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Original

Mayor Validez ecológica del Game-Based Performance Test en comparación con el Yo-Yo IR1 en jugadoras de balonmano amateur

Superior Ecological Validity from the Game-Based Performance Test Compared to the Yo-Yo IR1 in Women's Amateur Handball Players

Validade ecológica superior do teste de desempenho baseado em jogos em comparação com o Yo-Yo IR1 em jogadoras de handebol amador feminino

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MAYOR VALIDEZ ECOLÓGICA DEL GAME-BASED PERFORMANCE TEST EN COMPARACIÓN CON EL YO-YO IR1 EN JUGADORAS DE BALONMANO AMATEUR

RESUMEN

Objetivos: Evaluar la capacidad del Yo-Yo Intermittent Recovery Test level 1 (YYIRT-1) y el Game-Based Performance Test (GBPT) para reproducir las respuestas psicofisiológicas y metabólicas observadas durante los partidos oficiales en jugadoras de balonmano amateur.

Métodos: Dieciséis jugadoras (21,9 ± 3,2 años) de la Liga Catalana Femenina Senior (Cataluña, España) completaron ambas pruebas durante la pretemporada y en diez partidos oficiales consecutivos. Se analizaron variables cardiovasculares, perceptivas y fisiológicas-metabólicas mediante modelos mixtos lineales.

Resultados: Ambas pruebas alcanzaron frecuencias cardíacas máximas similares a la competición, pero solo el GBPT replicó la distribución temporal en las zonas moderadas y altas. El RPE fue mayor en ambas pruebas que en los partidos; el YYIRT-1 produjo un perfil de estado de ánimo más negativo que el GBPT y la competición. El lactato sanguíneo fue mayor en las pruebas (GBPT: 8,8 $mmol \cdot L^{-1}$; YYIRT-1: 10,2 $mmol \cdot L^{-1}$) que en los partidos (3,9 $mmol \cdot L^{-1}$). La pérdida de masa corporal fue mayor en competición (1,18%) que en el GBPT (0,15%) y YYIRT-1 (0,31%). Las jugadoras pasaron un 21,9% del tiempo activo de los partidos por encima de la frecuencia cardíaca máxima alcanzada en el YYIRT-1, y un 4,5% en el GBPT.

Conclusiones: El GBPT mostró mayor validez ecológica, reproduciendo mejor las demandas competitivas, mientras que el YYIRT-1 sobreestimó la exposición de baja intensidad e indujo un mayor estrés supramáximo y psicológico.

Palabras clave: Balonmano, Yo-Yo Intermittent Recovery Test, Game Based Performance Test, Capacidad Anaeróbica, Demandas fisiológicas, test de condición física.

SUPERIOR ECOLOGICAL VALIDITY FROM THE GAME-BASED PERFORMANCE TEST COMPARED TO THE YO-YO IR1 IN WOMEN'S AMATEUR HANDBALL PLAYERS

ABSTRACT

Objectives: To evaluate the ability of the Yo-Yo Intermittent Recovery Test level 1 (YYIRT-1) and the Game-Based Performance Test (GBPT) to reproduce the psychophysiological and metabolic responses observed during official matches in amateur handball players.

Methods: Sixteen players (21.9 ± 3.2 years old) from the Catalan Women's Senior League (Catalonia, Spain) completed both tests during the preseason and in ten consecutive official matches. Cardiovascular, perceptual and physiological-metabolic variables were analyzed using linear mixed models.

Results: Both tests achieved maximum heart rates similar to competition, but only the GBPT replicated the temporal distribution in the moderate and high zones. The RPE was higher in both tests than in the matches; the YYIRT-1 produced a more negative mood profile than the GBPT and the competition. Blood lactate was higher in the tests (GBPT: 8.8 $mmol \cdot L^{-1}$; YYIRT-1: 10.2 $mmol \cdot L^{-1}$) than in matches (3.9 $mmol \cdot L^{-1}$). Body mass loss was greater in competition (1.18%) than in GBPT (0.15%) and YYIRT-1 (0.31%). Players spent 21.9% of live time above the maximum heart rate reached in the YYIRT-1, and 4.5% in the GBPT.

Conclusions: The GBPT showed greater ecological validity, better reproducing competitive demands, while the YYIRT-1 overestimated low-intensity exposure and induced greater supramaximal and psychological stress.

Keywords: Handball, Yo-Yo Intermittent Recovery Test, Game Based Performance Test, Anaerobic capacity, Physiological demands, fitness test.

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VALIDADE ECOLÓGICA SUPERIOR DO TESTE DE DESEMPENHO BASEADO EM JOGOS EM COMPARAÇÃO COM O YO-YO IR1 EM JOGADORAS DE HANDEBOL AMADOR FEMININO

RESUMO

Objetivos: Avaliar a capacidade do Yo-Yo Intermitent Recovery Test nível 1 (YYIRT-1) e do Game-Based Performance Test (GBPT) para reproduzir as respostas psicofisiológicas e metabólicas observadas durante jogos oficiais em jogadores amadores de andebol.

Métodos: Dezasseis jogadoras (21,9 ± 3,2 anos) da Liga Sénior Feminina Catalã (Catalunha, Espanha) completaram ambos os testes durante a pré-época e em dez jogos oficiais consecutivos. As variáveis cardiovasculares, perceptivas e fisiológicas-metabólicas foram analisadas utilizando modelos lineares mistos.

Resultados: Ambos os testes alcançaram frequências cardíacas máximas semelhantes à da competição, mas apenas o GBPT replicou a distribuição temporal nas zonas moderada e alta. O RPE foi mais elevado em ambos os testes do que nos jogos; o YYIRT-1 produziu um perfil de humor mais negativo do que o GBPT e a concorrência. O lactato sanguíneo foi mais elevado nos testes (GBPT: 8,8 mmol· L^{-1}; YYIRT-1: 10,2 mmol· L^{-1}) do que nos combates (3,9 mmol· L^{-1}). A perda de massa corporal foi maior na competição (1,18%) do que no GBPT (0,15%) e YYIRT-1 (0,31%). Os jogadores passaram 21,9% do tempo ativo do jogo acima da frequência cardíaca máxima atingida no YYIRT-1, e 4,5% no GBPT.

Conclusões: O GBPT mostrou maior validade ecológica, melhor reprodução de exigências competitivas, enquanto o YYIRT-1 sobrestimou a exposição de baixa intensidade e induziu maior stress supramáximo e psicológico

Palabras-chave: Andebol, Yo-Yo Intermittent Recovery Test, Game Based Performance Test, Capacidade anaeróbia, Exigências fisiológicas, Teste de aptidão física.

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INTRODUCCIÓN
(INTRODUCTION)

Handball is a team sport characterized by intermittent high-intensity actions where jumps, sprints, changes of direction, and throws are combined. All these actions require high levels of strength, coordination, postural stability, and motor control to hit, block, push, or hold opponents during play (Gorostiaga et al., 2005). During the match, all of them generate considerable physical, cardiorespiratory, and metabolic demands that require rapid and efficient recovery between efforts, as well as a high capacity to tolerate accumulated fatigue (Madou, 2020). Moreover, handball alternates between attacking and defensive phases, where players position themselves around the six-metre area in an attempt to score in the opposing goal, generating an average of 35 to 70 goals per match depending on the competitive level (Fritz et al., 2020). The high density of game actions demands that players maintain technical skills, tactical perception, and rapid decision-making under fatigue, making handball a complex challenge for both training and performance evaluation.

In recent years, the analysis of physical performance in women's handball has attracted growing attention, largely driven by the sport's increasing participation and professionalization. To assess players' physical fitness, health, and performance, researchers have employed a range of field-based tests, which also serve as valuable tools for player selection, training planning, and load monitoring (Camacho-Cardenosa et al., 2019). Among these, anaerobic field tests are particularly common, especially those evaluating Repeated Sprint Ability (RSA). For instance, Vicente-Rodríguez et al. (2004) examined the relationship between exercise and bone density in young female players using a 300-metre sprint test. Similarly, Alonso-Fernández et al. (2017) and Ingebrigtsen et al. (2013) implemented RSA protocols consisting of six 30-metre sprints, while Chaabene et al. (2021) and Ingebrigtsen et al. (2013) applied six 20-metre RSA tests to replicate the competitive demands of acceleration, deceleration, and change of direction. Other protocols have incorporated more complex variants, combining sprints with multidirectional jumps, such as the Repeated Shuttle-Sprint and Jump Ability (RSSJA) test proposed by Mhenni et al. (2017), or the test developed by Andersen et al. (2018), which integrates sprints, lateral displacements, and handball-specific distances. Taken together, these studies highlight the wide variety of tools available for assessing anaerobic performance in female athletes. They also contribute to identifying key factors that differentiate players according to their experience, playing position, and competitive level.

Conversely, aerobic field tests are essential for evaluating intermittent endurance and recovery capacity. For instance, Granados et al. (2008, 2013), employed the Four-Stage Submaximal Discontinuous Progressive Running Test, where participants completed four progressive running stages around the court (40 × 20 m) with three-minute rest intervals at speeds ranging from 8.5 to 13 $km \cdot h^{-1}$. This protocol was used to distinguish differences in physical fitness and throwing velocity among amateur, national elite, and international players, to differentiate physical fitness and throwing velocity among amateur, national elite, and international players. Similarly, Buchheit (2008) proposed the 30-15 Intermittent Fitness Test (30-15 IFT). In this test, that was implemented by Karpan et al. (2015), players alternate 30 s of running with 15 s of recovery in an incremental speed test, allowing the estimation of individual VO_2max. The 20 m Shuttle Run Test has also been used to evaluate general aerobic endurance, to talent detection, and to compare training programmes and periodisation models (Alonso-Fernández et al., 2017; Camacho-Cardenosa et al., 2019; Fernandez-Fernandez et al., 2017; Manchado et al., 2018; Vicente-Rodriguez et al., 2004). Although these protocols provide valuable information, they present some limitations by failing to replicate sport-specific technical actions, directional changes, or in-game pauses, which may lead to discrepancies between assessed physical capacity and real competitive performance.

Within this context, the Yo-Yo Intermittent Recovery Test level 1 (YYIRT-1) and the Game-Based Performance Test (GBPT) emerge as tools with higher specificity. The YYIRT-1 assesses intermittent endurance and aerobic recovery through progressive shuttle runs interspersed with short rest periods (Krustrup et al., 2003), while the GBPT was designed based on detailed analyses of official matches, aiming to simulate real game situations through eight heats combining high-intensity efforts with controlled pauses, replicating the accelerations, decelerations, jumps, and technical actions characteristic of handball (Wagner et al., 2016, 2019). Michalsik et al. (2021) showed that, among elite female players, the GBPT

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offers a more comprehensive measure of sport-specific physical performance, while the 30 m sprint and YYIRT-1 primarily capture general locomotor capacity.

Although significant progress has been made through the use of field tests to characterize physical performance, certain limitations still remain. Most available research focuses on elite players, leaving notable gaps in our understanding of amateur populations, whose physical, technical, and tactical demands can differ considerably. Moreover, the extent to which these tests replicate the cardiorespiratory, metabolic, and perceptual demands of real match play is still not fully understood. Evidence from other intermittent sports, such as basketball (Batalla-Gavalda et al., 2024) indicates that traditional laboratory tests often fail to reproduce competition demands accurately, underscoring the need for sport-specific tests that integrate technical and motor actions reflective of the game itself.

Recent studies have also pointed out differences between genders and competitive levels in the physiological responses observed during match play. For example, Michalsik and Aagaard (2015) found that female players tend to cover longer distances at high intensity compared to males but perform fewer high-intensity actions and directional changes, suggesting distinct tactical strategies that should be accounted for when designing assessment protocols. Likewise, Moss et al. (2015) reported that higher levels of adiposity and lower muscle mass are linked to poorer results in sprint, jump, and intermittent endurance tests, highlighting the relevance of including anthropometric and physiological variables in performance evaluations. Collectively, these findings reinforce the need for sport-specific testing protocols that capture not only general physical capacity but also the technical, tactical, and biomechanical demands inherent to competition.

Therefore, evaluating the ability of such tests to reproduce the cardiorespiratory, metabolic, and perceptual demands of competition is essential for optimising and planning training, designing specific conditioning programmes, preventing injuries, establishing selection criteria, and monitoring training load. For all these reasons, the present study aimed to compare and analyse the capacity of the YYIRT-1 and the GBPT to reproduce the demands observed during official competition in amateur female handball players, determining which provides a more specific and representative assessment of match performance.

MATERIAL Y MÉTODOS
(METHODS)

Experimental approach to the problem

The study was organised into two distinct phases. Phase 1, corresponding to the pre-competitive period (one week prior to match monitoring), involved the administration of two field-based exercise tests: the Yo-Yo Intermittent Recovery Test Level 1 (YYIRT-1) (Krustrup et al., 2003) and the Game-Based Performance Test (GBPT) (Wagner et al., 2016, 2019). Phase 2, carried out during the competitive period, consisted of the monitoring of ten official league matches (rounds 2 to 11).

Across both phases, variables were recorded in two primary domains:

- Psychological variables: perceived stress (Spanish version of the Perceived Stress Scale, PSS; Remor, (2006), mood states (Spanish version of the Profile of Mood States, POMS, 58 items; Balaguer et al., (1993), and rating of perceived exertion (RPE; Original Borg scale, 6-20; Borg, (1982).

- Physiological variables: maximal heart rate (HRmax; highest value attained during each test or match) and mean heart rate (HRmean; average value across defined intervals). HRmean was analyzed relative to Total Time (TT)—total on-court time, including penalties, time-outs, and inactive phases without ball play but excluding halftime—and Live Time (LT)—effective time with ball in play and clock running (McInnes et al., 1995). For both TT and LT, the percentage of time spent in each heart rate zone (HRZ) was calculated following the model of Sanders et al. (2021), a variant of Edwards' SHRZ classification (1993), using Garmin™ devices (Garmin Ltd., Olathe, Kansas, US). In addition, hydration balance (Cox et al., 2002), blood pressure (James & Gerber, 2018), and blood lactate concentration (Sánchez Arjona et al., 2008) were assessed.

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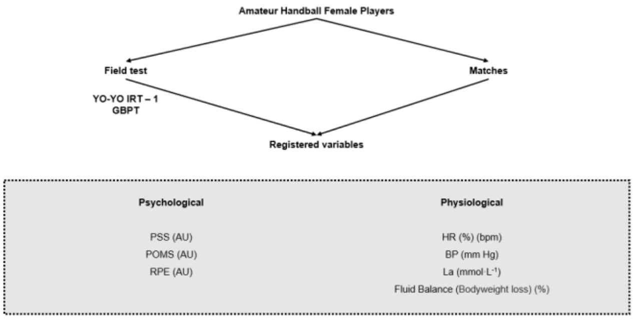
The schematic representation of the experimental design is shown in Figure 1.

Figure 1

Outline of the experimental design.



Participants

The study sample consisted of 16 amateur female handball players (age: 21,93 ± 3,25 years, height: 1,66 ± 0,06 m, weight: 64,36 ± 13,86 kg, wingspan: 1,69 ± 0,08 m, fat mass: 20,19 ± 3,37 %, experience: 10,44 ± 1,86 years), belonging to the maximum regional category of Catalonia (Spain) (Liga Catalana Sénior Femenina). The players had four 2-hour training sessions per week and one match on the weekend. In addition, during the study, special care was taken to ensure that participants did not engage in moderate- or high-intensity physical activity apart from the assessment or training sessions. The participants had no personal or family history of cardiac pathology or 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 study was approved by the ethics committee of the Consell Català de l'Esport (024-CEICGC-2022). This study was conducted taking into account the principles of the Declaration of Helsinki for human research (“World Medical Association Declaration of Helsinki,” 2013), as well as the criteria established in the Biomedical Research Act (BOE-A-2007-12945, 2007), and in accordance with the Data Protection Act (BOE-A-2018-16673, 2018).

Procedures

The temporal organization of variable recording is detailed in Table 1.

Table 1

Temporal organization of variable recording

Condition	Before	During	After
Field tests (Phase 1)			
YO-YO Intermittent Recovery test Level 1	PSS POMS BP La Fluid Balance	HR	BP La Fluid Balance RPE
GBPT	PSS POMS BP La Fluid Balance	HR	BP La Fluid Balance RPE
Matches (Phase 2)	PSS POMS BP La Fluid Balance	HR	BP La Fluid Balance RPE

PSS: perceived stress scale; POMS: profile of mood state; BP: blood pressure; La: lactate; HR: Heart rate; RPE: rate of perceived exertion Borg-20.

Phase 1

Medical history, physical examination, and anthropometry: Medical evaluations were conducted two weeks prior to the start of official match recordings. Three days before the assessment, players were contacted to schedule their appointment and reminded of the preparation guidelines: to refrain from engaging in intense physical activity and from consuming caffeinated or carbonated beverages during the 12 hours preceding testing, as well as from smoking within the three hours before evaluation.

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Upon arrival at the laboratory, players signed informed consent and data protection authorization forms. A sports medicine physician performed a complete medical history and a 12-lead electrocardiogram in a dedicated room maintained at 18–22 °C and 40–60% relative humidity. Anthropometric measurements were also obtained: height (stadiometer Seca® 220, Germany, accuracy 0,1 cm); body mass (column scale Seca® 700, Germany, accuracy 0,05 kg); arm span (anthropometer Smartmet, Mexico, wall-mounted and aligned parallel to the floor); and body fat percentage (HBF-306-E, Omron Healthcare Europe, B.V., accuracy 0,1%).

Temporal organization of the field tests: The tests were conducted across two sessions separated by 48 hours of recovery. In the first session, participants completed the YYIRT-1 (Krustrup et al., 2003), and in the second session the GBPT (Wagner et al., 2016, 2019). To control for potential order effects, half of the players began with the YYIRT-1 and the other half with the GBPT, performing the remaining test in the second session. The allocation of the first test was randomized.

YYIRT-1: The Yo-Yo Intermittent Recovery Test Level 1 (YYIRT-1) (Krustrup et al., 2003), administered following the protocol proposed by Bangsbo et al. (2008), consists of repeatedly covering 2 × 20 m shuttle runs with a 180° turn, followed by 10 s of active recovery (2 × 5 m walking). Speed is progressively increased according to audio signals until the participant reaches volitional exhaustion. The final score corresponds to the total distance covered before failing to complete two consecutive shuttles. Heart rate was recorded throughout the test at 4 Hz using a Garmin™ device (Garmin Ltd., Olathe, Kansas, US).

GBPT: The Game-Based Performance Test (GBPT) (Wagner et al., 2016, 2019) is based on movement patterns of elite handball players and consists of eight series of actions simulating offensive plays, defensive transitions, defensive situations, counterattacks, and active recovery phases. Heart rate was also recorded at 4 Hz using a Garmin™ device (Garmin Ltd., Olathe, Kansas, US).

Phase 2

Official matches: During Phase 2, ten consecutive official league matches (rounds 2 to 11) were analyzed, corresponding to the highest regional category in Catalonia (Lliga Catalana Senior Femenina, Catalonia, Spain).

Variable recording

To compare the demands between the field tests and official competition, the following variables were monitored:

Psychological Variables

- *Perceived Stress Scale (PSS):* The Spanish version of the PSS (Cohen et al., 1983); adapted by Remor, (2006) was administered prior to each test and match. The questionnaire consists of 14 items rated on a 5-point Likert scale (0 = never; 4 = very often). The total score is obtained after reversing items 4, 5, 6, 7, 9, 10, and 13, such that higher values indicate greater perceived stress.

- *Profile of Mood State* (POMS)*:* Mood states were assessed using the Spanish version of the Profile of Mood States (Balaguer et al., 1993), which comprises 58 items distributed across six subscales: tension–anxiety, depression–dejection, anger–hostility, vigor–activity, fatigue–inertia, and confusion–bewilderment. Responses were rated on a 5-point Likert scale (0 = not at all; 4 = extremely). With the exception of two reverse-scored items ("relaxed" in the tension–anxiety subscale and "efficient" in the confusion–bewilderment subscale), all items are summed to obtain the score for each dimension. The Total Mood Disturbance (TMD) was calculated by summing all subscales except vigor–activity, which is subtracted, and then adding a constant of 100 to prevent negative values.

- *Rate of Perceived Exertion (RPE):* After each test and match, players completed the original Borg scale (6–20) (Borg, 1982), responding to the question: "How hard have I exerted myself relative to my 100%?". Assessments were conducted individually, 30 minutes post-event (Moreira et al., 2012), in a designated area to ensure confidentiality and to avoid peer influence.

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Physiological variables

- *Heart Rate:* Heart rate was recorded during each test and match using Garmin™ chest strap sensors (Garmin Ltd., Olathe, KS, USA) at 4 Hz, synchronized with UWB WIMU Pro™ devices sampling at 100 Hz (RealTrack Systems, Almería, Spain). These systems have been previously validated both for HR monitoring (R^2 = 0,96) and positional tracking (ICC = 0,98) (Molina-Carmona et al., 2018; Muñoz-López et al., 2017). Matches were recorded with two video cameras (Panasonic HC-V380EG-K, 2.51 MP, Full HD, Kadoma, Osaka, Japan) synchronized with the UWB devices through an acoustic and visual signal at the beginning of the warm-up and each half. Cameras were positioned at an elevated location in the stands, ensuring coverage of half the court without the need for repositioning.

- *Fluid Balance:* Players were weighed 30 minutes before and 5 minutes after each test and match using a Siltec Large Capacity Model GS-1 scale (Ohaus, Ohio, USA). Each player was provided with an individual rehydration container, weighed before and after each event using a precision Traveler TA5000 scale (Ohaus, Ohio, USA). In cases where additional fluid was provided during competition, an investigator recorded the exact volume added. Fluid balance was calculated according to the formula of Cox et al. (2002):

Fluid loss (kg)=Pre-match body mass (kg)−post-match body mass (kg)+Fluid intake (kg)−Urine/feces losses (kg).

Values were expressed as a percentage of body mass.

- *Blood Pressure*: Blood pressure was assessed 30 minutes before and 3 minutes after each test and match using an OMRON HEALTHCARE M2 Basic sphygmomanometer (HEM-7120-E), a model derived from the Omron HEM-7130 and validated by Takahashi et al. (2015), following the recommendations of James and Gerber (2018). Measurements were taken immediately before and after each test and match.

- *Lactate:* Capillary blood samples were collected 30 minutes before and 3 minutes after each test and match from the earlobe following the protocol of Sánchez-Arjona et al. (2008) and analyzed using a Lactate Scout photometer (Lactate Plus DP110, Diaglobal GmbH, Berlin, Germany). Measurements were performed immediately before and after each test and match, in accordance with Warr-di Piero et al. (2018).

Statistical analyses

A Kolmogorov–Smirnov test, alongside visual inspection of Q-Q plots and random coefficient histograms, was used to confirm the normality of each dataset's residuals. Given the repeated-measures design and the potential for missing data, linear mixed models were selected as the primary analytical tool to compare the psycho-physiological demands across conditions (Match, GBPT, YYIRT-1) (Newans et al., 2022). The model fitted for each dependent variable included the type of condition (i.e., Match, GBPT, and YYIRT-1) as an independent fixed factor and random intercepts on the individual player. All available data were used in the models, as this approach does not require listwise deletion for missing data, maximizing the statistical power of the analysis. The goodness of fit of the models was assessed using log-likelihood ratio tests. Planned contrasts were specified to assess the differences between the Match condition and each field test (i.e. GBPT, YYIRT-1). To assess the differences between field tests in the percentage of live time that players' heart rate exceeded their test-derived HRmax, a separate mixed model was fitted with Condition (i.e. GBPT vs YYIRT-1) as a fixed factor and Player as a random intercept. Post-hoc analyses with Bonferroni's correction were applied. Standardized mean differences (Cohen's d) with 95% confidence intervals were calculated and interpreted as follows: < 0,2 = trivial; 0,2–0,6 = small; 0,6-1,2 = moderate; 1,2–2,0 = large; > 2,0 = very large (Hopkins et al., 2009). Statistical significance was established at $\alpha < 0.05$. Data analysis was performed using JAMOVI for Mac (version 2.7.6; the jamovi project (The jamovi project, 2024) and the GAMLj jamovi module: General analyses for linear models (Gallucci, 2019).

RESULTADOS
(RESULTS)

The descriptive values of the different dependent variables measured are shown in Tables 1, 2, and 3, and Figures 2, 3, and 4. The percentage of time of the

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LT in which the player's heart rate stayed above the registered heart rate max of the match is shown in Figure 5.

Table 2
Values of the HR variables measured in the different conditions.

Variable	Match	GBPT	YYIRT-1
HRmax	187,76 ± 17,63	191,50 ± 6,23	186,97 ± 5,82
z0	0,01 ± 0,10	0,54 ± 0,59*S	2,89 ± 2,48*M
z1	0,41 ± 1,49	1,33 ± 1,15*T	3,44 ± 2,98*S
z2	1,94 ± 4,88	3,76 ± 3,34	5,45 ± 2,56*S
z3	8,02 ± 11,66	10,74 ± 6,95	10,74 ± 7,48
z4	37,37 ± 22,98	34,31 ± 16,30	42,40 ± 18,77
z5	47,87 ± 28,68	49,33 ± 20,75	35,07 ± 24,62*T

Values are presented as mean ± SD. Match: Match condition during the live time; GBPT: Game-Based Performance Test condition; YYIRT-1: Yo Yo Intermittent Recovery Test 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; *p ≤ 0,05 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.

Table 3
Values of the psychological variables measured in the different conditions.

Variable	Match	GBPT	YYIRT-1
RPE-20 (AU)	14,29 ± 3,23	16,94 ± 1,73*S	16,69 ± 1,40*S
Stress (AU)	29,07 ± 8,28	26,63 ± 5,14	30,31 ± 10,67
Tension (AU)	10,17 ± 4,87	9,69 ± 3,50	11,56 ± 6,89
Depression (AU)	7,74 ± 8,47	6,50 ± 5,96	11,63 ± 10,90*T
Anger (AU)	8,03 ± 6,10	8,44 ± 5,35	10,13 ± 6,32
Vigour (AU)	10,78 ± 4,52	12,56 ± 3,67*T	10,50 ± 2,85
Fatigue (AU)	6,02 ± 4,28	6,00 ± 3,06	9,31 ± 6,23*S
Confusion (AU)	5,93 ± 3,61	5,88 ± 2,85	7,00 ± 3,76
TMD (AU)	127,12 ± 23,01	123,94 ± 14,78	139,13 ± 29,94*S

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Values are presented as mean ± SD, Match: Match condition; GBPT: Game-Based Performance Test condition; YYIRT-1: Yo Yo Intermittent Recovery Test condition; RPE-20: Rate of perceived exertion; Stress: Perceived stress scale; TMD: Total Mood Disturbance; AU: Arbitrary units; *p ≤ 0,05 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.

Table 4

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

Variable	Match	GBPT	YYIRT-1
Lactate (mmol·L^{-1})			
Pre	2,60 ± 0,57	2,28 ± 0,33^{*S}	2,00 ± 0,63^{*S}
Post	3,85 ± 1,49	8,75 ± 2,31^{*M}	10,21 ± 2,73^{*L}
Blood pressure (mm Hg)			
SBP_pre	113,12 ± 11,77	108,81 ± 8,77	111,88 ± 14,06
SBP_post	113,56 ± 11,86	117,06 ± 9,45	123,38 ± 10,40^{*S}
DBP_pre	77,36 ± 14,73	71,19 ± 7,23	69,00 ± 6,76^{*T}
DBP_post	80,09 ± 13,47	68,69 ± 5,21^{*S}	76,06 ± 9,79
SBPHR_pre	78,18 ± 10,41	71,69 ± 8,40^{*S}	70,13 ± 7,14^{*S}
SBPHR_post	100,55 ± 12,20	109,38 ± 8,72^{*S}	108,94 ± 12,82^{*S}
Bodyweight loss (%)	1,18 ± 0,83	0,15 ± 0,16^{*S}	0,31 ± 0,20^{*S}

Values are presented as mean ± SD. Match: Match condition; GBPT: Game-Based Performance Test condition; YYIRT-1: Yo Yo Intermittent Recovery Test condition; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; *p ≤ 0,05 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.

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Figure 2

Effect sizes of the cardiovascular demands comparing Field Tests with Match condition.

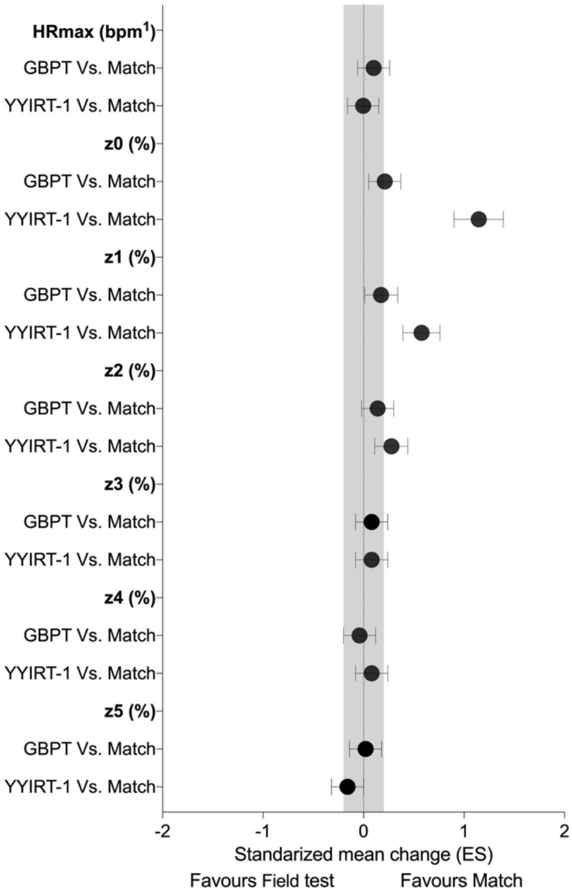

Figure 3

Effect sizes of the perceptual and psychological responses comparing Field Tests with Match condition.

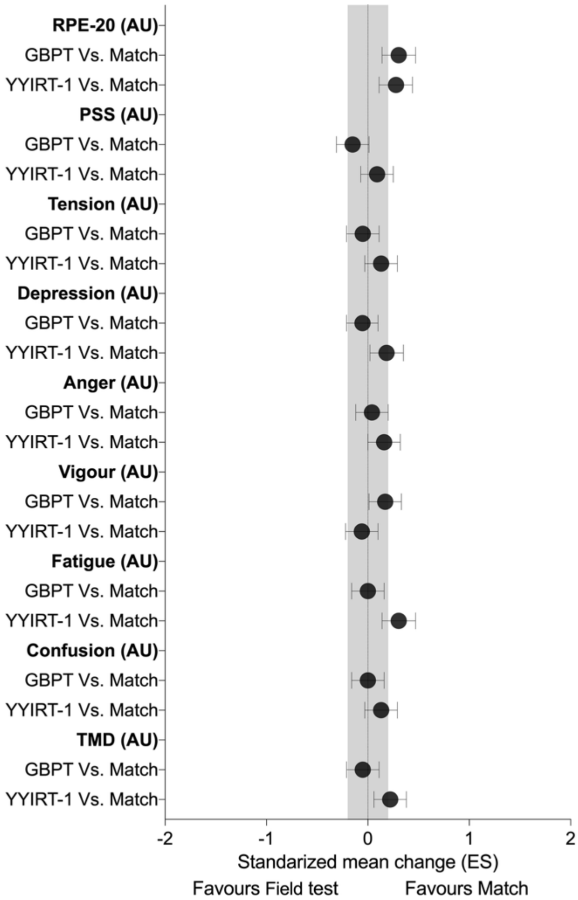

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Figure 4

Effect sizes of the metabolic and physiological responses comparing Field Tests with Match condition.

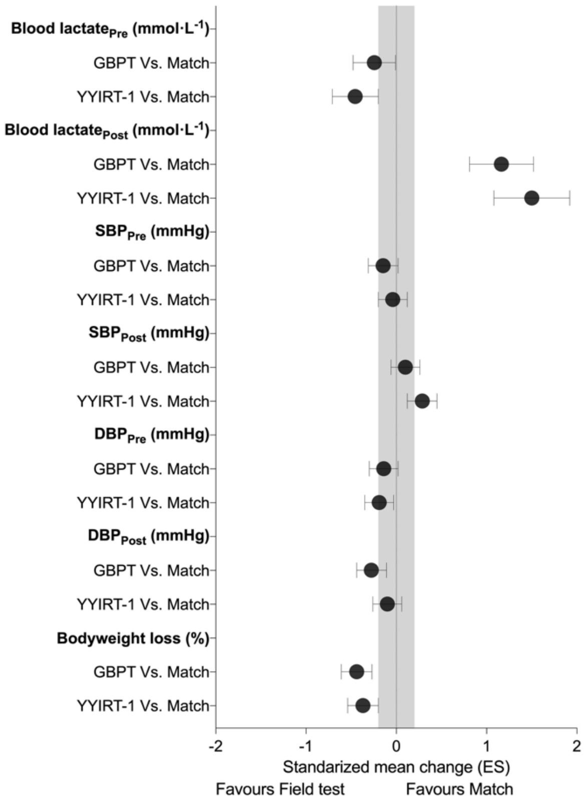
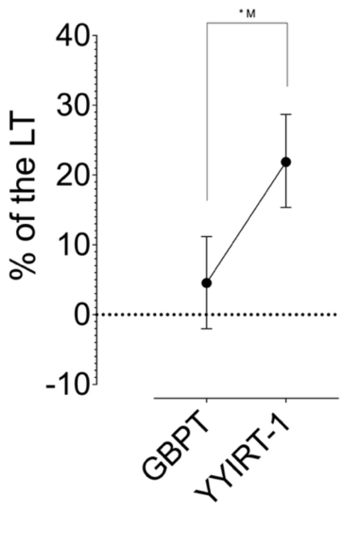


Figure 5

Percentage of time of the Live Time (LT) in which the player's heart rate stayed above the registered heart rate max of the match



Cardiovascular Demand

The distribution of time across heart rate zones (Table 1, Figure 2) differed significantly from match play. The GBPT elicited a greater proportion of time in the lowest zones, z0 (d = 0,21, 95% CI [0,05, 0,37], small) and z1 (d = 0,17, 95% CI [0,01, 0,34], trivial). In contrast, the YYIRT-1 resulted in significantly higher values for zones z0 (d = 1,15, 95% CI [0,90, 1,39], moderate), z1 (d = 0,58, 95% CI [0,39, 0,76], small), and z2 (d = 0,28, 95% CI [0,11, 0,44], small), alongside a trivial but significant reduction in the highest intensity zone z5 (d = -0,16, 95% CI [-0,32, 0,00]). The most striking divergence is illustrated in Figure 5: during official matches, the players maintained a HR above the HRmax obtained in the YYIRT-1 test for 21,86% of LT, whereas in the GBPT this proportion was 4,53% (MD = -17,33, 95% CI [-13,65, -20,73], p < ,001, d = -0,60, 95% CI [-0,74, -0,46], moderate).

Perceptual and Psychological Response

The psychological and perceptual responses to the tests, detailed in Table 2 and visualized in Figure 3, also showed clear differences. Both field tests triggered higher perceived exertion (RPE-20) than Match (GBPT: d = 0,30, 95% CI [0,14, 0,47], small; YYIRT-1: d = 0,28, 95% CI [0,11, 0,44], small). However, the YYIRT-1 uniquely induced a more negative mood profile, with higher levels of depression (d = 0,18, 95% CI [0,02, 0,35], trivial), fatigue (d = 0,30, 95% CI [0,14, 0,47], small), and Total Mood Disturbance (TMD) (d = 0,22, 95% CI [0,06, 0,38], small). The only significant psychological deviation for the GBPT was a trivial increase in vigour (d = 0,17, 95% CI [0,01, 0,33]).

Metabolic and Physiological Response

The metabolic and acute physiological data (Table 3, Figure 4) complete the comparative picture. Pre-exercise (pre) lactate was lower before both tests compared to Match (GBPT: d = -0,24, 95% CI [-0,48, -0,01], small; YYIRT-1: d = -0,46, 95% CI [-0,71, -0,20], small), while post-exercise (post) lactate was substantially elevated (GBPT: d = 1,16, 95% CI [0,81, 1,52], moderate; YYIRT-1: d = 1,50, 95% CI [1,08, 1,92], large). Body weight loss was less pronounced in both field conditions (GBPT: d = -0,44, 95% CI [-0,61, -0,27], small; YYIRT-1: d = -0,37, 95% CI [-0,54, -

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0,20], small). The GBPTwas associated with lower post-exercise diastolic blood pressure (DBP_post) (d = -0,28, 95% CI [-0,44, -0,11], small) and pre-exercise SBPHR_pre (d = -0,26, 95% CI [-0,42, -0,09], small), but a higher SBPHR_post (d = 0,25, 95% CI [0,08, 0,41], small). The YYIRT-1 showed lower DBP_pre (d = -0,19, 95% CI [-0,35, -0,03], trivial) and SBPHR_pre (d = -0,31, 95% CI [-0,48, -0,15], small), alongside higher SBP_post (d = 0,29, 95% CI [0,12, 0,45], small) and SBPHR_post (d = 0,23, 95% CI [0,07, 0,40], small).

DISCUSIÓN
(DISCUSSION)

The results of this study indicate that while both tests were effective in evaluating game-specific responses, the GBPT more closely reproduced the distribution of time spent across heart-rate zones observed in actual competition. It showed comparable proportions of time in moderate- to high-intensity zones (z3–z5) to those recorded during official matches. In contrast, YYIRT-1 underestimated the time spent in maximal-intensity zones (z5: 35.1% vs. 47.9% in match play) and overestimated low-intensity activity (z0: 2.9% vs. 0.01% in match play).

With respect to perceptual and psychological responses, both tests elicited higher ratings of perceived exertion than competition (RPE-20: GBPT = 16.9; YYIRT-1 = 16.7; match = 14.3). However, only the YYIRT-1 was linked to a more negative emotional profile, producing greater fatigue (9.3 vs. 6.0) and higher total mood disturbance (TMD = 139.1 vs. 127.1).

From a metabolic and physiological perspective, both tests induced significantly higher post-exercise blood-lactate concentrations than those measured during match play (GBPT = 8.8 mmol·L^{-1}; YYIRT-1 = 10.2 mmol·L^{-1}; match = 3.9 mmol·L^{-1}). Conversely, body-mass loss was greatest during competition (1.18%) compared with the GBPT (0.15%) and YYIRT-1 (0.31%). Notably, during official matches, players spent 21.86% of live time above the HRmax reached in the YYIRT-1, whereas this proportion was only 4.53% during the GBPT. These findings position the GBPT as a field test with higher ecological validity for assessing players' readiness and for replicating the overall physiological and perceptual demands of handball in amateur female athletes.

The analysis of time distribution across heart-rate zones revealed clear differences between the tests and actual competition, offering detailed insight into the associated cardiovascular demands. Although HRmax values were similar under both conditions—indicating that each protocol elicited near-maximal effort—variations emerged in how time was distributed across intermediate and high-intensity zones. The GBPT displayed a pattern more representative of real match play, maintaining comparable proportions within zones z3–z5. This reflects the natural alternation between maximal, submaximal, and brief recovery efforts that typify high-intensity intermittent sports (Fortunati et al., 2023; Sanders et al., 2021). Such a pattern may reflect variable muscle fibre recruitment (Jones & Vanhatalo, 2017), a balanced contribution of aerobic and anaerobic metabolism (Baker et al., 2015; Fiorenza et al., 2019), and heart-rate fluctuations that closely mirror competitive dynamics (Vermeulen et al., 2024).

In contrast, the YYIRT-1's linear and progressively intensifying structure resulted in greater time spent in low- to moderate-intensity zones (z0–z2), reducing exposure to intermittent high peaks (Ortega-Becerra et al., 2020). This discrepancy likely stems from the test's design, where continuous running and short recovery intervals generate a more uniform activation profile that fails to capture the acceleration–deceleration variability of match play (Belkadi et al., 2024; Iacono et al., 2015). Consequently, this may limit its ecological validity for reproducing the intermittent demands of handball (Font et al., 2023).

The perceptual and psychological results highlight how the design of each test influences players' subjective experience. Although both protocols elicited higher ratings of perceived exertion (RPE-20), the YYIRT-1 produced a more negative emotional response, marked by significant increases in fatigue, depression, and total mood disturbance (TMD), whereas the GBPT was accompanied by a slight rise in vigour. This contrast likely stems from the linear and monotonous structure of the YYIRT-1, which requires sustained effort with minimal tactical variation or opportunities for active recovery. Such continuous exertion can lead to persistent muscular discomfort and greater accumulation of lactate and protons (Soylu et al., 2021). By comparison, the GBPT incorporates game-like sequences—including offensive and defensive phases, counterattacks, and brief active recovery periods that allow partial

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physiological restoration, alternating muscle fibre recruitment, and natural heart-rate fluctuations (Wagner et al., 2016). These elements help regulate subjective perception and mitigate mood disturbance (L. Michalsik et al., 2021). Collectively, these findings suggest that ecological validity is determined not only by the ability to reach maximal intensity but also by the capacity to reproduce the intermittent, multidimensional structure of actual gameplay (Wagner et al., 2020), encompassing the cognitive and perceptual factors that directly influence motivation and adherence to training (Wagner & Hinz, 2023).

From a metabolic and physiological perspective, both tests produced post-exercise lactate concentrations higher than those observed during competition, with the YYIRT-1 reaching the highest levels (GBPT = 8.8 mmol·L^{-1}; YYIRT-1 = 10.2 mmol·L^{-1}; match = 3.9 mmol·L^{-1}). This pattern reflects greater glycolytic anaerobic activation and highlights that field-based tests, by enforcing sustained and progressively demanding efforts, temporarily overload energy systems compared with match play, where alternating intensities allow partial metabolic recovery (Hermassi et al., 2018; Souhail et al., 2010).

Similarly, post-exercise systolic blood pressure was elevated in both tests, particularly in the YYIRT-1, whereas the GBPT showed a slight reduction in diastolic pressure. This response is consistent with peripheral vasodilation resulting from brief active recovery periods and movement variability (Bocalini et al., 2017; Lu et al., 2024). The lower body-mass loss observed in both tests compared with competition reflects the combined influence of duration, continuity, and environmental conditions (Garth & Burke, 2013), suggesting that field tests cannot fully replicate the hydration and homeostatic demands of actual match play (Périard et al., 2021).

One particularly notable finding is the proportion of time players spent above the HRmax recorded in the tests. During match play, roughly 22% of live time exceeded the YYIRT-1 HRmax, compared with only 4.5% in the GBPT. This underscores the presence of peak efforts during official matches that field-based protocols fail to replicate, reflecting complex psychophysiological interactions such as sympathetic activation from competitive pressure, tactical decision-making, intrinsic and extrinsic motivation, and the unpredictable nature of gameplay (Póvoas et al., 2019; Santos-García et al., 2022).

These findings carry two key implications. First, standard tests tend to underestimate true cardiovascular exposure (Coutlianos et al., 2020). Second, results from field assessments should be interpreted within the context of actual competition, where cardiovascular and metabolic demands may exceed the predictions of testing protocols (Dikshit, 2022; Dimarucot & Macapagal, 2021). This justifies the use of the GBPT as an approximation tool, although it does not fully replicate all intensity peaks observed in competition.

Overall, the integrated findings indicate that the GBPT offers a more accurate reflection of cardiovascular, perceptual, and metabolic loads experienced during competition. While the YYIRT-1 remains useful for assessing maximal aerobic capacity and tolerance to progressive efforts, its linear design generates greater metabolic stress and a more pronounced emotional impact (L. Michalsik et al., 2021). In contrast, the GBPT captures the intermittent nature of handball, variability in energy system recruitment, fluctuations in perceived exertion, and the psychological dimensions of gameplay, making it a tool with higher ecological validity (Wagner & Hinz, 2023).

Future research should aim to validate these findings in larger, more heterogeneous samples and include additional control variables such as nutrition, sleep, and advanced monitoring technologies (e.g., GPS tracking, heart-rate sensors) to better characterize the intermittent and multidirectional patterns of the sport. Longitudinal studies could also assess whether regular implementation of the GBPT in training programs has a positive impact on competitive performance and psychological wellbeing.

CONCLUSIONES

(CONCLUSIONS)

In conclusion, while both tests elicit high-intensity physiological responses, the GBPT more accurately replicates the distribution of cardiovascular load, metabolic responses, and perceptual profiles of amateur female handball players. In contrast, YYIRT-1 imposes higher supra-maximal demands and a greater psychological burden. Considering the proportion of time spent above test-derived HRmax underscores the importance of selecting assessment tools that capture not only peak intensity but also the intermittent, variable, and complex nature of actual match play. This approach ensures both ecological validity and practical relevance for training evaluation and planning.

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