by 1 minutes and 45 seconds of passive rest. This activation phase aimed to enhance neuromuscular readiness before maximal testing (Geantă & de Hillerin, 2025).

Subsequently, participants realized three maximal countermovement jumps (CMJs) with 60 second of rest between trials (Markovic et al., 2004). Each CMJ (see Figure 1) began from an upright standing position with free arm swing. Participants were instructed to descend rapidly to approximately 90° of the hips, knees and ankles. The highest jump recorded by the OptoJump Next system was used for the analysis.

Fig. 1. Schematic representation of the CMJ test

Data processing

The maximum jump height (cm) obtained from the three CMJ trials was used for subsequent analysis. Based on this value, together with each participant's body mass and height, average power outputs were computed using the following predictive equations:

Lewis (Fox & Mathews, 1974) – Average Power

$$P_{avg}(W) = \sqrt{4.9 \text{ x mass (kg)x} \sqrt{\text{VJ (m)x 9.81}}} \quad (1)$$

Harman et al. (1991) – Average Power

$$P_{avg}(W) = 21.2\, x \text{ VJ (cm)} + 23.0 \text{ x mass (kg)} - 1393 \quad (2)$$

Johnson & Bahamonde (1996) – Average Power

$$P_{avg}(W) = 41.4 \text{ x VJ (cm)} + 31.2 \text{ x mass (kg)} - 13.9 \text{ x height (cm)} + 431 \quad (3)$$

Where: P_{avg} = average power (W/kg); mass = body mass of the subject in kilograms (kg), height = body height in centimeters (cm); VJ = vertical jump height in meters (m) or centimeters (cm); 9.81 = gravitational acceleration in m/s^2.

All calculations were performed in Microsoft Excel 365, applying each predictive formula individually to all participants.

Statistical Analyze

Descriptive statistics (mean ± standard deviation) were calculated for all variables. Normality of distribution was assessed using the Shapiro–Wilk test. As the data were not normally distributed ($p < 0.05$), the Friedman non-parametric test was applied to compare the three predictive models of relative power (Lewis, Harman, and Johnson & Bahamonde). In addition to significance testing, effect size was quantified using Kendall's W, which represents the degree of concordance among repeated measures (Field, 2005). The statistic was calculated as χ^2 / [N × (k - 1)], where χ^2 is the Friedman test statistic, N is the number of participants, and k is the number of conditions compared. Kendall's W ranges from 0 (no agreement) to 1 (perfect agreement). According to Cohen's thresholds (Cohen, 2013), W ≥ 0.1 indicates a small effect, ≥ 0.3 a medium effect, and ≥ 0.5 a large effect. Statistical significance was set at $p < 0.05$. All analyses were conducted with IBM SPSS Statistics v.23 software (IBM Corp.).

RESULTS

The descriptive statistics for participants were as follows: age 20.20 ± 0.20 years, body mass 73.00 ± 8.12 kg, height 178.60 ± 4.72 cm, and CMJ performance 50.20 ± 6.07 cm (see Table 1).

Table 1. Descriptive statistics of the sample (M±SD)

Variable	N	Mean	SD
Age (years)	5	20.2	0.20
Weight (kg)	5	73	8.12
Height (cm)	5	178.6	4.72
CMJ (cm)	5	50.2	6.07

Note. Values are presented as mean ± standard deviation. CMJ = countermovement jump.

Regarding the predictive equations, average power outputs were 15.36 ± 0.99 W/kg for Lewis, 18.36 ± 2.23 W/kg for Harman, and 27.45 ± 4.41 W/kg for Johnson & Bahamonde.

Table 2. Descriptive statistics of predictive equations

Average power equation	N	Mean	SD	Min	Max
Lewis (W/kg)	5	15.36	0.99	13.6	16.1
Harman (W/kg)	5	18.36	2.23	14.4	19.7
Johnson & Bahamonde (W/kg)	5	27.45	4.41	19.68	30.21

Note. Power output was calculated according to three predictive models: Lewis (Fox & Mathews, 1974), Harman et al. (1991), and Johnson & Bahamonde (1996). Values are expressed as mean ± standard deviation.

The Friedman test (see Table 3) revealed statistically significant differences between the three formulas (χ^2 (2) = 10.000, p = 0.007, Kendall's W = 0.67, large effect). The mean ranks indicated a consistent progression, with Lewis producing the lowest values (mean rank = 1.00), Harman intermediate (mean rank = 2.00), and Johnson & Bahamonde the highest (mean rank = 3.00).

Table 3. Friedman test results

Test	χ^2	df	p	Kendall's W	Effect sig.
Friedman	10	2	0.007	0.67	Large

Note. The Friedman test was applied to assess differences between formulas. Kendall's W was used as an effect size index (W = 0.67, large effect according to Cohen's thresholds).

DISCUSSION

This study aimed to analyze three predictive equations commonly used to estimate lower-limb power from vertical jump performance and revealed statistically significant discrepancies between models. The Johnson and Bahamonde equations (1996) consistently produced higher values than the Harman et al. (1991) and Lewis models (Fox & Mathews, 1974), suggesting a systematic bias rather and random variation. The magnitude of the differences ($\chi^2(2) = 10.000$, $p = 0.007$, $W = 0.67$) indicates that the predictive methods do not yield interchangeable outcomes. This inconsistency challenges the assumptions that power estimates derived from jump height are theoretically and practically comparable across models (Canavan & Vescovi, 2004; Duncan et al., 2008; Wright et al., 2012; Kons et al., 2018).

A key finding of this study concerns the lack of dimensional homogeneity in the analyzed equations. Mechanically, power represents the rate of doing work overtime (W= J/s), as emphasized by Knudson (2009) and Nestle (2022). However, the evaluated predictive formulas combine variables such as body mass, jump height, and body height without including a temporal component. Although the computed outputs are expressed in watts (W), the underlying equations are dimensionally inconsistent. This inconsistency undermines their biomechanical validity and limits their interpretability as measures of actual mechanical power output. The results therefore highlight a fundamental methodological issue within many field-based assessments protocols that rely on empirically derived yet theoretically inconsistent models (Knudson, 2009; Eythorsdottir et al., 2024).

The use of the OptoJump Next system ensured high accuracy in measuring jump height, which strengthens confidence that the observed differences are due to the equations themselves rather than measurement errors (Glathorn et al., 2011; Yingling et al., 2018; Buscemi et al., 2019). Notably, similar methodological inconsistencies have also been identified in other jump-bases assessments. Geantă & de Hillerin (2025) reported substantial differences between predictive models of average power (Bosco, MG and MGM-15) in a 15-second repeated vertical jump test. The previous study indicated that the problem extends beyond single-jump protocol. This reinforces the conclusion that discrepancies originate from the mathematical structure of the predictive models (Xu et al., 2023; Eythorsdottir et al., 2024).

In applied contexts, such variability poses a problem for coaches, practitioners, and researchers, as athletes could be differently classified depending on the equation employed (Ache-Dias et al., 2016; Lara-Sánchez et al., 2011). Consequently, comparisons between studies, or even between athletes assessed with distinct formulas, may be misleading. The current findings thus stress the importance of methodological standardization in performance diagnostics and of avoiding overreliance on power estimators (Duncan et al., 2013; Pupo et al., 2020).

Despite its contribution, this investigation has limitations. The sample was small and homogeneous, reflecting the preliminary nature of the study. Only three equations were evaluated, and no direct comparisons with force-time data, the biomechanical gold standard was conducted (Alba-Jiménez et al., 2022; Xu et al., 2023; Cameron et al., 2025). Therefore, these findings cannot yet be generalized to broader population, or to other predictive models. Future research should expand the sample size, include additional equations, and integrate simultaneous force platform measurements to verify the magnitude of error across models. Approaches like this would provide stronger empirical and theoretical foundations for estimating lower-limb power from field tests.

CONCLUSIONS

The results of this preliminary investigation demonstrated that commonly used predictive equations for estimating lower-limb power form vertical jumps are not consistent. The Johnson and Bahamonde model produced the highest values, whereas the Lewis models yielded the lowest, with the Harman equations occupying an intermediate position. These systematic differences stem from dimensional inconsistencies within the equations, which combine variables with incompatible measurements units and omit the time component essential to the mechanical definition of power. Consequently, these predictive models do not represent true mechanical power output, but rather empirically derived performance variables.

The findings confirm that current field-based predictive formulas should be interpreted with caution and not used interchangeably. The study fulfills its objective of identifying theoretical and computational discrepancies among widely applied models and highlights the need to reconsider their validity in both research and practice.

Future work should develop consistent predictive methods that include time-dependent factors to match biomechanical principles. Building these models would improve the reliability and scientific accuracy of lower-limb power assessment. This would also help with more consistent evaluation and monitoring of athletic performance.

AUTHOR CONTRIBUTIONS

Vlad Adrian Geantă and Pierre Joseph De Hillerin contributed to the design and implementation of the research, as well as to the analysis of the results and the writing of the manuscript. Both authors have read and approved the final version of the article.

CONFLICT OF INTEREST

The authors declare no conflict of interests.

ACKNOWLEDGEMENT

The authors would like to thank all the participants for their time, effort, and commitment throughout the testing sessions. Their contribution was essential to the completion of this preliminary study.

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