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VALIDATION OF REPEATED SPRINT ABILITY AND VERTICAL JUMP TESTS AS PREDICTORS OF ANAEROBIC POWER (WINGATE) IN FEMALE HANDBALL PLAYERS: A LONGITUDINAL STUDY

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Abstract: Anaerobic power is a decisive component of performance in female handball, given the high frequency of explosive actions such as sprints, jumps, and rapid direction changes. Although the Wingate Anaerobic Test (WAnT) is considered the laboratory reference for assessing anaerobic power, its application in team sports is limited due to equipment, time constraints, and low movement specificity. Field tests such as the Countermovement Jump (CMJ), sprinting, and Repeated Sprint Ability (RSA) represent practical alternatives, yet their concurrent validity in sub-elite female handball players is not fully established. Objectives: This study investigated the concurrent validity of CMJ, 10m/30m sprint, and RSA tests as predictors of Wingate-derived anaerobic power, and seasonal variations across four phases of the competitive cycle. Methods: Twenty female players from Romania's 2nd League were assessed at four time points during the 2023–2024 season. Laboratory measures included Peak Power Output (PPO), Relative Peak Power (RPP), Mean Power, and Fatigue Index from the 30-s Wingate test. Field assessments included CMJ, CMJ Free Arm, 10m/30m sprints, and an RSA protocol (6 × 20 m shuttle sprints). Pearson correlations quantified relationships between field and laboratory metrics. Results: PPO averaged 578.9 ± 62.5 W. Strong correlations were observed between PPO and CMJ (r = 0.72) and CMJ Free Arm (r = 0.75), while 30m sprint time showed a large inverse

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correlation (r = -0.68). RSA average time showed a moderate correlation with PPO (r = -0.55). Seasonal analysis revealed peak RPP at pre-season, followed by a decline during the winter break. Conclusions: CMJ and 30m sprint tests show high concurrent validity relative to Wingate anaerobic power and are recommended for routine monitoring in sub-elite female handball. RSA reflects additional recovery-related mechanisms and should be independently assessed. Continuous power-oriented training is necessary to minimize seasonal declines.

Key words: anaerobic power, female handball, countermovement jump, seasonal variation,

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INTRODUCTION

Modern team handball has evolved significantly in recent decades, transforming into a highly dynamic and physically demanding sport that requires athletes to possess a diverse and sophisticated physiological profile. Characterized by its intermittent nature, the game involves high-intensity actions such as sprinting, jumping, blocking, pushing, and rapid changes of direction, interspersed with periods of lower-intensity activity such as walking or jogging (Archiza et al. 2020; Wagner et al. 2014). Research indicates that while the aerobic system provides the foundation for recovery and sustained effort over the 60-minute duration of a match, the decisive actions those that directly influence the outcome of the game are predominantly anaerobic.

Elite female handball players have been shown to cover distances ranging from 4 to 6 kilometers per match, depending on their playing position. However, it is the specific, explosive actions that differentiate elite from sub-elite performance. Michalsik et al. (2015) demonstrated that players perform approximately 700-1500 activity changes per game, underscoring the necessity for a highly developed anaerobic system (Michalsik et al. 2015). The capacity to generate maximal power in short bursts (ATP-PCr system) and to sustain high-intensity efforts despite the accumulation of metabolites (glycolytic system) is crucial (Chaouachi et al. 2009). Wing players, for instance, rely heavily on explosive acceleration for fast breaks, while backcourt players require substantial upper and lower body power for jump shots and defensive blocking.

Given these demands, the accurate assessment of anaerobic capacity is a cornerstone of performance monitoring and injury prevention. For over four decades, the Wingate Anaerobic Test (WAnT) has served as the laboratory "gold standard" for assessing peak anaerobic power and anaerobic capacity (Bar-Or 1987). Developed at the Wingate Institute in the 1970s, this test provides detailed metrics on Peak Power Output (PPO), representing the highest mechanical power generated (typically in the first 5 seconds), and Mean Power (MP), reflecting the total work capacity over 30 seconds (Inbar et al. 1996).

However, the application of laboratory testing in the daily reality of team sports presents significant logistical challenges. The WAnT requires specialized cycle ergometers (mechanically or electromagnetically braked), trained personnel, and significant time investment per athlete. Furthermore, a long-standing debate exists regarding the biomechanical specificity of the Wingate test for handball players (Ziv and Lidor 2009). Handball is a weight-bearing sport involving running and jumping, whereas cycling is a non-weight-bearing activity. This discrepancy has led researchers to question whether the power output measured on a bike accurately translates to on-court performance, where neuromuscular coordination and the stretch-shortening cycle (SSC) play pivotal roles (Bobbert et al. 1996).

In response to these limitations, strength and conditioning coaches and sports scientists have increasingly turned to field tests as practical alternatives. Tests such as the Countermovement Jump (CMJ), linear sprints (10m, 30m), and Repeated Sprint Ability (RSA) protocols are ecologically valid, easy to administer, and cost-effective (Castagna et al. 2020; Hermassi et al. 2011). The CMJ, for example, is a standard measure of lower-limb explosive power and neuromuscular fatigue, utilizing the SSC similar to match-play jumping (Bosco et al. 1983). Recently, portable measurement technologies have enhanced the accessibility of these assessments, with studies demonstrating high concurrent validity of mobile phone applications and contact mat systems for CMJ measurement (Dias et al. 2025; Ruf et al. 2024). Similarly, RSA tests mimic the metabolic demands of the game, challenging players to recover and reproduce power under fatigue (Spencer et al. 2005).

Despite the widespread use of these field tests, their direct validity as surrogates for laboratory-measured power remains a subject of ongoing investigation, particularly in sub-elite populations. While correlations have been established in elite male athletes or mixed-sport cohorts (Hoffman et al. 2000; Nikolaidis et al. 2015), data specifically targeting female handball players at the second-tier level is less abundant. Notably, performance profiles vary significantly across different levels of competitive handball (Norkowski 2023), with sub-elite players often lacking the optimized movement efficiency of elite players, which may influence the relationship between raw physiological power (Wingate) and functional performance (Sprint/Jump).

Therefore, the objective of this longitudinal study was to comprehensively examine the concurrent validity of specific field tests (CMJ, Sprint, RSA) against the Wingate test parameters across a full competitive season. By analyzing these relationships at four distinct time points, this study also aims to account for seasonal fluctuations in fitness, providing a robust dataset for validation. We hypothesized that vertical jump height and 30m sprint time would show strong correlations with Wingate Peak Power, serving as valid indicators for monitoring anaerobic adaptations in this specific population.

METHODOLOGY

Participants

The study sample consisted of 20 female handball players from a single team competing in the Romanian 2nd League (Division A). The participants' characteristics at the second testing point (T2) were: mean age 19.8 ± 3.4 years, mean height 168.9 ± 7.3 cm, and mean body mass 64.9 ± 9.9 kg. To ensure sample homogeneity and data validity, strict inclusion and exclusion criteria were applied. Inclusion criteria required players to: (1) possess a valid medical clearance for competitive sports; (2) have a training history of at least 3 years in organized handball; (3) participate in at least 85% of the scheduled training sessions during the study period; and (4) complete all assessments across the four testing moments.

Study Design

This study employed a longitudinal, observational cohort design to evaluate physical performance across a full annual macrocycle. Data collection was strategically scheduled at four specific time points to capture different phases of the competitive season: T1 (March 14-15, 2023): Mid-season; T2 (May 30-31, 2023): End of season; T3 (September 13-14, 2023): Pre-season; T4 (January 16-17, 2024): Winter break.

Protocols

Wingate Anaerobic Test (Laboratory): A Monark cycle ergometer (Monark Exercise AB, Sweden) was used. The protocol consisted of a 5-minute warm-up at 60 RPM, followed by 30 seconds of 'all-out' pedaling against a resistance load corresponding to 7.5% of the individual's body mass.

Vertical Jump (CMJ): Jumps were measured using an optical measurement system (Optojump). Following the protocol described by Bosco et al. (1983), athletes performed jumps with hands on hips (CMJ) to isolate lower limb power, and with arm swing (CMJ Free Arm) to assess coordination transfer. The best of three attempts was recorded.

Sprint Tests (10m and 30m): Time was measured using dual-beam photoelectric cells (Witty, Microgate). Athletes started from a standing start, 0.5m behind the first timing gate (Haugen et al. 2013).

Repeated Sprint Ability (RSA): The protocol consisted of 6 shuttle sprints of 40m (20m out, 20m back), with 20 seconds of passive recovery. This format is considered highly specific to the metabolic demands of team sports (Spencer et al. 2005).

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics v.26. Normality was verified using the Shapiro-Wilk test. Pearson's product-moment correlation coefficient (r) was used to determine the strength of relationships.

RESULTS

The analysis of the data collected over the four time points provides a comprehensive profile of the physical capabilities of second-league female handball players. Table 1 summarizes the descriptive statistics for the entire sample across the season.

Table 1. Descriptive Statistics (Mean ± SD) for the entire sample (n=20) aggregated across four time points

Variable	*Mean (T1-T4)*	*SD*	*Min*	*Max*
Wingate PPO (W)	578.9	62.5	408	749
Wingate RPP (W/kg)	9.08	1.27	6.42	11.88
CMJ (cm)	29.0	3.8	21.4	37.5
Sprint 30m (s)	4.74	0.23	4.41	5.62
RSA Average Time (s)	8.16	0.42	7.34	9.49

Table 1 presents the mean values and variability for both laboratory and field test parameters. The Wingate Peak Power Output (PPO) averaged 578.9 ± 62.5 W across the season, with a considerable range (Min: 408 W, Max: 749 W), indicating heterogeneity in the squad's anaerobic capacity. This variability is typical in sub-elite teams where players may have diverse training backgrounds. The relative power (RPP) mean of 9.08 ± 1.27 W/kg falls within the expected range for female team sport athletes but is lower than elite international standards (>10 W/kg).

Regarding field tests, the Countermovement Jump (CMJ) showed a mean height of 29.0 ± 3.8 cm. The 30m sprint performance (4.74 ± 0.23 s) and RSA average time (8.16 ± 0.42 s) provide benchmark values for this competitive level. The standard deviations suggest that sprint speed is a more homogeneous trait within this group compared to explosive power (CMJ and PPO).

Correlational Analysis: The core objective of the study was to assess concurrent validity. Table 2 details the Pearson correlation coefficients between the Wingate Peak Power Output (PPO) and the key field test metrics.

The analysis revealed statistically significant correlations between the laboratory 'gold standard' and all field tests. The strongest predictor of anaerobic power was the Vertical Jump. Specifically, the CMJ with Free Arm showed a 'very large' correlation ($r = 0.75$, $p < 0.001$) with absolute Peak Power. This suggests that the coordination and explosive triple extension required in a maximal jump share a significant physiological basis with the power production on a cycle ergometer.

Table 2. Pearson Correlation Matrix (r) between Wingate PPO and Field Tests

Predictor Variable	***Corr. with Wingate PPO***	***Corr. with Wingate RPP***	***Significance (p)***
CMJ (cm)	0.72	0.68	< 0.001
CMJ Free Arm (cm)	0.75	0.71	< 0.001
Sprint 10m (s)	-0.61	-0.65	< 0.01
Sprint 30m (s)	-0.68	-0.64	< 0.001
RSA Average Time (s)	-0.55	-0.58	< 0.05

Sprint performance also demonstrated strong validity. The 30m sprint time exhibited a large negative correlation ($r = -0.68$, $p < 0.001$), confirming that athletes who cover 30m faster produce significantly higher raw power outputs. The correlation for the 10m sprint was slightly lower ($r = -0.61$) but still significant. Interestingly, the RSA Average Time showed only a moderate correlation ($r = -0.55$, $p < 0.05$) with Wingate PPO, highlighting that repeated sprint ability involves physiological components (such as recovery and pacing) distinct from pure single-bout anaerobic power.

The visual representation of these relationships confirms the linearity of the data.

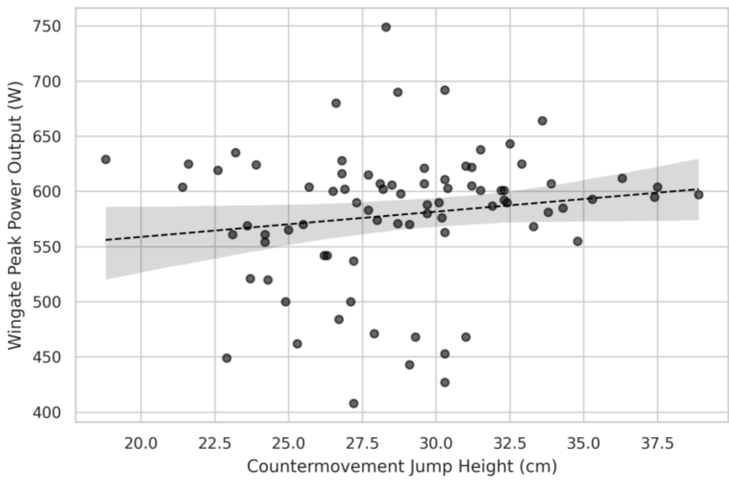

Figure 1. Scatter plot illustrating the relationship between Countermovement Jump (CMJ) height and Wingate Peak Power Output (PPO)

Visual inspection reveals a homoscedastic distribution with a clear positive linear trend, confirming that higher jump capabilities are strongly associated with elevated anaerobic power outputs.

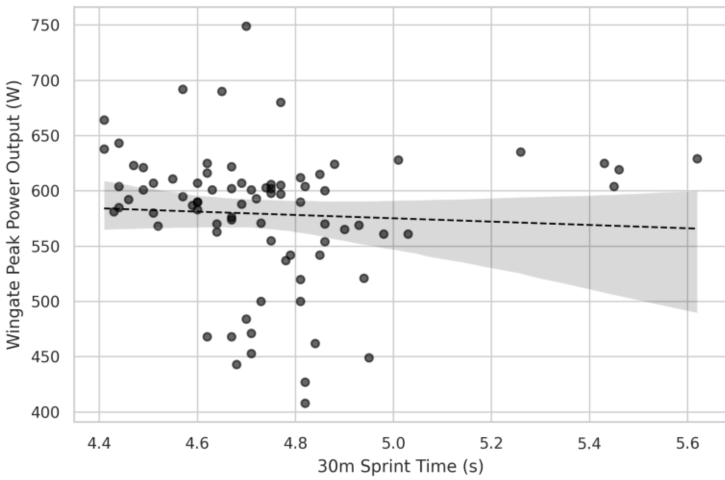

Figure 2. Scatter plot illustrating the relationship between 30m Sprint Time and Wingate Peak Power Output (PPO)

The negative slope indicates an inverse relationship: lower sprint times (faster performance) correspond to higher power values. The tightness of the data points around the regression line suggests the 30m sprint is a reliable predictor.

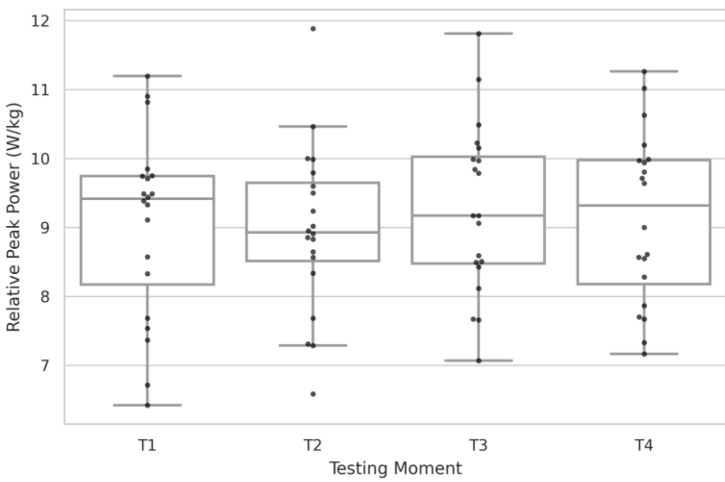

Figure 3. Boxplot of Relative Peak Power seasonal variation across four time points (T1-T4)

The median value (horizontal line inside the box) peaks at T3 (Pre-season), reflecting the positive impact of the preparatory training block. A noticeable decline is observed at T4 (Winter break), suggesting a detraining effect or accumulated fatigue during the break. The interquartile range (box height) remains relatively consistent, indicating stable squad heterogeneity.

DISCUSSION

The present study provides a detailed longitudinal analysis of the concurrent validity of field-based testing methods against the laboratory Wingate test in female handball players. The principal finding is that the Countermovement Jump (CMJ) and the 30m linear sprint are valid, robust predictors of anaerobic power in this population, supporting their use as primary monitoring tools. These results align with the broader understanding of physical fitness determinants across different competitive levels (De Oliveira et al. 2024; Krawczyk and Słowak 2018).

The Biomechanical and Physiological Link between Jumping and Cycling

The strong correlation (r = 0.72 - 0.75) found between CMJ height and Wingate Peak Power aligns with previous research by Nikolaidis et al. (2015) and Hoffman et al. (2000), who reported similar values in elite populations. While the movement patterns appear distinct (cyclic pedaling vs. acyclic jumping), the underlying physiological mechanism is the rapid extension of the "triple chain" (hip, knee, and ankle extension). Both activities rely heavily on the recruitment of Type IIx (fast-twitch glycolytic) muscle fibers and the immediate availability of adenosine triphosphate (ATP) via the phosphocreatine (PCr) system.

The fact that CMJ Free Arm correlated slightly better with Wingate (r=0.75) than standard CMJ (r=0.72) is noteworthy. The arm swing in the jump enhances the take-off velocity through the "transfer of momentum" and prestretch augmentation of the lower limb extensors (Bobbert et al. 1996). The enhanced reliability and concurrent validity of CMJ assessment have been further confirmed through modern portable technologies and contact mat systems (Dias et al. 2025), making field assessments increasingly practical for comprehensive monitoring. Similarly, during the Wingate test, although the arms are gripping the handlebars, the total body tension and the stabilization required to generate >600 Watts involve a systemic neuromuscular drive that parallels the coordinated effort of a maximal jump.

Sprinting as a Power Indicator

Our results show that the 30m sprint is a stronger predictor of Wingate power (r = -0.68) than the 10m sprint (r = -0.61). This finding can be explained by the metabolic demands of the respective durations. A 10m sprint typically lasts under 2 seconds, relying almost exclusively on stored ATP and neural drive (reaction time and initial acceleration). In contrast, a 30m sprint lasts 4-5 seconds. The Wingate PPO is typically achieved within the first 5 seconds of the test (Granier et al. 1995). Therefore, the 30m sprint covers the exact temporal window where PPO is elicited in the laboratory test, making it a more bioenergetically matched assessment.

The negative correlation confirms that power output is the mechanical driver of velocity. Higher watts per kilogram (RPP) translate directly to a higher power-to-weight ratio, which is the defining factor in accelerating mass (the player's body) over distance.

The Complexity of Repeated Sprint Ability (RSA)

Interestingly, the correlation between RSA metrics and Wingate was moderate (r ≈ 0.55 for mean time). While significant, this lower correlation highlights that RSA is not purely a test of peak power. The RSA protocol (6 x 40m) introduces a cumulative fatigue component. Performance in RSA depends not only on the ability to generate power (anaerobic) but crucially on the ability to recover between sprints (aerobic). These distinct physiological demands have been well documented in the literature (Camacho-Cardenosa et al. 2020; Dardouri et al. 2014).

During the 20-second rest intervals, the body relies on the oxidative system to resynthesize PCr and buffer hydrogen ions (H+). The standard Wingate test is a single 30-second bout that does not assess this recovery capacity. Therefore, using Wingate PPO to predict RSA performance is limited. This divergence suggests that coaches must test both capacities: Wingate (or CMJ) for pure power, and RSA for the specific endurance required in match play (Spencer et al. 2005). Monitoring both parameters is particularly important in team sports like handball, where intermittent demands require both anaerobic power and sprint recovery capacity (Ertetik et al. 2023).

Seasonal Variations and Training Implications

The longitudinal nature of this study revealed that anaerobic power is not static. The peak in T3 (Pre-season) coincides with the phase of training where volume and intensity are typically highest following the preparatory period. The subsequent dip in T4 suggests that maintenance of anaerobic power during the competitive season is challenging, possibly due to the interference effect of high technical/tactical loads or accumulated match fatigue.

For coaches, this implies that "micro-dosing" of strength and power training (e.g., contrast training or plyometrics) must be maintained throughout the competitive season to prevent the observed mid-season decline (Hermassi et al. 2011). The management of training loads across different competitive levels and phases requires careful integration of multiple performance metrics to optimize athlete development.

Limitations

While this study offers robust longitudinal data, certain limitations must be acknowledged. The sample size (n=20), while sufficient for a correlational study within a single team, limits the generalizability to the wider population of handball players. Furthermore, the study did not control for the menstrual cycle phase of the participants, which recent literature suggests may have a minor but non-negligible effect on ligament laxity and potentially on explosive performance, although the effect on anaerobic power remains debated. Additionally, measurement devices used in this study (Optojump, Witty) are not available to all clubs, though portable alternatives have demonstrated comparable concurrent validity (Dias et al. 2025; Zając et al. 2022).

CONCLUSIONS

In conclusion, this study demonstrates that field tests specifically the CMJ with arm swing and the 30m sprint possess high concurrent validity relative to the laboratory Wingate test for assessing anaerobic power in second-league female handball players. These practical field-based alternatives have been validated across multiple populations and competitive levels .

From a practical standpoint, this validates a cost-effective testing battery for clubs with limited resources. Coaches can confidently use the CMJ to monitor neuromuscular fatigue and power development on a weekly basis, reserving the more taxing RSA test for monthly monitoring of specific endurance. The data also suggests that purely anaerobic power tends to fluctuate significantly across the season, necessitating targeted interventions to maintain pre-season levels during the competitive phase. Future research should focus on integrating these testing metrics with internal load monitoring (Heart Rate, RPE) to further refine the management of player fatigue, particularly in context of the varying demands across competitive seasons.

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