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15-Second Repeated Vertical Jump Models versus Ergometer Approaches for Lower-Limb Average Power Assessment: A Preliminary Exploratory Comparison

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Abstract

Lower-limb average power is an important indicator of neuromuscular performance and can be assessed either indirectly through computational models derived from repetitive vertical jumps or directly using ergometers that quantify mechanical output. However, these approaches often yield different values, complicating interpretation and comparison across studies. This preliminary, exploratory within-subject study (n=5) aimed to examine discrepancies between lower-limb average power estimated from computational models applied to 15-second vertical jump tests and that measured during short-duration maximal efforts on cycle- and row-ergometers. Five male sport science university students performed a 15-second repeated vertical jump test assessed using the OptoJump Next system (Microgate, Bolzano, Italy). Average power was calculated using the Bosco, Miron Georgescu (MG), and Miron Georgescu Modified 15-second (MGM-15) formulas. Each participant subsequently completed two 20-second all-out trials on the Concept2 BikeErg and RowErg (Concept2 Inc., Morrisville, Vermont, USA). The analysis revealed a significant main effect of method ($F(1.03, 4.12)=77.04$, $p=0.001$, $\eta p^2=0.95$). The Bosco and MG equations generated substantially higher power outputs compared with both ergometer assessments ($p<0.05$). The MGM-15 model produced estimates not statistically different from RowErg ($p>0.05$), while slightly lower than those recorded on BikeErg ($p<0.01$). Substantial discrepancies were observed in lower-limb average power values obtained from different computational models applied to repeated vertical jump data. While classical equations produced markedly higher estimates, the MGM-15 formulation yielded power values that were closer to those obtained from direct ergometer measurements, highlighting the influence of computational assumptions on jump-derived power estimates.

Keywords: *lower-limb power, ergometer, vertical jump, computational modelling, athlete performance assessment*

Introduction

Lower-limb power is a fundamental determinant of athletic performance, reflecting neuromuscular system's ability to generate high mechanical output within short time intervals (Acar et al., 2025; Gross & Lüthy, 2020; Pleša et al., 2025). Accurate assessment of this parameter provides critical insights into mechanical efficiency, fatigue resistance, and sport-specific adaptations (Ding et al. 2025; Ivanov, 2025; Khemiri et al., 2025). Among various performance indicators, average power output is widely employed to characterize both the mechanical and metabolic dimensions of lower-limb function (DeLeo et al., 2025; Lai et al., 2025). In laboratory and field settings, power output can be quantified either indirectly, through computational models applied to vertical jump data (Geantă

& de Hillerin, 2023; Geantă & de Hillerin, 2025), or directly, using ergometric devices that record mechanical work in real time (DeLeo et al., 2025; Kostka & Kostka, 2024).

Building on this interest, early studies employed repeated-jump protocols, such as the 15-s repeated vertical jump test, to investigate muscular performance (Geantă et al., 2025). Miron Georgescu's (1953) pioneering model proposed one of the first theoretical formulations relating flight and contact times to average power output. His original protocol consisted of 35 continuous jumps, traditionally described as "ball-like jumps," from which the first 30 valid repetitions were analyzed (Geantă et al., 2025). In subsequent decades, Bosco, Luhtanen and Komi (1983) introduced a simplified biomechanical approach based solely on flight time, which became widely adopted in sports diagnostics. Extending these foundational approaches, Pierre de Hillerin (1997) developed the Modified Miron Georgescu Method (MGM-15), designed to capture not only mechanical outputs but also factors related to motor control and fatigue regulation. This approach aligns with the psycho-neuro-motor framework, integrating psychological, neural, and motor components to provide a more comprehensive representation of muscular effort and its temporal dynamics (Marin et al., 2015).

Recent computational studies employing modern photocell-based technologies such as OptoJump have revisited these classical models and revealed substantial discrepancies in average power values derived from identical jump data (Geantă & de Hillerin, 2025; Geantă et al., 2025). In particular, conventional equations, including those proposed by Georgescu (1953) and Bosco et al., (1983), have been shown to systematically overestimate average power compared with more recent models. Despite these methodological advances, direct comparisons between jump-based computational models and ergometer-derived mechanical power measurements remain scarce. This gap may lead to inconsistencies in performance evaluation and training prescription, underscoring the need for approaches that integrate indirect jump-based estimates with direct, real-time mechanical measurements (Borges et al., 2025; Joshi & Singh, 2024; Khemiri et al., 2025; Wehbe et al., 2015).

Modern ergometers, such as the Concept2 BikeErg and RowErg (Concept2, n.d.), provide real-time measurements of mechanical power under standardized resistance and cadence conditions and have been widely employed in high-intensity protocols involving trained athletes (Treff et al., 2022; Tongwu et al., 2025; Turner & Rice, 2021). Studies evaluating these devices have reported acceptable-to-high levels of technical accuracy and reliability in both cycling and rowing protocols (Podstawski et al., 2025; Treff et al., 2022). Furthermore, both ergometer modalities effectively engage the major lower-limb extensors, providing a relevant mechanical reference for comparative analysis (Czajkowska et al., 2023; Driss & Vandewalle, 2013; Gavala-González et al., 2024), and produce repeatable power measurements across different populations and exercise contexts (García-Ramos et al., 2018; Pérez-Castilla & García-Ramos, 2021; Wehbe et al., 2015).

To date, no study has directly compared multiple computational models of jump-derived average power with direct mechanical power measurements obtained from ergometers. Bosco et al. (1983) were among the first to explore the relationship between jump-based estimations and laboratory-derived anaerobic performance by comparing a continuous jump test with a modified Wingate protocol; however, that comparison relied on indirect estimations and analog instrumentation, which may have limited precision and external validity.

Therefore, the present preliminary and exploratory study extends the research line initiated by Geantă and de Hillerin (2025), representing the first systematic attempt to evaluate and contrast three computational models of lower-limb average power estimation against real-time, directly measured mechanical power recorded during short-duration maximal efforts. Based on previous findings, it was hypothesized that the MGM-15 model would yield average power values more closely aligned with the physiological reality reflected by direct ergometer measurements.

Accordingly, this study aimed to examine which computational approach yields average power estimates that tend to align more closely with direct mechanical output obtained from ergometer measurements.

Materials and methods

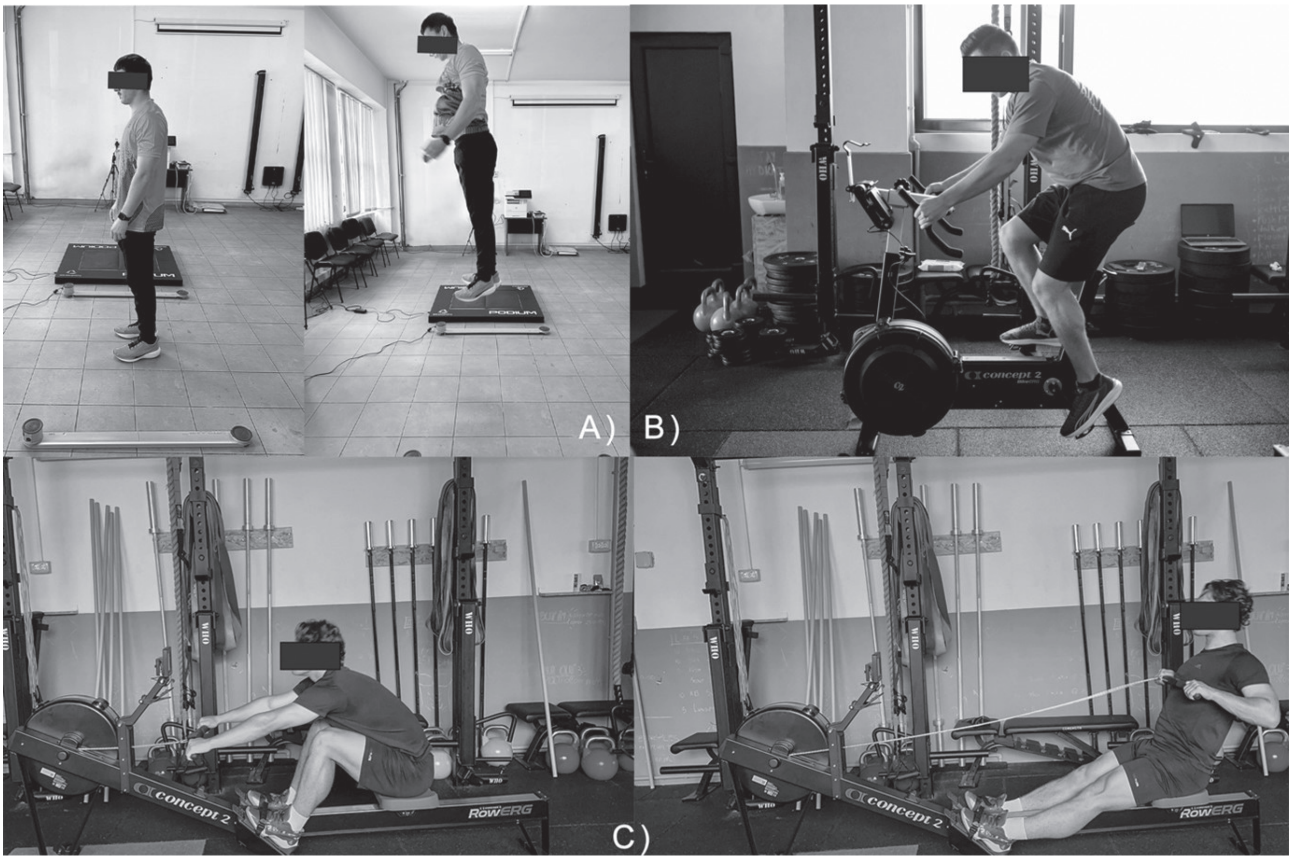
Participants

Five physically active male university students (age: 20.2±0.45 years; height: 178.6±4.72 cm; body mass: 73.0±8.12 kg) from the Faculty of Physical Education and Sport volunteered for this preliminary study. All were recreationally trained, with no musculoskeletal injuries or medical conditions affecting lower-limb neuromuscular performance. Before data collection, participants took part in a familiarization session in which they practiced both jump and ergometer protocols to ensure consistent execution and to minimize learning-related variability (Walsh et al., 2022; Wehbe et al., 2015). All subjects were informed about the study's procedure and risk before signing written consent forms. The study was approved by the Ethics Committee of the Aurel Vlaicu University of Arad (Registration number: 210/16.04.2025) adhering to the ethical principles of the Declaration of Helsinki.

Research design

The present preliminary study followed a cross-sectional within-subject design, allowing each participant to serve as their own control. The objective was to compare the average mechanical power output obtained from three computational models (Bosco, MG, MGM-15) with direct mechanical measurements recorded during maximal short-duration efforts on two ergometers (Concept2 BikeErg and Concept2 RowErg; Concept2 Inc., Morrisville, Vermont, USA). Each participant performed one 15-second repeated-jump test (15s-Jumps) using the Microgate OptoJump Next photocell system (Microgate, Bolzano, Italy), followed by two 20-second maximal effort ergometer tests. To control for fatigue, ergometer test order (BikeErg vs RowErg) was counterbalanced across participants. A 10-minute passive recovery period separated the jump and the first ergometer test, while a 15-minute passive rest interval was maintained between the two ergometers efforts, consistent with recovery protocols validated in short-duration power testing (Driss & Vandewalle, 2013; Maté-Muñoz et al., 2022; Turner & Rice, 2021).

Figure 1. Assessment protocols of the study: (A) 15-s jumping test; (B) BikeErg test; (C) RowErg test.



Experimental procedure

Vertical jump test

Participants completed a single 15-second series of repetitive vertical jumps with arm swings and maximal intensity, minimizing ground contact time (T_c) and maximizing flight time (T_f). The OptoJump Next system recorded contact and flight times with a sampling resolution of 0.001s (Microgate, n.d.). All measurements were conducted in the same research center and environmental conditions. The raw data were exported in XML format and subsequently processed in Excel for the computation of average mechanical power based on three established mathematical models.

Average power calculation formulas for 15s jumps

Average power output (PU, in W·kg^{-1} or W/kg) was computed using the equations previously exposed by Geantă et al. (2025), corresponding to the MG (Georgescu, 1953), Bosco (Bosco et al., 1983), and MGM-15 (Hillerin, 1997) methodologies:

MG model: $$PU = 1.5 \times \frac{g^2 \times {T_f}^2}{8 \times T_c} \tag{1}$$

Bosco model: $$PU = 2 \times \frac{g^2 \times T_f \times 15}{4n \times (15 - T_f)} \tag{2}$$

MGM-15 model: $$PU = \frac{g^2 \times {T_f}^2}{8 \times (T_c + T_f)} \tag{3}$$

where:
PU = Average power output (W/kg)
m = Body mass (kg)
g = Gravitational acceleration (typically 9.81 m/s2),
n = Number of jumps
t = Total test time (15 seconds)
T_f = Flight time (s)
T_c = Contact time (s)

Worked example

A worked example is provided for both the Miron Georgescu (MG) and Modified Miron Georgescu–15 s (MGM-15) models using raw temporal output from the OptoJump Next system. Flight time (T_f), contact time (T_c), and jump height (h, derived from flight time) were used to illustrate the calculations.

The computational procedure for the MGM-15 model was described previously (Geantă et al., 2025); here, the same approach is applied to independent jump data and extended to include the MG model for comparative purposes. Bosco average power output was obtained directly from the OptoJump software and did not require offline computation.

For a representative jump, the parameters were T_c=0.211 s, T_f=0.570 s, corresponding to a jump height of 0.398 m (39.8 cm). Substituting into the MG equation (1):

$$PU = 1.5\times\frac{g^2 \times T_f^2}{8 \times T_c} = 1.5\times\frac{(9.81)^2 \times (0.570)^2}{8 \times 0.211} = 1.5\times\frac{96.2361 \times 0.3249}{1.688} = 27.75 \text{ W/kg} \quad (4)$$

Using the same jump in the MGM-15 equation (3), which accounts for both flight and contact time:

$$PU = \frac{g^2 \times T_f^2}{8 \times (T_c + T_f)} = \frac{(9.81)^2 \times (0.570)^2}{8 \times (0.211 + 0.570)} = \frac{96.2361 \times 0.3249}{6.248} = 4.99 \text{ W/kg} \quad (5)$$

The calculations were then applied to a subsequent jump with Tc=0.185 s, Tf=0.508 s, and a jump height 0.316 m (31 cm), resulting in MG=25.16 W/kg and MGM-15=4.48 W/kg. This same approach was repeated for all jumps recorded during the 15-second test series, and the final values for each participant were determined as the arithmetic mean of all individual MG and MGM-15 power outputs. All computations can be reproduced directly from the raw OptoJump XML export, which contains the complete set of temporal and kinematic parameters. This worked example is intended for illustration; the procedure was applied consistently to every jump in the series to derive the final MG and MGM-15 results reported in this study.

Ergometer test

Each participant performed two maximal-effort trials, one on the Concept2 BikeErg and one on the Concept2 RowErg, both equipped with PM5 performance monitors (Concept2 Inc., Vermont, USA).

Before testing, participants completed a dedicated familiarization session on each ergometer to establish proper technique and consistent mechanical output.

During testing, participants were instructed to accelerate as quickly as possible and sustain maximal effort for 20 seconds. This duration corresponds to the minimum standardized test length provided by the Concept2 PM5 monitor for maximal effort assessments, and was therefore used consistently across participants (Concept2, n.d.). Seat position, handlebar height, and resistance settings were individually adjusted during familiarization and kept constant across all tests. Mean power output for the 20-second maximal effort, as reported by the Concept2 PM5 monitor, was used for analysis and normalized to body mass. A 15-minute rest period was provided between BikeErg and RowErg efforts to ensure adequate recovery and to minimize the influence of fatigue on subsequent performance, consistent with previous recommendations for high-intensity testing (Maté-Muñoz et al., 2022).

Statistical analysis

All data were analyzed using SPSS v31 (IBM Corp., Armonk, NY, USA), and graphical representations were produced in GraphPad Prism v10.3 (GraphPad Software, San Diego, CA, USA). Descriptive statistics (mean±SD) were calculated for each condition. Data normality was verified using the Shapiro–Wilk test. Differences among the five testing conditions (Bosco, MG, MGM-15, BikeErg, RowErg) were assessed via a one-way repeated-measures ANOVA. When the assumption of sphericity was violated according to Mauchly's test ($p<0.05$), the Greenhouse–Geisser correction was applied ($\varepsilon=0.26$). Post-hoc pairwise comparisons were performed using Bonferroni-adjusted tests, with statistical significance set at $p<0.05$. Effect sizes were reported as partial eta squared (ηp^2) and interpreted according to Cohen (2013), where values of $\eta p^2 \geq 0.01$, ≥ 0.06, and ≥ 0.14 correspond to small, medium, and large effects, respectively. Given the very small sample size (n=5), inferential statistics were used cautiously and exclusively to explore systematic within-subject differences rather than to support population-level inference or model validation. Accordingly, effect sizes and descriptive trends were emphasized alongside p-values, consistent with recommendations for exploratory and preliminary research designs.

Results

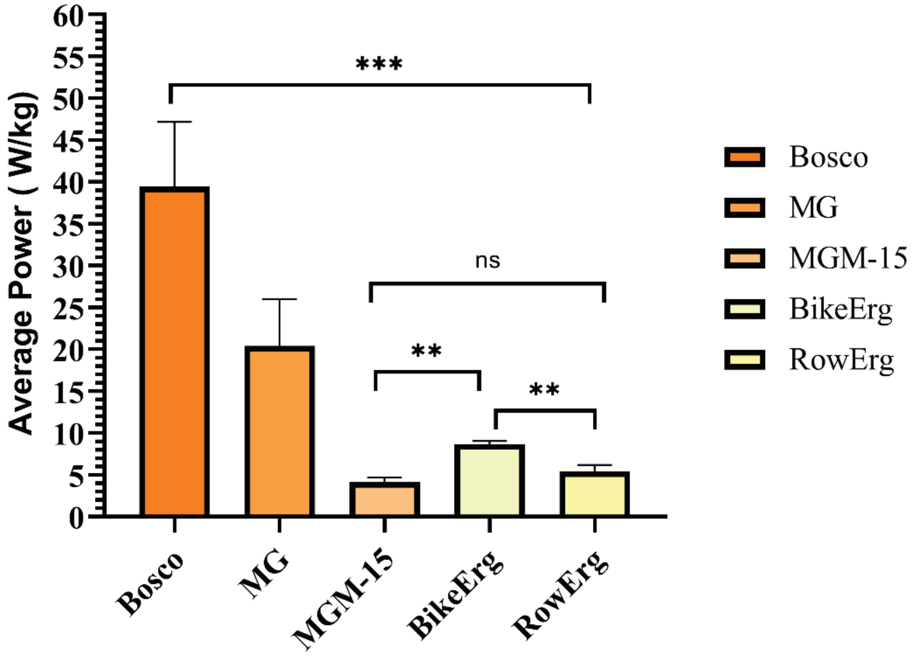
Descriptive statistics for all testing methods are shown in Table 1 and Figure 2. Mean values indicate substantial variability across the five power assessment approaches. The Bosco model produced the highest mean power (39.42±7.73 W/kg), followed by the MG model (20.38±5.59 W/kg). In contrast, the MGM-15 model yielded much lower values (4.13±0.53 W/kg), closer to the directly measured values from the BikeErg (8.67±0.39 W/kg) and RowErg (5.43±0.75 W/kg) tests.

Table 1. Descriptive statistics (Mean ± SD) of average power (W/kg) across assessment methods

Variable	Average Power (W/kg)	
	Mean	**SD**
Bosco	39.42	7.73
MG	20.38	5.59
MGM-15	4.13	0.53
BikeErg	8.67	0.39
RowErg	5.43	0.75

Note. Data are presented as mean ± SD. Bosco, MG, and MGM-15 are calculated power models, whereas BikeErg and RowErg are based on directly measured power output.

Figure 2. Descriptive statistics (Mean ± SD, W/kg) and results of inferential Bonferroni-adjusted pairwise comparisons across computational models (Bosco, MG, MGM-15) and direct ergometer measurements (BikeErg, RowErg)



*Note. Symbols indicate statistically significant differences (***p<0.001, **p<0.01, p<0.05, ns = not significant).*

A one-way repeated-measures ANOVA confirmed a significant main effect of method on power output (F (1.03, 4.12)=77.04, p=0.001, ηp²=0.95), indicating that power estimates differed systematically between models (Table 2). Mauchly's test revealed a violation of sphericity ($\chi^2(9)=38.35$, p<0.001); therefore, the Greenhouse–Geisser correction was applied. The large effect size (ηp²=0.95) indicates substantial differences in methodology between the approaches. This finding is particularly important in this exploratory study, which used a small sample.

Table 2. Repeated-measures ANOVA results for average power output across computational and direct measurement methods

Source	SS	df	MS	F	p	ηp²
Method	4367	1.03, 4.12	1092	77.04	0.001	0.95
Error	226.7	16	14.17	-	-	-

Note. Greenhouse–Geisser correction (ε = 0.26) applied due to violation of sphericity (Mauchly's W=0.073, p<0.05). The main effect of method was significant (p=0.001, ηp²=0.95), indicating strong differences between models

Post-hoc Bonferroni comparisons (Figure 2 and Table 3) revealed that both Bosco and MG models significantly overestimated average power relative to all other conditions (p<0.05). The MGM-15 model produced values that were not significantly different from RowErg outputs (p=0.36) but were slightly lower than BikeErg results (p=0.003). BikeErg and RowErg differed significantly (p=0.004).

Table 3. Bonferroni-Adjusted Pairwise Comparisons

Comparison	Mean Difference (W/kg)	95% CI of Diff	p
Bosco vs MG	19.04	[13.11–24.98]	0.001
Bosco vs MGM-15	35.29	[17.21–53.37]	0.004
Bosco vs BikeErg	30.75	[10.47–51.03]	0.011
Bosco vs RowErg	34.00	[14.21–53.79]	0.007
MG vs MGM-15	16.25	[3.44–29.05]	0.021

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Table 3. Bonferroni-Adjusted Pairwise Comparisons

Comparison	Mean Difference (W/kg)	95% CI of Diff	p
MG vs BikeErg	11.71	[−3.20–26.62]	0.117
MG vs RowErg	14.95	[0.40–29.50]	0.045
MGM-15 vs BikeErg	-4.54	[−6.79–2.29]	0.004
MGM-15 vs RowErg	-1.29	[−3.63–1.04]	0.363
BikeErg vs RowErg	3.25	[1.61–4.89]	0.004

Note. Bonferroni correction was applied for multiple comparisons (α=0.05). Significant pairwise differences are shown in bold (p<0.05). The MGM-15 model differed significantly from BikeErg (p=0.004) but not from RowErg (p=0.36)

Discussion

This study aimed to provide a preliminary, exploratory comparison of average power estimates derived from classical jump-based computational models and direct mechanical outputs recorded during short-duration maximal efforts on ergometers. Statistical analysis with Bonferroni-adjusted post-hoc comparisons revealed a significant main effect of method ($F(1.03, 4.12)=77.04$, $p=0.001$, $\eta p^2=0.95$), indicating that the different approaches produced systematically divergent power values. This large effect highlights that methodological choice is a major determinant of measured performance outcomes in lower-limb power assessment.

Comparison of computational models

Among the investigated methodologies, both the Bosco and MG models yielded considerably greater average power values when contrasted with the direct ergometer data. This observation aligns with prior research indicating that equations derived from jump performance frequently overestimate muscular output when compared to direct mechanical assessments, such as the Wingate test (Bosco et al., 1983; Driss & Vandewalle, 2013). The Bosco et al. (1983) model assumes constant mechanical efficiency and uniform jump mechanics across repetitions, disregarding the progressive reduction in force and stretch-shortening cycle efficiency typically observed during repeated jumps. This simplification may lead to an overestimation of mean power output (Acar et al., 2025; Khemiri et al., 2025). Similarly, the MG model relies on a theoretical derivation of the relationship between potential and kinetic energy, which does not account for real-time fluctuations in contact and flight durations.

Consequently, these models present a simplified biomechanical representation that deviates from the actual patterns of energy transfer observed during sustained neuromuscular effort. The observed discrepancy suggests that while these models offer practical field assessment tools, their outputs might not precisely reflect the intricate interplay of concentric and eccentric muscle actions and metabolic contributions inherent in dynamic movements (Samozino et al., 2008)

MGM-15 vs. direct ergometer measurements

In contrast, the MGM-15 model demonstrated the closest alignment with direct ergometer outputs. Although its values were slightly lower than those recorded on the BikeErg ($p<0.01$), they did not differ significantly from the RowErg results ($p>0.05$). This close similarity can be attributed to the model's careful accounting of both flight and contact time (Hillerin, 1997). These parameters are vital, as they comprehensively represent the dynamic and physiologically relevant alternation between concentric propulsion and eccentric phases inherent in repetitive jumping actions (Geantă & de Hillerin, 2025). Incorporating flight time into the formula enables the MGM-15 model to capture the full physiological structure of repeated jumping, encompassing both the eccentric–concentric transition and the airborne phase characteristic of cyclic, rebound-type (ballistic) movements. By integrating these distinct temporal components, the model may more accurately account for subtle fluctuations in mechanical efficiency intrinsic to genuine cyclic power production (Geantă et al., 2025), offering a plausible methodological explanation for why its estimated power values tended to be closer to those obtained from direct ergometer measurements. Ergometers, by their nature, continuously and precisely register the actual mechanical work performed, offering a robust standard for dynamic, real-time power output across the same muscle groups involved in jumping (Lai et al., 2021; Turner & Rice, 2021).

Discrepancies with ergometer-based outputs

The pronounced difference between the Bosco model and ergometer values echoes Bosco's own observations when comparing his jump test to the Wingate cycle test more than four decades ago (Bosco et al., 1983). The present findings reaffirm that such discrepancies persist even with modern measurement technologies. While ergometers directly measure the total mechanical work performed against external resistance (Pitto et al., 2025), jump-based models infer power indirectly from kinematic parameters, which are sensitive to small errors in timing or execution (Rong et al., 2025). This fundamental difference in measurement principles likely explains the magnitude of the observed discrepancies, particularly in short-duration maximal tasks, where instantaneous output fluctuates rapidly (Gross & Lüthy, 2020; Pérez-Castilla & García-Ramos, 2021).

Methodological considerations

To our knowledge, this preliminary study is among the first to compare multiple computational models of repeated vertical jump performance (Bosco, MG, and MGM-15) with directly measured ergometer power outputs. This comparative approach helps quantify the magnitude of methodological discrepancies rather than attempting validation. The consistent alignment between MGM-15 and ergometer results suggests that refined temporal modelling can narrow the gap between theoretical and empirical values. From a methodological standpoint, these pivotal findings highlight that classical computational models, such as Bosco and MG, systematically overestimate average power due to inherent simplifications in their formulas. By contrast, the MGM-15 model, which accounts for both flight and contact times, provides estimates that closely match direct ergometer measurements, offering a closer approximation of cyclic mechanical efficiency.

Practical implications

From an applied perspective, these findings help clarify how jump-based power estimates should be interpreted in everyday practice. Classical equations such as Bosco and Miron Georgescu remain useful for monitoring relative changes within the same athlete over time; however, their computational limitations and systematic calculation errors have already been documented in previous studies (Geantă & de Hillerin, 2025; Geantă et al., 2025). These documented inaccuracies raise important questions regarding the interpretation of average power values derived from these models, particularly when such values are implicitly assumed to reflect the athlete's actual mechanical or energetic output.

In contrast, the MGM-15 model yielded more conservative estimates that, within this exploratory sample, were closer to ergometer-derived power values. This difference arises from the integration of both flight and contact times into the computational structure of the MGM-15 formula, which reduces the systematic overestimation of power observed in the Bosco and MG models. By constraining power values toward the magnitude of mechanical energy externalized during cyclic muscular work, the MGM-15 approach produces estimates that are closer, as a result, to those recorded by ergometer-based measurements. Importantly, jump-based computational models and ergometer assessments should be regarded as complementary rather than interchangeable, as they rely on different mechanical principles and modes of energy externalization.

Limitations and future directions

As with all research, this study has several limitations that should be considered when interpreting the findings. First, the preliminary nature of the investigation, including a small and homogenous sample of five participants, limits the generalizability of the results. Maintaining a consistent protocol with prior research (Geantă et al., 2025; Geantă & de Hillerin, 2025), ensured continuity within this research line, but future studies should include larger and various populations for strengthening the external validity and to enhance the robustness of comparisons. Second, additional factors that may influence discrepancies between computational models and direct measurements were not examined in this study. These include muscle fiber composition, fatigue kinematics, and neuromuscular coordination. Longitudinal designs could determine whether MGM-15 values are sensitive to training-induced changes in mechanical efficiency, further expanding the interpretative relevance of this method in applied sport science. Also, the methodological extensions could improve cross-modality comparability and the rigor of quantitative analyses. Incorporating force-platform analyses as the biomechanical gold standard would allow verification instantaneous ground reaction forces and mechanical power during vertical jumps (Lake et al., 2018). While Monark cycle ergometers (Driss & Vandewalle, 2013) are widely used in cycling protocols, Concept2 ergometers were selected in this preliminary exploratory study due to their documented technical validity and measurement reliability in cycling and rowing protocols (Podstawski et al., 2025; Treff et al., 2022; Turner & Rice, 2021). Although no ergometer is without limitations, these instruments provide standardized mechanical measurements that can serve as reference points for comparisons with computational models. Future research combining these methodological improvements with larger, more heterogeneous samples will allow for a more rigorous quantification of discrepancies among computational, kinetic, and ergometric approaches.

Conclusions

This preliminary exploratory study demonstrates that methodological choice substantially influences lower-limb power estimates derived from repeated vertical jump tests. Classical computational models, such as Bosco and Miron Georgescu, produced systematically higher power values compared with direct ergometer measurements, highlighting inherent limitations in their calculation assumptions. In contrast, the MGM-15 model, which integrates both flight and contact times, yielded more conservative estimates that were closer in magnitude to ergometer-derived power outputs, reflecting a closer approximation of the mechanical energy externalized during cyclic muscular work. These findings underscore the importance of critically evaluating and standardizing jump-based power calculation models, with particular attention to their computational structure. Given the preliminary nature of the study, further research using larger and more diverse samples is required to confirm these methodological observations.

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Conflict of interests
The authors declare no conflicts of interest related to this study.

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