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**Original Investigation**

# Ecological Validity of Maximal Exercise Tests to Simulate Competitive Demands in Amateur Female Handball

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***Purpose:*** Laboratory tests are fundamental for assessing handball performance, but their ecological validity for amateur female players is unclear. This exploratory study compared physiological and perceptual responses between common maximal exercise tests and official match play to determine if they replicate competitive demands.
***Methods:*** Sixteen amateur female handball players completed three laboratory tests (Wingate, cycle ergometer, treadmill) and were monitored during ten official matches. The data collection included both physiological and psychological indicators: heart rate (HR), blood lactate concentration, rating of perceived exertion (RPE), perceived stress, and mood states.
***Results:*** Peak HR values recorded in the Wingate and Cycle ergometer were lower than those reached during actual competition ($d$ = -.77 to -.75, $P$< .05). In addition, compared with the Wingate and cycle ergometer tests, competitive matches required players to spend a significantly larger proportion of time with their HR exceeding 90% of its maximum. This contrast was less evident when compared with the treadmill test. A clear mismatch was observed between physiological and perceptual measures. Despite showing stronger physiological strain during matches -such as greater weight loss and higher pre-exercise lactate levels- players reported significantly lower RPE values than in the laboratory conditions ($d$ = .27 to .36, $P$< .05).
***Conclusions:*** None of the laboratory-based tests accurately reproduced the full demands of a handball match. Although the treadmill test elicited similar peak HR values, it failed to reflect the sport's intermittent nature. The Wingate and cycle tests showed even greater discrepancies in cardiovascular intensity. These findings underline the importance of developing sport-specific or hybrid assessment protocols that integrate intermittent workloads and cognitive demands for a more valid evaluation of performance.

***Keywords:*** Ecological Validity, Female Athletes, Exercise Testing, Team Sports, Perceived Exertion

## Introduction

The most effective method for early detection of cardiovascular pathology is the administration of a maximal exercise test.[1] Myers et al.[2] defined such tests as "a non-invasive procedure that provides diagnostic information on cardiopulmonary function and evaluates an individual's capacity to perform dynamic exercise".

Beyond their primary role in assessing physical performance capacity, maximal exercise tests are also valuable tools for evaluating overall health status and identifying cardiovascular and metabolic conditions that may limit or contraindicate participation in physical activity.[3] For these evaluations to be effective, it is essential that athletes reach their maximal heart rate

(HRmax) during testing.[4] As noted by Currell and Jeukendrup,[5] the intensity achieved during testing should match or exceed that reached in actual sports participation; otherwise, pathological conditions may either go undetected or be misdiagnosed.

Handball is a physically demanding sport characterized by frequent high-intensity actions such as jumping, sprinting, and throwing, which require significant muscular strength for actions like striking, blocking, pushing, and holding. As noted by Fritz et al.,[6] handball is characterized by constant shifts between attack and defense, with players operating mainly around a 6-meter line while seeking to score against the opposing goalkeeper. A typical match produces roughly 35-70 goals, which illustrates the sport's intense physical nature. For this reason, it is important to examine both internal and external load indicators to better understand the physiological demands of the game.

However, current evidence on the physiological demands of female handball players during competition is scarce, with most studies focusing on elite-level athletes and small sample sizes. For instance, Manchado et al.[7] analyzed a single match between a top-tier German club (n = 11) and the Norwegian national team (n = 14), reporting average intensities of 86.50 ± 4.50% HRmax for field players and 78.40 ± 5.90% HRmax for goalkeepers. Similarly, Michalsik et al.[8] reported mean HR of 171.00 ± 7.00 bpm during Live Time and 162 ± 8 bpm when considering Total Time across five Danish elite teams. Bělka et al.[9] observed that exercise intensity varied according to playing position among 14 elite junior Czech players: wings averaged 89.90 ± 3.50% HRmax, pivots 90.10 ± 4.30% HRmax, and backs 89.20 ± 4.40% HRmax.

While these findings offer valuable insights into the physiological demands of competitive women's handball, they are not easily generalizable to amateur-level athletes. Therefore, research targeting this specific population is needed. In this context, Karpan et al.[10] analyzed heart rate zone distribution in amateur players and found that goalkeepers and defenders spent more time in the 80–89% HRmax zone, while wings and pivots spent more time in the 90–100% zone. These results suggest that heart rate responses are influenced by a player's tactical role on the court.

Several maximal exercise tests have been used in laboratory settings depending on study objectives. Regarding anaerobic capacity, the Wingate test has been used to assess the impact of physical preparation and the effectiveness of training programs such as six-week plyometric regimens.[11] For aerobic capacity, incremental, interval-based protocols have been applied to determine HRmax and VO2max, which are later used to calculate internal training load.[8]

Despite these efforts to characterize physical demands, to our knowledge, only one study has directly examined whether laboratory-based exercise tests can accurately replicate the physiological demands experienced during official competition with amateur players.[12] The controlled conditions of laboratory testing, combined with the potential physiological alterations driven by competitive stress and motivation, raise important questions about the ecological validity of these assessments.[13]

Therefore, the main objective of this study is to determine whether the most used maximal laboratory exercise tests can replicate the physiological and psychological demands experienced by amateur female handball players during official matches.

## Methods

### *Participant*

The study sample consisted of 16 amateur female handball players (age: 21.93 ± 3.25 years, height: 1.66 ± .06 m, weight: 64.36 ± 13.86 kg, wingspan: 1.69 ± .08 m, fat mass: 20.19 ± 3.37 %, experience: 10.44 ± 1.86 years). The players completed four two-hour training sessions per week and one match on the weekend. Participants were monitored to prevent moderate- or high-intensity physical activity outside assessment or training sessions. The participants had no personal or family history of cardiac pathology, nor had they suffered any injury that could alter regular sports practice in the 6 months prior to the study. None of the participants received any financial or in-kind reward for their collaboration in the study. They also signed an informed consent form, and a protocol was established for the delivery and explanation of the results. At the time of the study, none of the participants were taking any type of medication, nor were they following a specific dietary pattern, nor did they suffer from any respiratory or metabolic disorder. The sample size was determined using the G*Power3 for Mac. The effect size value used was: $d = .70$, based on the findings of a similar study from Batalla-Gavaldà et al.,[12] that analyzed the differences between the values of various physiological and psychological variables, obtained in different maximal stress tests performed in the laboratory and the values obtained during official competition, in a group of amateur male basketball players. The alpha error probability set at .05 and a power of .80. The minimum required sample size was 13 participants. Accounting for a potential dropout rate of 25%, 16 participants were required. To assess the minimum effect size to which the model would remain sensitive, a sensitivity analysis was conducted with this final sample size assuming a 25% dropout rate (n = 16). The power and alpha values were kept at .80 and .05, respectively, showing that the model would be sensitive enough to detect effects as small as $d = .61$.[14] This study was conducted considering the principles of the Declaration of Helsinki for human research.

### *Experimental Design*

The study was temporally structured into two distinct phases:

- Phase 1: A pre-competitive period (two weeks prior to the onset of the season), during which maximal laboratory-based exercise tests were conducted.
- Phase 2: A competitive period, during which 10 consecutive official league matches (Matchdays 2 to 11) were analyzed.

The laboratory tests performed during Phase 1 included:

1. A Wingate anaerobic test (WIN),
2. A maximal incremental ramp test on a cycle ergometer (CYC), and
3. A maximal incremental step test on a treadmill (TRE).

In Phase 2, 10 official league matches spanning from Matchday 2 to Matchday 11 were analyzed.

For each phase, two categories of variables were monitored:

1. Psychological variables: Perceived stress levels (PSS), Mood states (POMS), and Perceived exertion (RPE).
2. Physiological variables: Maximum heart rate (HRmax), defined as the highest absolute value recorded during each laboratory test and competitive match; Heart rate zones (HRZ), according to Edwards,[15] and analyzed during Live Time (LT) defined as the period in which the player is on the court, the ball is in play, and the game clock is running; Fluid balance;[16] Blood pressure[17] and Blood lactate concentration.[18]

### *Procedures*

#### Phase 1: Pre-Competition Assessments

Two weeks prior to the start of official match data collection, players underwent a comprehensive medical evaluation that included anamnesis, physical examination, and anthropometric measurements. Three days before the scheduled medical assessments, players were contacted and instructed to avoid strenuous physical activity and the consumption of caffeinated or carbonated beverages for at least 12 hours before testing. Participants were asked to abstain from smoking for at least three hours before testing. Upon arrival at the laboratory, they provided written informed consent, confirming their agreement with both the testing procedures and the data protection policy.

A certified sports medicine physician conducted a full medical screening, which included a detailed health history interview and a resting 12-lead electrocardiogram. All procedures were carried out under controlled environment (temperature: 18–22ºC; relative humidity: 40–60%). Anthropometric measurements were then obtained, including height (Seca® 220 stadiometer, Hamburg, Germany; accuracy: .10 cm), body mass (Seca® 700 column scale, Hamburg, Germany; accuracy: .05 kg), arm span (Smartmet anthropometer, Zapopan, Mexico; wall-mounted, level with the floor), and body fat percentage (HBF-306-E, Omron Healthcare Europe, B.V., Hoofddorp, The Netherlands; accuracy: .10%).

*Laboratory Test Scheduling*

The laboratory evaluations were distributed across two separate sessions, spaced 48 hours apart to allow for adequate recovery. During the first session, participants performed the Wingate test (WIN) and the incremental ramp cycle ergometer test (CYC), separated by a 30-minute recovery period. The incremental treadmill test (TRE) was administered in the second session. To minimize possible order effects, participants were randomly assigned to two groups: one group completed the WIN and CYC test first, while the other began with the TRE test and carried out the remaining assessments on the following day.

*Test Descriptions*

- Wingate Test (WIN): this anaerobic test required participants to pedal on a cycle ergometer (Ergoline, Ergoselect 4, Bitz, Germany) at maximal speed for 30 seconds after a 5-minute warm-up. Revolutions per minute (rpm) were recorded every 5 seconds, and gas exchange was analyzed using the Quark CPET system (Cosmed, Rome, Italy). Resistance was set at 75 g/kg of body weight.
- Cycle Ergometer Test (CYC): this maximal ramp protocol on a cycle ergometer (Ergoline, Ergoselect 4, Bitz, Germany) began with a 4-minute warm-up at 20 W. Starting from minute 4, power output increased by 25 W every minute. Cadence was maintained between 70 and 100 rpm. Gas analysis was performed using the Quark CPET (Cosmed, Rome, Italy).
- Treadmill Test (TRE): this continuous, maximal incremental test on a treadmill (hp Cosmos Saturn, hp Cosmos, Traunstein, Germany) used a constant incline of 1%. After a 2-minute warm-up at 4 km/h, speed increased by 1 km/h every minute starting from minute 3 (baseline 6 km/h). Gas exchange was measured with the Quark CPET system (Cosmed, Rome, Italy).

**Phase 2: Competition Period**

To ensure proper familiarization with data collection protocols, the first official league match (Matchday 1) served as a preparatory session for both participants and the research staff. During Phase 2, data were collected across 10 consecutive official matches (Matchdays 2 to 11), corresponding to the highest regional competitive category in Catalonia (Spain): the Catalan Women's Senior League.

**Variable Recording**

Throughout the execution of both laboratory tests and official matches, a set of variables was systematically recorded with the aim of comparing the physical and psychological demands across different settings.

**Psychological Variables:**

*Perceived Stress Scale (PSS):* Perceived stress was evaluated using the Spanish adaptation of the Perceived Stress Scale (PSS),[19] administered prior to each test and competitive match. The PSS is a widely used self-report tool that assesses perceived stress levels over the past month. It consists of 14 items rated on a five-point Likert scale (0 = never, 1 = almost never, 2 = sometimes, 3 = often, 4 = very often).

To calculate the total score, responses to items 4, 5, 6, 7, 9, 10, and 13 are reverse-coded (i.e., 0 = 4, 1 = 3, 2 = 2, 3 = 1, 4 = 0), after which all item scores are summed. The resulting score reflects the participant's overall level of perceived stress, with higher scores indicating greater stress.

*Profile of Mood State:* Mood states were assessed using the Spanish translated version of the POMS questionnaire.[20] This is a 58-item inventory of six subscales: tension–anxiety, depression–dejection, anger–hostility, vigor–activity, fatigue–inertia, and confusion–bewilderment. Each item was responded to by the participants on a 5-point Likert scale anchored by 0 (not at all) and 4 (extremely). The score of each factor is obtained by the sum of the answers of the items that compose each subscale. All items have the same direction except two: "relaxed" from the tension–anxiety subscale and "efficient" from the confusion–bewilderment subscale, which are inverted. Total Mood Disturbance (TMD) is obtained with the sum of the subscale scores. It should be noted that the vigor–activity subscale is subtracted instead of summed. To avoid negative scores, a 100-point constant was added to the total score.

*Rate of Perceived Exertion*: Obtaining the RPE declared after the laboratory test and Match, once the event ended, the players completed the Original Borg scale[21] (a scale of 15 points (6-20), where 6 is a very, very slight perception, and 20 is a very, very hard perception) in response to the question "How much have I exerted myself in relation to my 100% best?" The questionnaire was administered 30' after each event.[22] To prevent participants' responses being influenced by those of their peers, the registration was carried out individually in an area set up for this purpose, and the participants were prevented from commenting on the marked result.

**Physiological Variable Monitoring**

*Heart Rate Monitoring*: Heart rate (HR) was continuously monitored using Garmin™ chest strap sensors (Garmin Ltd., Olathe, Kansas, USA) operating at a frequency of 4 Hz, paired with WIMU Pro™ UWB devices (RealTrack Systems, Almería, Spain) recording at 100 Hz. This system has been previously validated for HR measurement ($R^2$ = .96) and spatial tracking (*ICC* = .98).[23,24] To complement the physiological data, each match was also recorded using two synchronized video cameras (Panasonic HC-V380EG-K, 2.51 MP, Full HD, Kadoma, Osaka, Japan). Synchronization with the UWB devices was achieved using both visual and acoustic signals at three specific moments: immediately before the warm-up, at the start of the match, and at the beginning of the second half.

*Fluid Balance Assessment*: To assess hydration status, players underwent body mass measures immediately before and after each test and match using a Siltec Large Capacity Model GS-1 scale (Ohaus, Ohio, USA). Individual rehydration containers were also assigned and weighed pre- and post-activity using a precision scale (Traveler TA5000, Ohaus, Ohio, USA). In cases where containers were refilled during the session, a member of the research team documented the volume added. Fluid balance was calculated using the formula by Cox et al.:[16] Fluid loss (kg) =

Pre-match body mass (kg) – Post-match body mass (kg) + Fluid ingested (kg) – Fluid excreted (kg). Results were expressed as a percentage relative to the player's body mass.

*Blood Pressure Measurement*: Blood pressure was assessed before and after each test and match using the OMRON HEALTHCARE M2 Basic sphygmomanometer (HEM-7120-E, Omron Healthcare Europe, B.V., Hoofddorp, The Netherlands), a validated derivative of the Omron HEM-7130 model, following the guidelines provided by James & Gerber.[17]

*Lactate Analysis*: Capillary blood lactate was measured before and after each test and match. Samples were obtained from the earlobe using the Lactate Scout photometer (Lactate Plus DP110, Diaglobal GmbH, Berlin, Germany), following the protocol by Sánchez-Arjona et al.[18]

***Statistical analysis***

To confirm the data normality of each dataset, a Kolmogorov–Smirnov test, a *Q-Q* plot of residuals, and a random coefficient histogram were used. Mixed model analyses were used to compare the psycho-physiological demands of Match, Wingate, Treadmill and Cycle Ergometer conditions. The model used for each dependent parameter included type of condition (i.e., Match, Wingate, Cycle, and Treadmill) as independent fixed factor and random intercepts on the individual player. A log-likelihood ratio test was used to assess the goodness of fit of the models. Planned contrasts were specified to assess the differences between the Match and the other conditions. To evaluate differences in risk across conditions, mixed-model analyses were conducted. The model used included type of condition (i.e., Wingate, Cycle, and Treadmill) as independent fixed factor and random intercepts on the individual player. A log-likelihood ratio test was used to assess the goodness of fit of the models. To assess the differences between each condition, post-hoc analyses with Bonferroni's correction were applied. Standardized mean difference and Cohen effect sizes were obtained and interpreted as: <.20 = trivial; .20–.60 = small; .60-1.20 = moderate; 1.20–2.00 = large; > 2.00 = very large.[14] Statistical significance was established at α <.05. Data analysis was performed using JAMOVI for Mac (version 2.6.25, The Jamovi Project, Sidney, Australia) and the GAMLj jamovi module: General analyses for linear models.

## Results

**Cardiovascular responses.**

Heart rate profiles revealed distinct patterns between match and laboratory conditions (Table 1). Both the WIN and CYC tests elicited a lower HRmax compared to the Match (WIN: *d* = -.75, 95% CI [-.95, -.56], *P*< .001, moderate; CYC: *d* = -.77, 95% CI [-.96, -.57], *P*< .001, moderate). In contrast, no difference was observed for the Treadmill (TRE) condition.

The distribution of time across HR zones showed pronounced differences. All laboratory tests resulted in a significant reduction in the highest intensity zone (z5) compared to the Match (WIN: *d* = -.38, 95% CI [-.54, -.22], *P*< .001, small; CYC: *d* = -.53, 95% CI [-.70, -.36], *P*< .001, small; TRE: *d* = -.29, 95% CI [-.45, -.13], *P*< .001, small). This was compensated by increased time in lower and moderate-intensity zones. The CYC and TRE conditions showed significant increases in zones z0, z1, z2, and z3 (all with small to moderate effect sizes). The WIN test, however, led to a significant increase specifically in the z3 (*d* = .43, 95% CI [.27, .60], *P*< .001, small) and z4 zones (*d* = .32, 95% CI [.16, .48], *P*< .001, small), while the CYC condition showed a decrease in z4 (*d* = -.16, 95% CI [-.31, .00], *P*= .045, trivial).

A key additional finding concerned the proportion of match live time that athletes spent above the HRmax values obtained in each of the laboratory tests (t> HRmax). During the WIN and CYC tests, players' heart rates exceeded this threshold for a substantial portion of the match live time (54.36 ± 33.83% and 54.02 ± 32.77%, respectively). These values were significantly greater than the time recorded during the TRE condition (8.99 ± 16.88%; WIN vs. TRE: *MD* = -45.37%, 95% CI [-50.42, -40.32], *P*< .001, *d* = -.89, 95% CI [-1.02, -.76], moderate; CYC vs. TRE: *MD* = 45.03%, 95% CI [39.98, 50.08], *P*< .001, *d* = .88, 95% CI [.75, 1.01], moderate), with no statistically significant difference between the WIN and CYC protocols (*MD* = .34%, 95% CI [-4.71, 5.39], *P*= 1.000, *d* = .01, 95% CI [-.09, -.11], trivial).

**Psychological Variables.**

Marked differences in perceptual responses were found (Table 2). Participants reported higher RPE values on both the RPE-20 and RPE-10 scales following all laboratory tests compared to the Match (all with small effect sizes ranging from *d* = .27, 95% CI [.11, .42] to .36, 95% CI [.20, .53], all *P*< .001). Regarding mood states, both the WIN and CYC tests induced greater feelings of fatigue (*d* = .16, 95% CI [.00, .31], *P*= .046, trivial) compared to the Match. The TRE condition was uniquely associated with a significant increase in vigour (*d* = .23, 95% CI [.08, .39], *P*= .003, small). No other significant differences were found for stress, tension, depression, anger, confusion, or TMD. It should be noted that, due to the testing protocol, the Stress and POMS variables for the WIN and CYC tests were measured only once, hence the identical values.

**Metabolic, Hemodynamic, and Body Composition Measures.**

Significant contrasts emerged in metabolic and cardiovascular strain (Table 3). All laboratory conditions began with lower pre-exercise lactate levels than the Match (WIN: *d* = -.48, 95% CI [-.69, -.26], *P*< .001, small; CYC: *d* = -.47, 95% CI [-.69, -.25], *P*< .001, small; TRE: *d* = -.34, 95% CI [-.55, -.14], *P*< .001, small). Post-exercise, this pattern reversed dramatically, with substantially elevated lactate concentrations in all tests compared to the Match, showing large to moderate effect sizes (WIN: *d* = 1.22, 95% CI [.88, 1.55], *P*< .001, large; TRE: *d* = 1.04, 95% CI [.74, 1.34], *P*< .001, moderate; CYC: *d* = .91, 95% CI [.62, 1.19], *P*< .001, moderate).

Regarding blood pressure, DBP_post was consistently lower in WIN and CYC conditions compared to the Match (WIN: *d* = -.23, 95% CI [-.39, -.08], *P*= .003, small; CYC: *d* = -.29, 95% CI [-.45, -.13], *P*< .001, small). In contrast, the WIN test produced a significantly higher SBP_post than the Match (*d* = .32, 95% CI [.16, .48], *P*< .001, small), a difference not observed in the other tests. A lower SBPHR_pre was also found for the WIN condition compared to the Match (*d* = -.25, 95% CI [-.42, -.10], *P*= .001, small).

Finally, a critical finding was that all laboratory protocols resulted in significantly less body weight loss than the Match condition, with the most pronounced effect observed after the WIN test (*d* = -.63, 95% CI [-.80, -.45], *P*< .001, moderate), followed by the CYC (*d* = -.58, 95% CI [-.75, -.40], *P*< .001, small) and TRE (*d* = -.52, 95% CI [-.69, -.35], *P*< .001, small) tests.

***INSERT TABLE 1 NEAR HERE***

***INSERT TABLE 2 NEAR HERE***

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**Table 1.** Values of the HR variables measured in the different conditions.

| Variable | Match | WIN | CYC | TRE |
|---|---|---|---|---|
| HRmax (bpm) | 187.76 ± 17.63 | 175.76 ± 9.90$^{*M}$ | 175.69 ± 9.07$^{*M}$ | 188.52 ± 8.98 |
| z0 (%) | .01 ± .10 | .00 ± .00 | .72 ± 1.69$^{*S}$ | .54 ± 1.26$^{*S}$ |
| z1 (%) | .41 ± 1.49 | .00 ± .00 | 15.67 ± 11.15$^{*M}$ | 5.21 ± 6.63$^{*S}$ |
| z2 (%) | 1.94 ± 4.88 | .83 ± 3.33 | 20.69 ± 8.28$^{*M}$ | 17.75 ± 13.17$^{*M}$ |
| z3 (%) | 8.02 ± 11.66 | 22.50 ± 18.99$^{*S}$ | 28.71 ± 5.55$^{*M}$ | 21.13 ± 5.12$^{*S}$ |
| z4 (%) | 37.37 ± 22.98 | 57.93 ± 18.33$^{*S}$ | 27.05 ± 12.00$^{*T}$ | 30.01 ± 7.91 |
| z5 (%) | 47.87 ± 28.68 | 18.76 ± 26.60$^{*S}$ | 7.16 ± 9.65$^{*S}$ | 25.36 ± 15.45$^{*S}$ |
| t>HRmax (%) | -- | 54.36 ± 33.83$^{\wedge M}$ | 54.02 ± 32.77$^{\wedge M}$ | 8.99 ± 16.88 |

Values are presented as mean ± SD. Match: mean values of the heart rate variables for the Match condition during the live time; WIN: mean values for the Wingate condition; CYC: mean values for the Cycle ergometer condition; TRE: mean values for the treadmill condition; z0: percentage of minutes accumulated under 50% of the heart rate maximum; z1: percentage of minutes accumulated between 50 and 60 % of the heart rate maximum; z2: percentage of minutes accumulated between 60 and 70 % of the heart rate maximum; z3: percentage of minutes accumulated between 70 and 80 % of the heart rate maximum; z4: percentage of minutes accumulated between 80 and 90 % of the heart rate maximum; z5: percentage of minutes accumulated between 90 and 100 % of the heart rate maximum; t>HRmax (%): time of the match live time spent above the HRmax obtained in the laboratory test; **P*≤ .05 statistically significant from Match values; $^{T}$: trivial effect size; $^{S}$: small effect size; $^{M}$: medium/moderate effect size; $^{L}$: large effect size; $^{VL}$: very large effect size. ^: *P*≤ .05 statistically significant from TRE values.

**Table 2.** Values of the psychological variables measured in the different conditions.

| Variable | Match | WIN | CYC[a] | TRE |
|---|---|---|---|---|
| RPE-20 (AU) | 14.29 ± 3.23 | 17.56 ± 1.26$^{*S}$ | 17.44 ± 1.90$^{*S}$ | 16.69 ± .95$^{*S}$ |
| RPE-10 (AU) | 6.34 ± 2.30 | 8.50 ± .52$^{*S}$ | 8.63 ± 1.15$^{*S}$ | 8.13 ± .72$^{*S}$ |
| Stress (AU) | 29.07 ± 8.28 | 27.81 ± 5.89 | 27.81 ± 5.89 | 27.88 ± 5.54 |
| Tension (AU) | 10.17 ± 4.87 | 10.81 ± 3.90 | 10.81 ± 3.90 | 11.00 ± 4.37 |
| Depression (AU) | 7.74 ± 8.47 | 8.13 ± 4.57 | 8.13 ± 4.57 | 7.06 ± 4.43 |
| Anger (AU) | 8.03 ± 6.10 | 8.19 ± 3.82 | 8.19 ± 3.82 | 8.50 ± 4.31 |
| Vigour (AU) | 10.78 ± 4.52 | 11.88 ± 3.58 | 11.88 ± 3.58 | 13.31 ± 4.05$^{*S}$ |
| Fatigue (AU) | 6.02 ± 4.28 | 7.69 ± 3.75$^{*T}$ | 7.69 ± 3.75$^{*T}$ | 7.25 ± 4.07 |
| Confusion (AU) | 5.93 ± 3.61 | 6.13 ± 3.07 | 6.13 ± 3.07 | 6.13 ± 3.03 |
| TMD (AU) | 127.12 ± 23.01 | 129.06 ± 9.48 | 129.06 ± 9.48 | 126.63 ± 13.35 |

Values are presented as mean ± SD. Match: mean values of the psychological variables for the Match condition; WIN: mean values for the Wingate condition; CYC: mean values for the Cycle ergometer condition; TRE: mean values for the treadmill condition; RPE-20: Rate of perceived exertion; Stress: Perceived stress scale; TMD: Total Mood Disturbance; AU: Arbitrary units; **P*≤ .05 statistically significant from Match values; $^{T}$: trivial effect size; $^{S}$: small effect size; $^{M}$: medium/moderate effect size; $^{L}$: large effect size; $^{VL}$: very large effect size. [a]: Due to the protocol applied for conducting the tests, the WIN and CYC tests were performed with a 30-minute interval. This made it impossible to repeat the measurement of psychological variables, as these tests are not sensitive to short time periods. That is why Stress and POMS values are the same in both tests.

**Table 3.** Values of the lactate, blood pressure and bodyweight loss variables measured in the different conditions.

| Variable | Match | WIN | CYC | TRE |
|---|---|---|---|---|
| Lactate (mmol·L$^{-1}$) | | | | |
| Pre (mmol·L$^{-1}$) | 2.60 ± .57 | 1.94 ± .27$^{*S}$ | 1.96 ± .27$^{*S}$ | 2.13 ± .46$^{*S}$ |
| Post (mmol·L$^{-1}$) | 3.85 ± 1.49 | 9.39 ± 1.77$^{*L}$ | 7.98 ± 2.33$^{*M}$ | 8.58 ± 2.78$^{*M}$ |
| Blood pressure (mm Hg) | | | | |
| SBP_pre (mm Hg) | 113.12 ± 11.77 | 111.38 ± 8.58 | 108.56 ± 5.55 | 113.88 ± 8.44 |
| SBP_post (mm Hg) | 113.56 ± 11.86 | 124.69 ± 8.30$^{*S}$ | 114.50 ± 7.48 | 117.81 ± 9.79 |
| DBP_pre (mm Hg) | 77.36 ± 14.73 | 73.69 ± 8.61 | 74.00 ± 8.98 | 75.44 ± 7.48 |
| DBP_post (mm Hg) | 80.09 ± 13.47 | 70.69 ± 6.42$^{*S}$ | 68.31 ± 5.85$^{*S}$ | 76.50 ± 6.68 |
| SBPHR_pre (mm Hg) | 78.18 ± 10.41 | 70.44 ± 10.42$^{*S}$ | 80.31 ± 11.94 | 75.44 ± 7.48 |
| SBPHR_post (mm Hg) | 100.55 ± 12.20 | 105.31 ± 12.43 | 97.75 ± 13.85 | 102.50 ± 11.56 |
| Body mass loss (%) | 1.18 ± .83 | .00 ± .00$^{*S}$ | .09 ± .10$^{*S}$ | .19 ± .19$^{*S}$ |

Values are presented as mean ± SD. Match: mean values of the lactate and blood pressure variables for the Match condition; WIN: mean values for the Wingate condition; CYC: mean values for the Cycle ergometer condition; TRE: mean values for the treadmill condition; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; **P*≤ .05 statistically significant from Match values; $^{T}$: trivial effect size; $^{S}$: small effect size; $^{M}$: medium/moderate effect size; $^{L}$: large effect size; $^{VL}$: very large effect size.

## Discussion

The primary objective of this study was to determine the ecological validity of common maximal laboratory exercise tests by comparing them with the demands of official competition in amateur female handball players. Our findings indicate that none of the laboratory tests—Wingate (WIN), cycle ergometer (CYC), or treadmill (TRE)—fully replicated the multifaceted physiological, psychological, and metabolic demands encountered during actual match play. The following discussion is structured to address these discrepancies in alignment with the results, focusing sequentially on cardiovascular, psychological, and metabolic/hemodynamic responses.

**Cardiovascular Responses**

The analysis of cardiovascular profiles revealed fundamental differences between laboratory tests and match play. Both the WIN and CYC tests elicited significantly lower HRmax compared to matches, with moderate effect sizes (*d* = -.75 to -.77). In contrast, the TRE test achieved a comparable HRmax to competition. However, the distribution of time across heart rate zones provided a more nuanced picture of intensity distribution. All laboratory tests resulted in a significantly reduced proportion of time spent in the highest intensity zone (z5) compared to matches, which was compensated by increased time in low-to-moderate intensity zones (z0-z3). Specifically, the WIN test led to more time in zones z3 and z4, while the CYC and TRE tests showed pronounced increases in zones z0 to z3.

This pattern suggests that the continuous or short-term maximal nature of laboratory tests fails to replicate the intermittent, high-intensity bursts characteristic of the sport,[25] where players frequently operate at or near their maximum cardiovascular capacity. A critical finding underscoring this limitation is the proportion of match live time that players spent above their laboratory-derived HRmax (i.e. t> HRmax).[26] For over half of the effective playing time (54.36% and 54.02% for WIN and CYC, respectively), players' heart rates exceeded the peaks recorded in these tests. The large standard deviation observed for WIN (± 33.83%) suggests that positional roles may have contributed to this variability. This starkly illustrates that the cardiovascular system is subjected to far greater and more frequent peak strains during competition than what is elicited by the WIN and CYC protocols. Although the TRE test matched the absolute HRmax, the significantly lower t>HRmax value (8.99%) confirms that even this test does not provoke the repeated supra-maximal cardiovascular efforts seen in actual play. These results align with the intermittent nature of team sports, where the physiological profile is defined by variability and peak efforts rather than sustained high outputs.[27,28]

**Psychological Variables**

Marked dissociations were observed between physiological and perceptual measures. Despite experiencing a lower overall physiological strain in the laboratory—as indicated by lower body mass loss and pre-exercise lactate levels—participants reported significantly higher Ratings of Perceived Exertion (RPE) on both the RPE-20 and RPE-10 scales following all laboratory tests compared to matches (small effect sizes: *d* = .27 to .36). This paradox highlights a critical limitation in the ecological validity of these tests.

The standardized, monotonous, and physically isolating environment of the laboratory, where the athlete's focus is directed almost exclusively to the sensation of effort, likely amplifies the perception of exertion.[29,30] In contrast, during competition, psychological factors such as game strategy, situational awareness, scoreboard pressure, and the motivating context of team dynamics and spectatorship may divert attention from internal sensations of fatigue, leading to a lower RPE for a given, or even greater, physiological cost.[31] This is supported by the "rebound effect" described in intermittent activities, where affective responses and perceived exertion are more favorable compared to continuous exercise.[32] Furthermore, mood state profiles indicated that the WIN and CYC tests induced greater feelings of fatigue than matches, while the TRE test was associated with a significant increase in vigour. No significant differences were found for stress, tension, depression, anger, confusion, or Total Mood Disturbance, suggesting that the laboratory tests primarily increased the perception of physical effort and fatigue without markedly altering emotional states.

**Metabolic, Hemodynamic, and Body Composition Measures**

Significant contrasts were also evident in metabolic and hemodynamic responses, reinforcing the gap between laboratory and competitive environments. Pre-exercise blood lactate levels were consistently lower in all laboratory conditions compared to matches, likely reflecting the absence of the pre-competitive activation and warm-up routines inherent to official games. Post-exercise, this pattern reversed dramatically, with lactate concentrations substantially elevated in all tests compared to matches, showing large to moderate effect sizes (WIN: *d* = 1.22; TRE: *d* = 1.04; CYC: *d* = .91). In intermittent sports, blood lactate concentration reflects a balance between production and clearance; thus, the lower post-match values may partly result from clearance during low-intensity phases prior to the final whistle. This indicates that while the laboratory tests provide an intense, concentrated glycolytic challenge, they do not mimic the dynamic lactate kinetics of a handball match, where intermittent activity allows for periods of resynthesis and clearance.[33,34] The single post-exercise measurement in the match likely underestimates the peak lactate levels reached during the most intense phases of play.

Hemodynamic responses further differentiated the conditions. Diastolic blood pressure (DBP_post) was consistently lower after the WIN and CYC tests compared to the match, while the WIN test produced a significantly higher systolic blood pressure (SBP_post) than match play. The combination of high SBP and low DBP in the WIN test resulted in an increased pulse pressure, a response characteristic of intense, isolated anaerobic efforts that differs from the more variable circulatory demands of match play, which allow for partial hemodynamic recovery during lower-intensity periods.[35,36]

Finally, a key indicator of overall physiological strain, body mass loss (a proxy for fluid loss and thermoregulatory demand), was significantly lower in all laboratory conditions than during matches. The most pronounced difference was observed after the WIN test (*d* = -.63, moderate). This finding strongly suggests that the laboratory setting, with its controlled climate and shorter duration, fails to induce the thermoregulatory and metabolic stress imposed by the prolonged, intermittent, and externally influenced conditions of real competition.[37]

**Future Directions**

In line with findings from other sports, such as basketball,[12] and supporting evidence from field-based testing in soccer,[38] our study suggests that traditional laboratory-based fitness tests do not accurately reflect the physiological demands experienced by amateur handball players during official matches. These findings underscore the need for develop assessment protocols that more closely reflect the demands of actual gameplay.[39] Nevertheless, they should be interpreted with caution, as the findings are particularly relevant to amateur female handball players with characteristics comparable to those of the sample analyzed.

Despite the insights provided by this study, some limitations should be acknowledged. The small sample size may limit the generalizability of the results, and caution is warranted when extrapolating the findings to other sports with different gameplay characteristics. In addition, testing was conducted only once, prior to the competitive period. Future studies should consider repeating assessments after the monitored matches to track potential changes over time. Finally, performing the WIN and CYC within the same session, with only 30 minutes of recovery, may have led to residual fatigue affecting the second test results.
To more accurately evaluate player performance, upcoming research should explore protocols that capture the physiological, metabolic, and psychological demands of handball. This might include validated field tests for intermittent sports[40] or the creation of handball-specific assessments that integrate intermittent effort, pace variations, and decision-making tasks. Moreover, hybrid protocols that combine laboratory measures with sport-specific exercises could help bridge the gap between controlled testing and the realities of competition.

## Practical Applications

The results of this study can help coaches better evaluate amateur female handball players. Traditional laboratory tests often fail to capture the stop-and-start rhythm and repeated bursts of high intensity that occurs during real matches, so assessments and training programs should reflect these demands.
For instance, drills that mix repeated sprints with changes of direction and brief recovery periods are likely to prepare athletes more effectively for the metabolic challenges of competition. Coaches may also find it useful to track both heart rate and players perceived exertion during these drills, as this combination offers a more complete sense of a player's readiness and resilience in situations that mimic actual match play.
In addition, sport-specific field tests, such as the Yo-Yo Intermittent Recovery Test or the 30-15 Fitness Test, could provide further insights into player fitness under conditions that closely resemble match play. Implementing these practical tools can help amateur coaches design more effective and realistic training programs.

## Conclusions

The results of this study highlight important limitations of traditional maximal laboratory tests in capturing the physiological, metabolic, and psychological demands faced by amateur female handball players during official competition. None of the tests examined were able to reproduce the peak heart rates observed in actual match play. Interestingly, players reported significantly higher ratings of perceived exertion (RPE) in the laboratory, even though their body mass was lower and the thermoregulatory strain was reduced compared with competition. These findings suggest that conventional performance evaluations may not fully reflect the realities of the sport, emphasizing the need to adopt testing protocols that are more specific and contextually relevant.

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## Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

## Ethical Committee approval

The study protocol was approved by the "Ethics Committee for Clinical Research of the Catalan Sports Council" n. 024/ CEICGC/2022, Esplugues de Llobregat, Catalonia, Spain.

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## Topic

Sport science

## Conflicts of interest

The authors have no conflicts of interest to declare.

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## Author-s contribution

Conceptualization, A.B-G, J.V.B-G and G.D-S.; methodology, A.B-G, J.V.B-G and G.D-S; software, R.M-C and J.V.B-G; validation, F.C; formal analysis, J.V.B-G; investigation, A.B-G,; resources, A.B-G, F.C and G.D-S; data curation, J.V.B-G; writing—original draft preparation, A.B-G, J.V.B-G and A.R-G; writing—review and editing, R.M-C., F.C and G.D-S; visualization, J.V.B-G.

## References

1. American College of Sports Medicine, Liguori G, Feito Y, Fountaine CJ, Roy B, eds. *ACSM's Guidelines for Exercise Testing and Prescription*. Eleventh edition. Philadelphia: Wolters Kluwer; 2022.
2. Myers J, Arena R, Franklin B, et al. Recommendations for Clinical Exercise Laboratories: A Scientific Statement From the American Heart Association. *Circulation*. 2009;119(24):3144-3161. doi:10.1161/ CIRCULATIONAHA.109.192520
3. Löllgen H, Leyk D. Exercise Testing in Sports Medicine. *Dtsch Ärztebl Int*. June 2018. doi:10.3238/ arztebl.2018.0409
4. Hamlin M, Draper N, Blackwell G, Shearman J, Kimber N. Determination of Maximal Oxygen Uptake Using the Bruce or a Novel Athlete-Led Protocol in a Mixed Population. *J Hum Kinet*. 2012;31(2012):97-104. doi:10.2478/v10078-012-0010-z
5. Currell K, Jeukendrup AE. Validity, Reliability and Sensitivity of Measures of Sporting Performance: *Sports*

*Med*. 2008;38(4):297-316. doi:10.2165/00007256-200838040-00003
6. Fritz B, Parkar AP, Cerezal L, et al. Sports Imaging of Team Handball Injuries. *Semin Musculoskelet Radiol*. 2020;24(03):227-245. doi:10.1055/s-0040-1710064
7. Manchado C, Pers J, Navarro F, Han A, Sung E, Platen P. Time-motion analysis in women's team handball: importance of aerobic performance. *J Hum Sport Exerc*. 2013;8(2):376-390. doi:10.4100/jhse.2012.82.06
8. Michalsik L, Madsen K, Aagaard P. Match Performance and Physiological Capacity of Female Elite Team Handball Players. *Int J Sports Med*. 2014;35(07):595-607. doi:10.1055/s-0033-1358713
9. Bělka J, Hůlka K, Šafář M, Weisser R. External and internal load of playing positions of elite female handball players (U19) during competitive matches. *Acta Gymnica*. 2016;46(1):12-20. doi:10.5507/ag.2015.025
10. Karpan G, Škof B, Bon M, Šibila M. Analysis of female handball players' effort in different playing positions during oficial matches. *Kinesiology*. 2015;(47(1)):100-107.
11. Kale M. Effects of 6-week pre-season plyometric training to performance characteristics in female handball players. *Fiz Kult*. 2016;70(2):145-154. doi:10.5937/fizkul1602145K
12. Batalla-Gavalda A, Beltran-Garrido JV, Garrosa-Martín G, Montoliu-Colás R, Corbi F. Do stress tests reflect the intensity reached during competition in amateur men's basketball? *Kinesiology*. 2024;56(2):312-324. doi:10.26582/k.56.2.14
13. Gadea Uribarri H, Lago-Fuentes C, Bores-Arce A, et al. Validity of a new tracking device for futsal match. *Acta Kinesiol*. 2024;17(2):17-21. doi:10.51371/issn.1840-2976.2023.17.2.3
14. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive Statistics for Studies in Sports Medicine and Exercise Science. *Med Sci Sports Exerc*. 2009;41(1):3-12. doi:10.1249/MSS.0b013e31818cb278
15. Edwards S. *Heart Rate Monitor Book*. Polar CIC Inc.,US. New York: New York; 1993.
16. Cox G, Broad E, Riley M, Burke L. Body mass changes and voluntary fluid intakes of elite level water polo players and swimmers. *J Sci Med Sport*. 2002;5(3):183-193. doi:10.1016/S1440-2440(02)80003-2
17. James GD, Gerber LM. Measuring arterial blood pressure in humans: Auscultatory and automatic measurement techniques for human biological field studies. *Am J Hum Biol*. 2018;30(1):e23063. doi:10.1002/ajhb.23063
18. Sánchez Arjona C, Ruiz Martínez Y, Martín Fernández MC. Influencia del lugar de extracción en la determinación de los niveles de lactato durante una prueba de esfuerzo incremental. *Rev Andal Med Deporte*. 2008;1(2):57-60.
19. Remor E. Psychometric Properties of a European Spanish Version of the Perceived Stress Scale (PSS). *Span J Psychol*. 2006;9(1):86-93. doi:10.1017/S1138741600006004
20. Balaguer I, Durá I, Meliá J, García-Merita M, Pérez-Recio G. El perfil de los estados de ánimo (POMS): Baremo para estudiantes valencianos y su aplicación en el contexto deportivo. *Rev Psicol Deporte*. 1993;4:39-52.
21. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14(5):377-381.
22. Moreira A, McGuigan MR, Arruda AF, Freitas CG, Aoki MS. Monitoring Internal Load Parameters During Simulated and Official Basketball Matches. *J Strength Cond Res*. 2012;26(3):861-866. doi:10.1519/JSC.0b013e31822645e9
23. Molina-Carmona I, Gómez-Carmona C, Bastida-Castillo A. Validez del dispositivo inercial WIMU PROtm para el registro de la frecuencia cardiaca en un test de campo. *SPORT TK-Rev Euroam Cienc Deporte*. 2018;7 (1):81-86. doi:https://doi.org/10.6018/321921
24. Muñoz-López A, Granero-Gil P, Pino-Ortega J, De Hoyo M. The validity and reliability of a 5-hz GPS device for quantifying athletes' sprints and movement demands specific to team sports. *J Hum Sport Exerc*. 2017;12(1). doi:10.14198/jhse.2017.121.13
25. Batalla-Gavalda A, Beltran-Garrido JV, Garrosa-Martín G, Montoliu-Colás R, Corbi F. Do stress tests reflect the intensity reached during competition in amateur men's basketball? *Kinesiology*. 2024;56(2):312-324. doi:10.26582/k.56.2.14
26. Rudarlı G, Tutar M, KAYITKEN B. Effects of Different Endurance Training Models on Players' Fitness Levels during the National Break in the Football Season. *Acta Kinesiol*. 2024;18(3):69-77.
27. Castañeda-Babarro A. The Wingate Anaerobic Test, a Narrative Review of the Protocol Variables That Affect the Results Obtained. *Appl Sci*. 2021;11(16):7417. doi:10.3390/app11167417
28. García-Sánchez C, Navarro RM, Nieto-Acevedo R, De La Rubia A. Does the Final Score Influence the Physical Demands of Women's Handball Matches? *Montenegrin J Sports Sci Med*. 2024;13(2):21-27. doi:10.26773/mjssm.240903
29. Sansone P, Gasperi L, Tessitore A, Gomez M. Training load, recovery and game performance in semiprofessional male basketball: influence of individual characteristics and contextual factors. *Biol Sport*. 2021;38(2):207-217. doi:10.5114/biolsport.2020.98451
30. Batalla Gavaldà A, Bofill Ródenas AM, Montoliu Colás R, Corbi Soler F. Relación entre la frecuencia cardíaca y el marcador durante una fase de descenso [Relationship between Heart Rate and the Scoreboard during a Relegation Playoff]. *Apunts Educ Física Deport*. 2018;(136):110-122. doi:10.5672/apunts.2014-0983.es.(2018/2).132.08
31. McLaren SJ, Graham M, Spears IR, Weston M. The Sensitivity of Differential Ratings of Perceived Exertion as Measures of Internal Load. *Int J Sports Physiol Perform*. 2016;11(3):404-406. doi:10.1123/ijspp.2015-0223
32. Jung ME, Bourne JE, Little JP. Where Does HIT Fit? An Examination of the Affective Response to High-Intensity Intervals in Comparison to Continuous Moderate- and Continuous Vigorous-Intensity Exercise in the Exercise Intensity-Affect Continuum. Newton RL, ed. *PLoS ONE*. 2014;9(12):e114541. doi:10.1371/journal.pone.0114541
33. Tortu E, Ouergui I, Ulupinar S, Özbay S, Gençoğlu C, Ardigò LP. The contribution of energy systems during 30-second lower body Wingate anaerobic test in combat sports athletes: Intermittent versus single forms and gender comparison. Kuvačić G, ed. *PLOS ONE*. 2024;19(5):e0303888. doi:10.1371/journal.pone.0303888
34. Warr-di Piero D, Valverde-Esteve T, Redondo-Castán JC, Pablos-Abella C, Sánchez-Alarcos Díaz-Pintado JV. Effects of work-interval duration and sport specificity on blood lactate concentration, heart rate and perceptual responses during high intensity interval training. Sandbakk Ø, ed. *PLOS ONE*. 2018;13(7):e0200690. doi:10.1371/journal.pone.0200690

35. Huang Z, Wang B, Song K, et al. Metabolic and cardiovascular responses to continuous and intermittent plank exercises. *BMC Sports Sci Med Rehabil*. 2023;15(1):1. doi:10.1186/s13102-022-00613-z
36. Batra A. Monitoring anaerobic performance in combat sport athletes - call for test specificity. *Sport Perform Sci Rep*. 2019;(53):1-3.
37. Macan I, Marinovic M, Kezic A. Asymmetries in Postural Stability and Balance Parameters during Specific Elements in Sub-Elite Rhythmic Gymnasts. *Acta Kinesiol*. 2024;18(3):27-32.
38. Slimani M, Ghouili H, Dhahbi W, et al. Position-specific biomarker responses to match vs. VAMEVAL test modalities in elite female soccer players: a comparative analysis study. *Cogent Soc Sci*. 2025;11(1):2447399. doi: 10.1080/23311886.2024.2447399
39. Khemiri A, BelHaj Amor A, Dhahbi W, Padulo J, Hachana Y, Attia A. Development and Internal Validation of a Field-Based Equation for Predicting Half-Squat One-Repetition Maximum in Youth Soccer Players Using Standing Long Jump Performance and Body Mass. *Acta Kinesiol*. 2025;19(2):35-43. doi:10.51371/issn.1840-2976.2025.19.2.5
40. Dhahbi W, Hachana Y, Souaifi M, Souidi S, Attia A. Tennis-Specific Incremental Aerobic Test (TSIAT): Construct Validity, Inter Session Reliability and Sensitivity. *Tunis J Sports Sci Med*. 2024;2(1):25-32. doi:10.61838/kman.tjssm.2.1.4

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