DO STRESS TESTS REFLECT THE INTENSITY REACHED DURING COMPETITION IN AMATEUR MEN'S BASKETBALL?

Abraham Batalla-Gavalda[1,2]**, Jose Vicente Beltran-Garrido**[3]**, Gerson Garrosa-Martín**[1]**,**
Raúl Montoliu-Colás[4]**, and Francisco Corbi**[5]

[1]*University School of Health and Sport (EUSES), Universitat Rovira i Virgili, Amposta, Spain*
[2]*INEFC Barcelona Sports Sciences Research Group, University of Barcelona, Barcelona, Spain*
[3]*Physical Exercise and Performance Research Group, Department of Education Science, School of Humanities and Communication Sciences, Universidad Cardenal Herrera-CEU, CEU Universities, Castellon de la Plana, Spain.*
[4]*Institute of New Imaging Technologies (INIT), Jaume I University, Castellón, Spain*
[5]*National Institute of Physical Education of Catalonia, Facultat de Lleida, University of Lleida, Lleida, Spain*

Original scientific paper
DOI 10.26582/k.56.2.14

Abstract:

In recent years, stress tests have emerged as one of the best ways to assess fitness and health of athletes. However, there is some controversy as to their ability to replicate the actual physiological needs generated during competition. The aim of the study was to compare the levels of various physiological variables measured during laboratory stress tests with those observed during competition. Heart rate, blood lactate, blood pressure, rate of perceived effort and stress level were analysed in ten amateur male basketball players, during three maximal laboratory tests (TREADMILL, CYCLE and Wingate test), and in five official competition games. The level of significance for the study was set at $p \leq .05$. Statistically significant differences between the physiological needs of competitive matches and those of stress tests were reported ($p < .05$). Furthermore, the time during which a higher HR was recorded during the competition compared to the HR obtained during the stress tests was calculated. This time was 12.36 ± 9.21% of the Live Time (LT) on TREADMILL, 35.04 ± 11.78% of the LT on CYCLE and 63.75 ± 11.57% of the LT on Wingate. The results suggest that laboratory stress tests do not reproduce the physiological requirements of amateur basketball players during competition.

Key words: *amateur basketball, stress testing, perceived effort, intensity, physiological needs*

Introduction

In recent years, an increase in the number of cardiovascular accidents occurring during sport competitions has been observed (Emery & Kovacs, 2018), which has been related to several factors such as the continuous increase in the number of sport practitioners, the type of sources consulted when accounting for accidents (media, insurance reports or sport federations) (Harmon, Zigman, & Drezner, 2015), the inclusion criteria used in epidemiological studies (Hajduczok, Ruge, & Emery, 2022) and, more recently, an increase in the number of myocarditis caused by coronavirus 2 (SARS-CoV-2) (Daniels et al., 2021). Moreover, it seems the variation in incidence depends on several factors such as race, gender and the intensity at which the sport is done (Maron, Haas, Ahluwalia, Murphy, & Garberich, 2016). Although some authors suggest a higher incidence among high-level athletes, in some countries such as Spain, 96% of athletes who suffered a sudden death were recreational or amateur athletes (Morentin et al., 2021), showing a direct relationship between a lower level of physical fitness and a higher probability of suffering a serious cardiovascular accident (Kokkinos et al., 2017).

Therefore, early detection of cardiovascular pathology prior to any physical activity is particularly important (Çetin, Ekici, Kibar, Sürücü, & Orgun, 2018). A complete anamnesis, physical examination and 12-lead resting electrocardiogram are some of the recommended tools for early detection of cardiac impairment (Löllgen & Leyk, 2018). In addition, the heart rate achieved during high-intensity physical exercise has been associated with an increased risk of sudden death (predictive factor), especially when the exercise is strenuous (Jouven et al., 2005). On the other hand, several studies suggest that the combination of high training volumes and intensities could lead to negative cardiac adaptations such as accelerated coronary artery calcification, acute release of cardiac biomarkers or the development of certain pathologies such as myocardial fibrosis or atrial fibrillation (Franklin et al., 2020). For example, in recent years, an increase in the latter pathology has been observed in high-intensity endurance sports (Estes & Madias, 2017).

In this regard, the American College of Sports Medicine (ACSM) suggested that the best way for early detection of cardiovascular pathology is the performance of a maximal stress test (American College of Sports Medicine, Liguori, Feito, Fountaine, & Roy, 2021). This has been defined as "a non-invasive procedure that provides diagnostic information on cardiopulmonary function and assesses individual dynamic exercise capacity" (Myers et al., 2009).

Furthermore, apart from their usefulness for the assessment of physical performance capacity and advice before the start of training, they could also be used as a tool for: 1) the assessment of the general state of health of the athlete, 2) the detection of various cardiovascular and metabolic pathologies that could limit and/or contraindicate the practice of physical exercise and sport (Löllgen & Leyk, 2018), and 3) as a way of assessing the evolution of sporting performance throughout a competitive season.

Given that a direct relationship has been observed between the inability to reach certain heart rates—calculated from an estimated maximum heart rate—and an increased risk of death from cardiovascular disease (Harber et al., 2017), for this type of assessment to be effective, the athlete must reach maximum intensities (HRmax) during performance (Hamlin, Draper, Blackwell, Shearman, & Kimber, 2012).

Therefore, a stress test should reproduce the maximum intensity levels at which the athlete performs when doing sport in order to be considered effective (Currell & Jeukendrup, 2008), since the intensity reached could determine whether a pathology can be detected or, on the contrary, would go undetected. As such, it is essential that the intensity of effort reached during the performance of an exercise test is equal to or higher than that the athlete will attain during the competition and that there are no significant differences between the two (Santos et al., 2012). In fact, the performance of a stress test without meeting the completion criteria, which ensures maximum effort by the participant, is considered a cause of a false negative in the performance of the test (Higgins & Higgins, 2007). Moreover, the existing differences may vary depending on the sport, the type of ergometer (treadmill, cycle ergometer...), the population group practising, and, finally, they may also be influenced by various psychological factors such as stress or anxiety (Sánchez-Beleña & García-Naveira Vaamonde, 2017).

Unfortunately, as far as we are aware, there are no studies in basketball that have made an in-depth analysis of the differences between the intensity levels reached during stress tests and during competition, which opens the door to questioning whether the intensities reached during stress tests are high enough to reflect the true intensity developed during competition. On the other hand, in many cases the players and/or the clubs they play for do not have qualified personnel and/or laboratories where all these aspects can be assessed, so many assessments are carried out by applying field tests (Durmić et al., 2019).

On the other hand, although during the performance of the laboratory tests an attempt is made to reproduce the conditions and patterns applied during competition (movement patterns, types of effort, duration, etc.), the need to apply standardised protocols, the performance of the tests in a limited space and the impossibility of adapting the type of test used to all movement patterns and sports, means that the tests are performed in reduced spaces and using instruments such as the cycle ergometer or treadmill, which could cause a change in the performance conditions that would limit the intensities achieved in the tests. This could lead to very different perceptions of fatigue depending on the assessment conditions used.

Therefore, the main objective of this study was to analyse whether there were differences between the values of various physiological and psychological variables related to cardiovascular pathology, 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.

Methods

Experimental approach to the problem

The study was organised in two phases: Phase 1: pre-competitive period (two weeks before the start of the competition), in which the maximal laboratory tests were carried out, and Phase 2: competitive period, in which the physiological and psychological variables of the first five official matches (MATCH) were recorded.

The maximal laboratory tests consisted of the following: 1) a Wingate (WIN) test (Ayalon, Inbar, & Bar-Or, 1974), 2) a treadmill (TREADMILL) maximum incremental step-up test (Manoelles, 2005), and 3) a cycle ergometer (CYCLE) maximum incremental ramp test (Keir et al., 2015). These tests were selected because they are the most commonly used in laboratory assessments during pre-season in many competitive sports (Manonelles P., Franco L., & Naranjo, J., 2016).

Two types of variables were monitored: 1) physiological: heart rate, blood lactate, and blood pressure, and 2) psychological: level of effort and perceived stress. In the case of matches, HR data were recorded and the corresponding Live Time (LT; defined as "the time that elapses when the player is on the court, the ball is in play and the stopwatch is running") was considered for the analysis (McInnes, Carlson, Jones, & McKenna, 1995). The experimental design of the study is shown in Figure 1.

Subjects

The study sample consisted of 10 amateur male basketball players (age: 21.40 ± 2.22 years; body height: 1.92 ± 0.07 m; body mass: 88.44 ± 8.52 kg; fat mass: 15.49 ± 3.41 %; years of practice: 12.40 ± 2.50 years), belonging to the top-level regional category (1st National Division). The players had three 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 regular training sessions. The participants had no personal or family history of cardiac pathology, nor had they suffered from any injury that could alter regular sports practice in the six months prior to the study.

To check the minimum effect size to which the statistical model was sensitive, a sensitivity analysis with the analysed sample size (n = 10, number of groups = 1, number of measurements = 4, and non-sphericity correction of $\varepsilon = 1$) was done. The power and alpha values used were 0.80 and 0.05, respectively. The model was sensitive enough to detect moderate effects of at least f = 0,39 or the equivalent d = 1,12 described as moderate (Hopkins, Marshall, Batterham, & Hanin, 2009).

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.

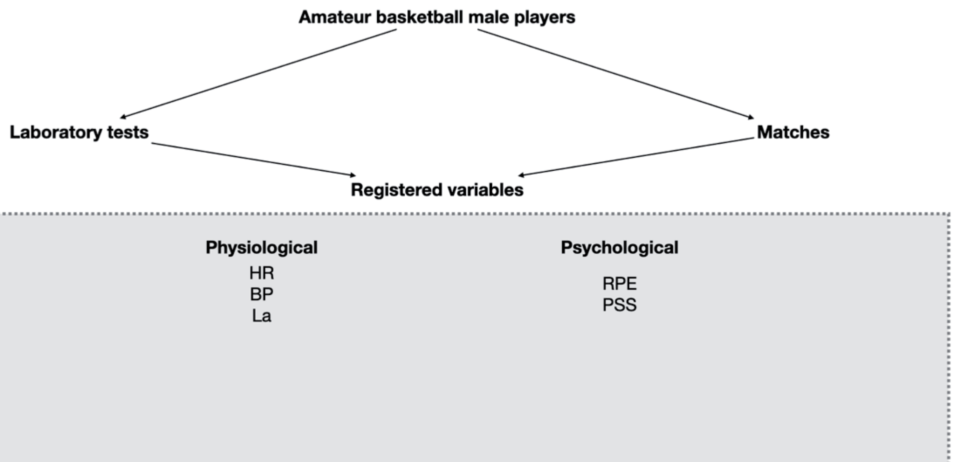
Procedures

The timing of the records of the variables is detailed in Table 1.

Information prior to the initiation of the research. Three days prior to the first exercise test, participants were contacted to remind them not to exercise or consume caffeinated or carbonated beverages at least 12 hours before the assessments. They were also not to smoke in the three hours prior to data collection.

Information protocol and consents in the laboratory. When they arrived at the laboratory, having understood the procedure to follow for data collection and clarified any queries they might have, they were asked to sign the informed consent form for the study and for the clinic where the stress tests were carried out.

Anamnesis and physical examination of the participants. A complete anamnesis and a 12-lead electrocardiogram were performed by a sports medicine physician in a specially equipped room (18-22°C and 40-60% relative humidity). In addition, anthropometry was assessed (height: Seca® 220 measuring rod with an accuracy of 0.1 cm; weight: Seca® 700 column scale (Germany) with an accuracy of 0.05 kg; and body fat: BC-601 meter (Tanita® scale) with an accuracy of 0.1%).



Note. HR: heart rate; BP: blood pressure; La: lactate; RPE: rate of perceived exertion; PSS: perceived stress scale.

Figure 1. Experimental design.

Table 1. Timing of the recording of variables from laboratory tests and matches

Condition	Before	During	After
Laboratory tests			
Wingate	PSS BP La	HR	BP La RPE
Cycle ergometer	PSS BP La	HR	BP La RPE
Treadmill	PSS BP La	HR	BP La RPE
Matches	PSS BP La	HR	BP La RPE

Note. HR: heart rate; BP: blood pressure; La: lactate; RPE: rate of perceived exertion Borg-20; PSS: perceived stress scale.

Laboratory tests

Temporal organisation of stress tests. The laboratory assessments were divided into two recording sessions separated by 48 hours of recovery time. In the first session, the WIN test (Ayalon et al., 1974) and the CYCLE test (Keir et al., 2015) were performed, leaving a full recovery period of 30 min between the tests. In the second session, the TREADMILL test (Rabadán & Boraita, 2005) was performed. Half of the participants took the WIN and CYCLE on the first day, while the other half started with the TREADMILL and took the rest of the tests on the second day, in order to avoid that the order of the tests could influence the final result of the study.

Wingate test (WIN). It followed the protocol proposed by Ayalon et al. (1974). After a 5-minute warm-up on the cycle ergometer, the participant pedalled at the maximum possible speed for 30 seconds, and revolutions per minute (rpm) were collected every five seconds. The load applied was 75 g/kg body weight.

Cycle ergometer test (CYCLE). It followed the protocol described by Keir et al. (2015), which consists of a maximum incremental ramp test, starting at 20W for four minutes, increasing by 25W every minute, maintaining a pedalling cadence of between 70 and 100 rpm at all times.

TREADMILL test. A continuous stepwise maximum incremental test with a constant slope of 1% was performed. The test began with a 2-minute warm-up at 6 km/h with progressive increases of 1 km/h every minute (Manoelles, 2005).

Competitive matches

The week before the start of the recording of physiological and psychological variables during the competition, a friendly match was organised so that both the participants and the research team could familiarise themselves with the data collection protocol. Subsequently, the first five official competition matches were assessed.

Recording of physiological variables

Heart rate. Polar Team heart rate monitors (Polar Electro, Corp., Finland) with a recording rate of 1 Hz (second by second) were used for HR monitoring. At the same time, the matches were recorded with two video cameras (JVC -GZ620SE HDD. Hong Kong, China) synchronised with the heart rate monitors by means of an acoustic and visual signal, just before the start of the warm-up. The cameras were placed in an elevated position in the grandstand from where they could record at least half of the arena without having to be moved. The heart rate monitors were placed 10 minutes before the start of the warm-up (36 min before the start of the matches, the specific warm-up had a duration of 26 min). The recording was synchronised acoustically and visually with the video cameras at the beginning and end of each quarter.

Blood pressure. An OMRON HEALTHCARE M2 Basic (HEM-7120-E) sphygmomanometer (Derivative of Omron HEM-7130) was used for blood pressure assessment following the recommendations proposed by James and Gerber (2018). This model was previously validated by Takahashi, Yoshika, and Yokoi, (2015). The assessments were carried out before and after each test and each match.

Lactate. Blood samples were drawn from the earlobe of each participant following the protocol proposed by Sanchez-Arjona, Ruiz Martínez, and Martín Fernández (2008). For this purpose, the lactate scout photometer (Lactate Plus DP110, Diaglobal GmbH, Berlin, Germany) was used. Measurements were taken before and after each test and match, following the protocol by Warr-di Piero, Valverde-Esteve, Redondo-Castán, Pablos-Abella, and Sánchez-Alarcos Díaz-Pintado (2018).

Recording of psychological variables

Perceived Stress Scale (PSS). The Spanish version of the Perceived Stress Scale (PSS) (Remor, 2006) was administered before each test and match. This questionnaire is a self-report instrument that assesses the level of perceived stress over the past month, consisting of 14 items with a five-point scale response format (0 = never, 1 = hardly ever, 2 = occasionally, 3 = often, 4 = very often). The total PSS score is obtained by inverting the scores of items 4, 5, 6, 7, 9, 10 and 13 (in the following sense: 0 = 4, 1 = 3, 2 = 2, 3 = 1 and 4 = 0) and then adding up the 14 items. The direct score obtained indicates that a higher score corresponds to a higher level of perceived stress.

Rate of Perceived Exertion (RPE). The original Borg Scale (Borg, 1982), consisting of 15 items (6-20), where 6 is a very, very mild perception, and 20 is a very, very hard perception, was administered in response to the question "How hard have I tried relative to my 100% effort?". The scale was administered after each test and match (30 min after) and during match breaks.

Statistical analyses

To compare the psycho-physiological demands of Match, Wingate, Treadmill and Cycle Ergometer conditions, a repeated measure analysis of variance (ANOVA) was used. Normality assumptions were checked using the Shapiro-Wilk test and exploring the Q-Q plots and the histogram plot of the residuals. Assumptions of sphericity were evaluated using the Mauchly's test. When sphericity was violated (p≤.05), the Greenhouse-Geisser correction factor was applied. Whenever a significant main effect was observed, *post-hoc* comparisons were performed with the Bonferroni correction. Effect sizes were evaluated using a partial omega squared (ω^2), with 0.06, 0.06-0.14, and > 0.14 indicating a small, medium, and large effect, respectively. Mean difference was obtained and the standardised mean difference Cohen's *d* effect size was calculated (Lakens, 2013), where *t* is the *t* statistic and *n* is the sample size. Effect sizes were interpreted as: < 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). The level of significance was set at 0.05 for all the tests. Statistical analyses were performed using JASP for Mac (version 0.16.4; JASP Team (2024)).

Results

The descriptive values of the different dependent variables measured are shown in Tables 2, 3, and 4. The percentage of time of the LT in which the player's heart rate stayed above the registered heart rate max of each laboratory test is shown in Figure 2.

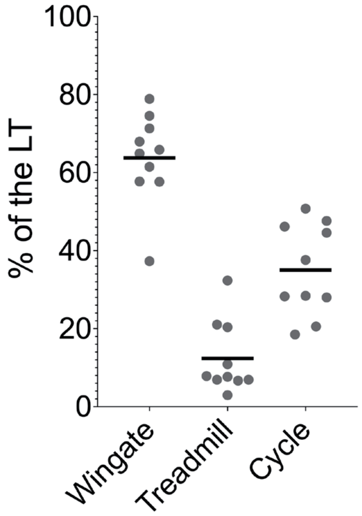


Figure 2. Percentage of time of the live time (LT) in which the player's heart rate stays above the registered heart rate max of each laboratory test.

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

Variable	Match	Wingate	Treadmill	Cycle ergometer
HRmax	197.91 ± 4.72	164.90 ± 12.19 *^{VL}	188.70 ± 8.49 *^{M}	179.60 ± 8.87 *^{VL}
z0	0.00 ± 0.00	0.00 ± 0.00	8.88 ± 6.49 *^{VL}	0.14 ± 0.46
z1	0.00 ± 0.00	1.00 ± 3.16	9.17 ± 4.15 *^{VL}	4.97 ± 9.36 *^{M}
z2	1.09 ± 0.73	6.00 ± 7.17	12.71 ± 5.21 *^{VL}	16.43 ± 14.32 *^{VL}
z3	9.91 ± 4.88	22.67 ± 4.10 *^{VL}	13.77 ± 3.07	21.01 ± 8.78 *^{VL}
z4	43.84 ± 9.91	25.00 ± 4.23 *^{VL}	20.97 ± 6.26 *^{VL}	24.04 ± 7.71 *^{VL}
z5	45.16 ± 13.55	45.33 ± 9.96	34.50 ± 5.78 *^{M}	33.40 ± 7.17 *^{VL}

Note. Values are presented as mean ± SD. Match_LT: mean values of the heart rate variables for the match condition during the live time; Wingate: mean values of the heart rate variables for the Wingate condition; Treadmill: mean values of the heart rate variables for the treadmill condition; Cycle ergometer: mean values of the heart rate variables for the cycle ergometer 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≤.05 statistically significantly different 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	Wingate	Treadmill	Cycle ergometer
RPE-20	14.13 ± 2.31	16.20 ± 0.92 *^{L}	18.20 ± 0.42 *^{VL}	18.30 ± 0.95 *^{VL}
Stress	10.17 ± 4.26	10.40 ± 3.41	7.60 ± 5.52	10.40 ± 3.41

Note. Values are presented as mean ± SD. Match: mean values of the psychological variables for the match condition; Wingate: mean values of the psychological variables for the Wingate condition; Treadmill: mean values of the psychological variables for the treadmill condition; Cycle ergometer: mean values of the psychological variables for the cycle ergometer condition; RPE-20: Rate of perceived exertion; Stress: Perceived stress scale; *p≤.05 statistically significantly different 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 and blood pressure variables measured in the different conditions

Variable	Match	Wingate	Treadmill	Cycle ergometer
Lactate	(mmol/L)			
Pre	0.85 ± 0.07	0.94 ± 0.05	0.94 ± 0.13	0.95 ± 0.05
Post	4.12 ± 1.20	12.02 ± 0.87 *^{VL}	6.99 ± 0.54 *^{VL}	6.59 ± 0.35 *^{VL}
Blood pressure	(mm Hg)			
SBP_pre	130.17 ± 5.39	125.50 ± 7.62	125.00 ± 12.02	125.00 ± 9.13
SBP_post	125.33 ± 6.15	165.50 ± 13.43 *^{VL}	166.00 ± 8.43 *^{VL}	177.00 ± 13.37 *^{VL}
DBP_pre	74.73 ± 4.30	71.00 ± 7.38	65.50 ± 4.97*^{L}	72.00 ± 7.89
DBP_post	77.45 ± 3.65	70.00 ± 6.67 *^{L}	62.50 ± 3.54 *^{VL}	66.50 ± 3.37 *^{VL}

Note. Values are presented as mean ± SD. Match: mean values of the lactate and blood pressure variables for the match condition; Wingate: mean values of the lactate and blood pressure variables for the Wingate condition; Treadmill: mean values of the lactate and blood pressure variables for the treadmill condition; Cycle ergometer: mean values of the lactate and blood pressure variables for the cycle ergometer condition; SBP: systolic blood pressure; DBP: diastolic blood pressure; *p≤.05 statistically significantly different 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.

Match vs. Wingate differences

Regarding the HR variables, statistically significant lower values of HRmax (very large) and z4 (very large) variables were shown in Wingate than in Match. However, statistically significant higher values of z3 (very large) were shown in Wingate than in Match (Table 2).

Regarding the psychological variables, statistically significant higher values of RPE-20 (very large) were shown in Wingate than in Match (Table 3).

Regarding the lactate and blood pressure variables, statistically significant lower values of DBP_post (large) were shown in Wingate than in Match. However, statistically significant higher values of Lactate at post condition (very large) and SBP_post (very large) were shown in Wingate than in Match (Table 4).

Finally, when the Wingate test was performed 63.75 % of the time of the LT, the players' heart rate stayed above the registered HRmax at the test itself (Figure 2).

Match vs. cycle ergometer differences

Regarding the HR variables, statistically significant lower values of HRmax (very large), z4 (very large) and z5 (very large) variables were shown in Cycle ergometer than in Match. However, statistically significant higher values of z1 (moderate), z2 (very large) and z3 (very large) variables were shown in Cycle ergometer than in Match (Table 2).

Regarding the psychological variables, statistically significant higher values of RPE-20 (very large) were shown in Cycle ergometer than in Match (Table 3).

Regarding the lactate and blood pressure variables, statistically significant lower values of DBP_post (very large) variables were shown in Cycle ergometer than in Match. However, statistically significant higher values of lactate at post condition (very large) and SBP_post (very large) were shown in Treadmill than in Match (Table 4).

Finally, when the Cycle ergometer test was performed, 35.04 % of the time of the LT, the players' heart rate stayed above the registered HRmax at the test itself (Figure 2).

Match vs. treadmill differences

Regarding the HR variables, statistically significant lower values of HRmax (moderate) and z5 (moderate) variables were shown in Treadmill than in Match. However, statistically significant higher values of z0 (very large), z1 (very large), z2 (very large) and z5 (moderate) variables were shown in Treadmill than in Match (Table 2).

Regarding the psychological variables, statistically significant higher values of RPE-20 (very large) were shown in Treadmill than in Match (Table 3).

Regarding the lactate and blood pressure variables, statistically significant lower values of DBP_pre (large) and DBP_post (very large) variables were shown in Treadmill than in Match. However, statistically significant higher values of Lactate at post condition (very large) and SBP_post (very large) were shown in Treadmill than in Match (Table 4).

Finally, when the Treadmill test was performed 12.36 % of the time of the LT, the players' heart rate stayed above the registered HRmax at the test itself (Figure 2).

Discussion and conclusions

This is the first study, at least to our knowledge, to compare the differences between the intensity achieved during various laboratory stress tests and the intensity recorded during an official competition in amateur men's basketball. The results seem to confirm the existence of differences between the two conditions in some of the variables analysed. Although the intensity levels observed were higher during the competition, the levels of RPE, lactate and blood pressure were found to be lower than in the stress tests. In contrast, no significant differences were observed in the vast majority of variables between conditions prior to the match, ensuring that the tests and the match were conducted under equal conditions.

Match vs. Wingate differences

Basketball is a sport with a combination of high intensity aerobic and anaerobic actions (Petway, Freitas, Calleja-González, Medina Leal, & Alcaraz, 2020) and lactate concentrations ranging from 2.7 to 6.8mmol-L-1 (Stojanović et al., 2018), suggesting the importance of the glycolytic pathway in energy production. The Wingate test is a maximal anaerobic test in which the adenosine triphosphate-phosphocreatine system and the glycolytic system are significantly stimulated, activating purine catabolism and lactate production (Granier, Mercier, Mercier, Anselme, & Préfaut, 1995; Sawada et al., 2023). This makes it the gold standard tool for monitoring improvements in anaerobic capacity and power in sports where anaerobic metabolism is clearly involved (Bar-Or, 1987; Dobashi, Katagiri, Fujii, & Nishiyasu, 2023). It is also the most commonly used test to assess anaerobic performance in some groups such as athletes with disabilities (Marszałek, et al., 2019).

This test has been used in basketball as a way of assessing anaerobic performance, both in competitive players and young basketball players (Apostolidis, Nassis, Bolatoglou, & Geladas, 2004; Gholami, Ali, Hasani, & Zarei, 2022), although its usefulness has been questioned, due to the fact that its duration allows the assessment of capacity and not so much anaerobic power, which seems to be the most relevant in basketball (Delextrat & Cohen, 2008).

Despite this, it has been used in the field of prevention and health promotion as a way of assessing cardiac and respiratory function and arterial response to exercise (Coates, Millar, & Burr, 2023; Iamonti et al., 2022). In our study, this test was used because of its simplicity and short duration and because it can be applied in conjunction with other laboratory tests in the same assessment session, which means that it is used by many clubs as a complementary test to the stress test. Furthermore, it seems that this test could correlate with other anaerobic track tests (Fatouros et al., 2011; Yanci et al., 2014), which would allow us to obtain a first approximation of the state of this pathway in the athletes analysed.

When comparing the results obtained between the WIN test and the MATCH, we observed that the HR levels achieved were lower in the WIN than in the MATCH, with the exception of the z3 values. This could indicate that the players did not reach the maximum heart rate intensity during the test (see Table 2). This may be due to the short duration of the WIN test (30 seconds). However, the subjective perception of reported effort was higher in the WIN test (see Table 3). This could indicate that, although the intensity during the test was not maximal, the perception of exertion experienced by the participant during the test was maximal. This point leads to the view that individual perception of effort should not be considered as synonymous with the level of intensity achieved, which could lead to a false-negative, when the aim is to ensure the cardiovascular health of the athlete (Higgins & Higgins, 2007).

Although this could be attributed to the fact that the lactate values achieved in the WIN test were significantly higher (large effect size), since for many years there has been a certain consensus on the idea that the higher the lactate concentration, the greater the subjective perception of effort, recent studies question this relationship (Lee et al., 2023). In addition, it seems that intermittent exercises, such as basketball practice, could generate a "rebound effect" that would generate a lower perception of effort, generating more pleasurable effects (Jung, Bourne, & Little, 2014), which would suggest that the subjective perception of effort should be greater in continuous efforts. On the other hand, the data collection of all players was performed following the protocol proposed during the stress tests by Warr-di Piero et al. (2018), consisting of the collection of lactate and blood pressure values after the end of the effort. However, the application of this protocol during competition can only be effectively carried out on players who have finished the match on court, losing the information on lactate kinetics during competition. In addition, several studies suggest that the specificity of the movement pattern to be assessed could influence the final result of the test, as it has been found that the higher the specificity and complexity of the test, the lower the performance during the test (Batra, 2019). This could be caused by the fact that stress tests are performed in a controlled and standardised environment (Weichenberger, Esefeld, & Müller, 2023), where all the player's attention is focused on completing the test with the best possible effort, whereas during competition, there are many variables that can affect the perceived effort, such as emotions, game strategy, the match environment or the score (Batalla Gavaldà, Bofill Ródenas, Montoliu Colás, & Corbi Soler, 2018; Sansone, Gasperi, Tessitore, & Gomez, 2021). In addition, the complexity and intermittent nature of movement patterns are also factors that should be considered, as in the case of the court movement patterns may vary depending on the needs of the game (Boutios et al., 2022).

Blood pressure has been associated with an increased risk of cardiovascular disease (Yang et al., 2021), although its influence will vary depending on various factors such as age, arterial elasticity and the existence of atheromatous plaques (Wu et al., 2023). In our study, an increase in both post-exercise SBP and post-exercise BOD was observed in both tests, although this increase was greater in the WIN test. This fact could be determined by the different nature of the effort made (continuous vs. intermittent high intensity) and by the existence of pauses during the competition, which would naturally tend to normalise blood pressure (Huang et al., 2023). In addition, the high intensities reached, together with the fact that in the WIN test, the action of the arms and trunk are performed in a quasi-isometric manner, could further increase blood pressure in the trunk (Lässing et al., 2023).

Match vs. cycle ergometer differences

When comparing the variables recorded between the MATCH and the CYCLE, significant differences of large or very large magnitude were observed in almost all the variables analysed (with the exception of the values recorded in z0, which did not present significant differences, and the values of z1, which presented significant differences of moderate magnitude), with the results obtained on the court being higher in relation to HRmax, % time spent in z4 and z5 (see Table 2), and DBP_post (see Table 4), and lower in % time spent in z1, z2 and z3 (see Table 2), and RPE-20 (see Table 3), lactate post, and SBP_post.

These differences could be due to a number of reasons. First, it is different types of efforts made in both situations. While in the CYCLE test a continuous effort is made (Keir et al., 2015), in match situations the type of effort made involves actions of an intermittent high intensity (Khoramipour et al., 2021). In fact, as indicated by Hauer, Tessitore, Binder, & Tschan (2018), one of the elements to take into account is exercise density, i.e., the ratio of activity time to pause time within an event, as this can modify intensity levels. In addition, the alternation between high intensity and recovery in match situations could lead to spontaneous regulation of blood pressure behaviour, moderating the difference between the two variables (Ghasem, Abouzeid, Toresdahl, & Shah, 2022). Second, due to the fact that during the match the HR is in the z4 and z5 for more than 85% of the time, the workload at high intensity is considerably higher than in the CYCLE test. These values are similar to those reported by Sanders, Boos, Rhodes, Kollock, and Peacock (2021) in an NCAA female population, who found that players were at values above 85% of HRmax for an average of 34.5 minutes of the match. Third, the type of motor patterns performed during competition is very different from that used during the CYCLE test, since in pedalling actions, hip flexors and extensors would not be fully activated, contrary to what happens in running actions (Dorel, Guilhem, Couturier, & Hug, 2012). This justifies the greater capacity to generate power during competition, an aspect that allows higher levels of intensity to be reached (Medbø & Toska, 2001). Fourth, the change in blood pressure, which was much greater during the CYCLE test compared to the MATCH, as a result of peripheral vasoconstriction in the upper limbs and vasodilation in the lower limbs (Joyner & Casey, 2015).

Match vs. treadmill differences

A comparison of the variables analysed between the MATCH and the TREADMILL shows significant differences in the vast majority of the variables analysed. While HRmax and % at z4 and Z5 were higher during the competition, RPE-20, lactate and blood pressure were higher during the TREADMILL test. This aspect could be related, as mentioned above, to the conditions in which the test was carried out and the psychological factors that derive from its performance, as it is difficult to reproduce the emotional situations generated by the competition in a laboratory test (Khoramipour et al., 2021).

In relation to the lactate levels obtained during the MATCH, these were similar to those obtained in previous studies carried out on players during competition (Ben Abdelkrim, El Fazaa, El Ati, & Tabka, 2007; McInnes et al., 1995; Stojanović et al., 2018). In addition, the ability to clear lactate also appears to be related to the position and type of movements performed by participants after exercise (Wilson, 2016) and there appears to be a movement pattern specificity in the recording of lactate concentrations (Legaz-Arrese, Munguía-Izquierdo, Carranza-García, & Torres-Dávila, 2011), which may be related to the amount of muscle mass recruited. On the other hand, the need to counteract the inertial loads generated by body mass on the vertical component during running may also lead to increased lactate concentrations (Quittmann et al., 2021).

Therefore, and as a result of the above, our study suggests that laboratory stress tests do not reproduce the real physiological needs that amateur basketball players have on the court during an official competition. All this suggests the need to adapt the assessment protocols to the real competitive context of amateur basketball, as it seems that the type of pattern selected for the assessments could contribute significantly to the final result of the test.

Limitations of the study

This study has several limitations. Firstly, the gas exchange during the stress tests was not assessed. Although from the respiratory exchange ratio we can know the level of involvement of the athlete during the test (Myers, et al., 2009) and whether this is a reflection of the true level of effort applied (Mehra, et al., 2006), there are significant drawbacks to these assessments, such as the necessity of specialized technology and knowledge how to use it, associated legal constraints, and practical issues like athlete discomfort when using masks (Pinkstaff, Peberdy, Kontos, Finucane, & Arena, 2010). Additionally, the equipment requires regular calibration, and its use during competition is not feasible.

Secondly, due to the nature of official competition, certain variables (e.g., lactate levels and blood pressure) had to be measured post-competition. Regulations and methodological limitations prevented in-progress assessments, potentially leading to an underestimation of these as delays could allow partial recovery of the athletes (Ben Abdelkrim, et al., 2007).

Moreover, the study included only amateur basketball players, which limits the generalizability of the findings. The responses of professional athletes, with their advanced physiological and psychological characteristics, may differ significantly. This limitation is further emphasized by a relatively small sample size. Although the sensitivity analysis indicates that the study could identify moderate effects, the small sample size necessitates caution when drawing specific conclusions and making recommendations for new test protocols.

In summary, the findings highlight significant differences in the physiological and psychological variables analysed, suggesting that current laboratory stress test protocols do not accurately replicate the demands of competitive amateur men's basketball. Practical applications include the need to develop new laboratory and on-court test protocols that better mimic competitive conditions. This work justifies the introduction of modified and novel test approaches to more accurately reflect the reality of competition.

References

American College of Sports Medicine, Liguori, G., Feito, Y., Fountaine, C., & Roy, B. (Eds.). (2021). *ACSM's guidelines for exercise testing and prescription* (Eleventh edition). Philadelphia: Wolters Kluwer.

Apostolidis, N., Nassis, G. P., Bolatoglou, T., & Geladas, N. D. (2004). Physiological and technical characteristics of elite young basketball players. *The Journal of Sports Medicine and Physical Fitness*, *44*(2), 157–163.

Ayalon, A., Inbar, O., & Bar-Or, O. (1974). Relationships Among measurements of explosive strength and anaerobic power. In R. C. Nelson & C. A. Morehouse (Eds.), *Biomechanics IV* (pp. 572–577). London: Macmillan Education UK. https://doi.org/10.1007/978-1-349-02612-8_85

Bar-Or, O. (1987). The Wingate Anaerobic Test: An Update on Methodology, Reliability and Validity. *Sports Medicine*, *4*(6), 381–394. https://doi.org/10.2165/00007256-198704060-00001

Batalla Gavaldà, A., Bofill Ródenas, A. M., Montoliu Colás, R., & Corbi Soler, F. (2018). 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 Educación Física y Deportes*, (136), 110–122. https://doi.org/10.5672/apunts.2014-0983.es.(2018/2).132.08

Batra, A. (2019). *Monitoring anaerobic performance in combat sport athletes—Call for test specificity.*

Ben Abdelkrim, N., El Fazaa, S., El Ati, J., & Tabka, Z. (2007). Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition * Commentary. *British Journal of Sports Medicine*, *41*(2), 69–75. https://doi.org/10.1136/bjsm.2006.032318

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise*, *14*(5), 377–381.

Boutios, S., di Cagno, A., Buonsenso, A., Centorbi, M., Iuliano, E., Calcagno, G., & Fiorilli, G. (2022). Does the Type of Anaerobic Test Matter? A Comparison between the Anaerobic Intermittent Kick Test and Wingate Anaerobic Test in Taekwondo Athletes. *Sports*, *10*(10), 154. https://doi.org/10.3390/sports10100154

Çetin, İ. İ., Ekici, F., Kibar, A. E., Sürücü, M., & Orgun, A. (2018). The pre-participation screening in young athletes: Which protocol do we need exactly? *Cardiology in the Young*, *28*(4), 536–541. https://doi.org/10.1017/S1047951117002438

Coates, A. M., Millar, P. J., & Burr, J. F. (2023). Investigating the roles of exercise intensity and biological sex on postexercise alterations in cardiac function. *Journal of Applied Physiology*, *134*(2), 455–466. https://doi.org/10.1152/japplphysiol.00570.2022

Currell, K., & Jeukendrup, A. E. (2008). Validity, Reliability and Sensitivity of Measures of Sporting Performance: *Sports Medicine*, *38*(4), 297–316. https://doi.org/10.2165/00007256-200838040-00003

Daniels, C. J., Rajpal, S., Greenshields, J. T., Rosenthal, G. L., Chung, E. H., Terrin, M., … Eimer, M. (2021). Prevalence of Clinical and Subclinical Myocarditis in Competitive Athletes With Recent SARS-CoV-2 Infection: Results From the Big Ten COVID-19 Cardiac Registry. *JAMA Cardiology*, *6*(9), 1078. https://doi.org/10.1001/jamacardio.2021.2065

Delextrat, A., & Cohen, D. (2008). Physiological Testing of Basketball Players: Toward a Standard Evaluation of Anaerobic Fitness. *Journal of Strength and Conditioning Research*, *22*(4), 1066–1072. https://doi.org/10.1519/JSC.0b013e3181739d9b

Dobashi, K., Katagiri, A., Fujii, N., & Nishiyasu, T. (2023). Combined Effects of Hypocapnic Hyperventilation and Hypoxia on Exercise Performance and Metabolic Responses During the Wingate Anaerobic Test. *International Journal of Sports Physiology and Performance*, *18*(1), 69–76. https://doi.org/10.1123/ijspp.2022-0121

Dorel, S., Guilhem, G., Couturier, A., & Hug, F. (2012). Adjustment of Muscle Coordination during an All-Out Sprint Cycling Task. *Medicine & Science in Sports & Exercise*, *44*(11), 2154–2164. https://doi.org/10.1249/MSS.0b013e3182625423

Durmić, T., Đjelić, M., Gavrilović, T., Antić, M., Jeremić, R., Vujović, A., … Zdravković, M. (2019). Usefulness of heart rate recovery parameters to monitor cardiovascular adaptation in elite athletes: The impact of the type of sport. *Physiology International*, *106*(1), 81–94. https://doi.org/10.1556/2060.106.2019.03

Emery, M. S., & Kovacs, R. J. (2018). Sudden Cardiac Death in Athletes. *JACC: Heart Failure*, *6*(1), 30–40. https://doi.org/10.1016/j.jchf.2017.07.014

Estes, N. A. M., & Madias, C. (2017). Atrial Fibrillation in Athletes. *JACC: Clinical Electrophysiology*, *3*(9), 921–928. https://doi.org/10.1016/j.jacep.2017.03.019

Fatouros, I. G., Laparidis, K., Kambas, A., Chatzinikolaou, A., Techlikidou, E., Katrabasas, I., … Taxildaris, K. (2011). Validity and reliability of the single-trial line drill test of anaerobic power in basketball players. *The Journal of Sports Medicine and Physical Fitness*, *51*(1), 33–41.

Franklin, B. A., Thompson, P. D., Al-Zaiti, S. S., Albert, C. M., Hivert, M.-F., Levine, B. D., … On behalf of the American Heart Association Physical Activity Committee of the Council on Lifestyle and Cardiometabolic Health; Council on Cardiovascular and Stroke Nursing; Council on Clinical Cardiology; and Stroke Council. (2020). Exercise-Related Acute Cardiovascular Events and Potential Deleterious Adaptations Following Long-Term Exercise Training: Placing the Risks Into Perspective–An Update: A Scientific Statement From the American Heart Association. *Circulation*, *141*(13). https://doi.org/10.1161/CIR.0000000000000749

Ghasem, W., Abouzeid, C., Toresdahl, B. G., & Shah, A. B. (2022). Updated Blood Pressure Guidelines: Implications for Athletes. *Current Hypertension Reports*, *24*(10), 477–484. https://doi.org/10.1007/s11906-022-01210-8

Gholami, F., Ali, A., Hasani, A., & Zarei, A. (2022). Effect of Beta-Alanine Supplementation on Exercise-Induced Cell Damage and Lactate Accumulation in Female Basketball Players: A Randomized, Double-Blind Study. *Journal of Human Kinetics*, *83*, 99–107. https://doi.org/10.2478/hukin-2022-0034

Granier, P., Mercier, B., Mercier, J., Anselme, F., & Préfaut, C. (1995). Aerobic and anaerobic contribution to Wingate test performance in sprint and middle-distance runners. *European Journal of Applied Physiology and Occupational Physiology*, *70*(1), 58–65. https://doi.org/10.1007/BF00601809

Hajduczok, A. G., Ruge, M., & Emery, M. S. (2022). Risk Factors for Sudden Death in Athletes, Is There a Role for Screening? *Current Cardiovascular Risk Reports*. https://doi.org/10.1007/s12170-022-00697-9

Hamlin, M., Draper, N., Blackwell, G., Shearman, J., & Kimber, N. (2012). Determination of Maximal Oxygen Uptake Using the Bruce or a Novel Athlete-Led Protocol in a Mixed Population. *Journal of Human Kinetics*, *31*(2012), 97–104. https://doi.org/10.2478/v10078-012-0010-z

Harber, M. P., Kaminsky, L. A., Arena, R., Blair, S. N., Franklin, B. A., Myers, J., & Ross, R. (2017). Impact of Cardiorespiratory Fitness on All-Cause and Disease-Specific Mortality: Advances Since 2009. *Progress in Cardiovascular Diseases*, *60*(1), 11–20. https://doi.org/10.1016/j.pcad.2017.03.001

Harmon, K. G., Zigman, M., & Drezner, J. A. (2015). The effectiveness of screening history, physical exam, and ECG to detect potentially lethal cardiac disorders in athletes: A systematic review/meta-analysis. *Journal of Electrocardiology*, *48*(3), 329–338. https://doi.org/10.1016/j.jelectrocard.2015.02.001

Hauer, R., Tessitore, A., Binder, N., & Tschan, H. (2018). Physiological, perceptual, and technical responses to continuous and intermittent small-sided games in lacrosse players. *PLOS ONE*, *13*(10), e0203832. https://doi.org/10.1371/journal.pone.0203832

Higgins, J. P., & Higgins, J. A. (2007). Electrocardiographic exercise stress testing: An update beyond the ST segment. *International Journal of Cardiology*, *116*(3), 285–299. https://doi.org/10.1016/j.ijcard.2006.04.047

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive Statistics for Studies in Sports Medicine and Exercise Science. *Medicine & Science in Sports & Exercise*, *41*(1), 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Huang, Z., Wang, B., Song, K., Wu, S., Kong, H., Guo, L., & Liang, Q. (2023). Metabolic and cardiovascular responses to continuous and intermittent plank exercises. *BMC Sports Science, Medicine and Rehabilitation*, *15*(1), 1. https://doi.org/10.1186/s13102-022-00613-z

Iamonti, V. C., Souza, G. F., Castro, A. A. M., Porto, E. F., Cruz, L. G. B., Colucci, E., … Jardim, J. R. (2022). Upper Limb Anaerobic Metabolism Capacity is Reduced in Mild and Moderate COPD Patients. *COPD: Journal of Chronic Obstructive Pulmonary Disease*, *19*(1), 265–273. https://doi.org/10.1080/15412555.2022.2079485

James, G. D., & Gerber, L. M. (2018). Measuring arterial blood pressure in humans: Auscultatory and automatic measurement techniques for human biological field studies. *American Journal of Human Biology*, *30*(1), e23063. https://doi.org/10.1002/ajhb.23063

JASP Team. (2024). *JASP* [Mac]. Retrieved from https://jasp-stats.org/

Jouven, X., Empana, J.-P., Schwartz, P. J., Desnos, M., Courbon, D., & Ducimetière, P. (2005). Heart-Rate Profile during Exercise as a Predictor of Sudden Death. *New England Journal of Medicine*, *352*(19), 1951–1958. https://doi.org/10.1056/NEJMoa043012

Joyner, M. J., & Casey, D. P. (2015). Regulation of Increased Blood Flow (Hyperemia) to Muscles During Exercise: A Hierarchy of Competing Physiological Needs. *Physiological Reviews*, *95*(2), 549–601. https://doi.org/10.1152/physrev.00035.2013

Jung, M. E., Bourne, J. E., & Little, J. P. (2014). 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. *PLoS ONE*, *9*(12), e114541. https://doi.org/10.1371/journal.pone.0114541

Keir, D. A., Fontana, F. Y., Robertson, T. C., Murias, J. M., Paterson, D. H., Kowalchuk, J. M., & Pogliaghi, S. (2015). Exercise Intensity Thresholds: Identifying the Boundaries of Sustainable Performance. *Medicine & Science in Sports & Exercise*, *47*(9), 1932–1940. https://doi.org/10.1249/MSS.0000000000000613

Khoramipour, K., Gaeini, A. A., Shirzad, E., Gilany, K., Chashniam, S., & Sandbakk, Ø. (2021). Metabolic load comparison between the quarters of a game in elite male basketball players using sport metabolomics. *European Journal of Sport Science*, *21*(7), 1022–1034. https://doi.org/10.1080/17461391.2020.1805515

Kokkinos, P. F., Faselis, C., Myers, J., Narayan, P., Sui, X., Zhang, J., … Fletcher, R. (2017). Cardiorespiratory Fitness and Incidence of Major Adverse Cardiovascular Events in US Veterans: A Cohort Study. *Mayo Clinic Proceedings*, *92*(1), 39–48. https://doi.org/10.1016/j.mayocp.2016.09.013

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00863

Lässing, J., Maudrich, T., Kenville, R., Uyar, Z., Bischoff, C., Fikenzer, S., … Falz, R. (2023). Intensity-dependent cardiopulmonary response during and after strength training. *Scientific Reports*, *13*(1), 6632. https://doi.org/10.1038/s41598-023-33873-x

Lee, S., Choi, Y., Jeong, E., Park, J., Kim, J., Tanaka, M., & Choi, J. (2023). Physiological significance of elevated levels of lactate by exercise training in the brain and body. *Journal of Bioscience and Bioengineering*, *135*(3), 167–175. https://doi.org/10.1016/j.jbiosc.2022.12.001

Legaz-Arrese, A., Munguía-Izquierdo, D., Carranza-García, L. E., & Torres-Dávila, C. G. (2011). Validity of the Wingate Anaerobic Test for the Evaluation of Elite Runners. *Journal of Strength and Conditioning Research*, *25*(3), 819–824. https://doi.org/10.1519/JSC.0b013e3181c1fa71

Löllgen, H., & Leyk, D. (2018). Exercise Testing in Sports Medicine. *Deutsches Ärzteblatt International*. https://doi.org/10.3238/arztebl.2018.0409

Manoelles, P. (2005). *Cardiología del deporte*. Nexus Médica.

Manonelles P., Franco L., & Naranjo, J. (2016). Pruebas de esfuerzo en medicina del deporte Documento de consenso de la Sociedad Española de Medicina del Deporte (SEMED-FEMEDE). *Archivos de medicina del deporte*, *33 Suppl. 1.*

Maron, B. J., Haas, T. S., Ahluwalia, A., Murphy, C. J., & Garberich, R. F. (2016). Demographics and Epidemiology of Sudden Deaths in Young Competitive Athletes: From the United States National Registry. *The American Journal of Medicine*, *129*(11), 1170–1177. https://doi.org/10.1016/j.amjmed.2016.02.031

Marszałek, J., Kosmol, A., Morgulec-Adamowicz, N., Mróz, A., Gryko, K., Klavina, A., … Molik, B. (2019). Laboratory and Non-laboratory Assessment of Anaerobic Performance of Elite Male Wheelchair Basketball Athletes. *Frontiers in Psychology*, *10*, 514. https://doi.org/10.3389/fpsyg.2019.00514

McInnes, S. E., Carlson, J. S., Jones, C. J., & McKenna, M. J. (1995). The physiological load imposed on basketball players during competition. *Journal of Sports Sciences*, *13*(5), 387–397. https://doi.org/10.1080/02640419508732254

Medbø, J. I., & Toska, K. (2001). Lactate Release, Concentration in Blood, and Apparent Distribution Volume after Intense Bicycling. *The Japanese Journal of Physiology*, *51*(3), 303–312. https://doi.org/10.2170/jjphysiol.51.303

Mehra, M., Kobashigawa, J., Starling, R., Russell, S., Uber, P., Parameshwar, J., … Barr, M. (2006). Listing Criteria for Heart Transplantation: International Society for Heart and Lung Transplantation Guidelines for the Care of Cardiac Transplant Candidates—2006. *The Journal of Heart and Lung Transplantation*, *25*(9), 1024–1042. https://doi.org/10.1016/j.healun.2006.06.008

Morentin, B., Suárez-Mier, M. P., Monzó, A., Ballesteros, J., Molina, P., & Lucena, J. (2021). Muerte súbita relacionada con la actividad deportiva en España. Estudio poblacional multicéntrico forense de 288 casos. *Revista Española de Cardiología*, *74*(3), 225–232. https://doi.org/10.1016/j.recesp.2020.05.035

Myers, J., Arena, R., Franklin, B., Pina, I., Kraus, W. E., McInnis, K., & Balady, G. J. (2009). Recommendations for Clinical Exercise Laboratories: A Scientific Statement From the American Heart Association. *Circulation*, *119*(24), 3144–3161. https://doi.org/10.1161/CIRCULATIONAHA.109.192520

Petway, A. J., Freitas, T. T., Calleja-González, J., Medina Leal, D., & Alcaraz, P. E. (2020). Training load and match-play demands in basketball based on competition level: A systematic review. *PLOS ONE*, *15*(3), e0229212. https://doi.org/10.1371/journal.pone.0229212

Pinkstaff, S., Peberdy, M. A., Kontos, M. C., Finucane, S., & Arena, R. (2010). Quantifying Exertion Level During Exercise Stress Testing Using Percentage of Age-Predicted Maximal Heart Rate, Rate Pressure Product, and Perceived Exertion. *Mayo Clinic Proceedings*, *85*(12), 1095–1100. https://doi.org/10.4065/mcp.2010.0357

Quittmann, O. J., Schwarz, Y. M., Mester, J., Foitschik, T., Abel, T., & Strüder, H. K. (2021). Maximal Lactate Accumulation Rate in All-out Exercise Differs between Cycling and Running. *International Journal of Sports Medicine*, *42*(04), 314–322. https://doi.org/10.1055/a-1273-7589

Rabadán, M., & Boraita, A. (2005). Las pruebas de esfuerzo en la valoración cardiológica y funcional del deportista. In *Cardiología del deporte* (Vol. 7, p. Capítulo 7). Barcelona: Nexus Médica.

Remor, E. (2006). Psychometric Properties of a European Spanish Version of the Perceived Stress Scale (PSS). *The Spanish Journal of Psychology*, *9*(1), 86–93. https://doi.org/10.1017/S1138741600006004

Sánchez Arjona, C., Ruiz Martínez, Y., & Martín Fernández, M. C. (2008). Influencia del lugar de extracción en la determinación de los niveles de lactato durante una prueba de esfuerzo incremental. *Revista Andaluza de Medicina Del Deporte*, *1*(2), 57–60.

Sánchez-Beleña, F., & García-Naveira Vaamonde, A. (2017). Sobreentrenamiento y deporte desde una perspectiva psicológica: Estado de la cuestión. *Revista de Psicología Aplicada al Deporte y el Ejercicio Físico*, *2*(2), e12, 1–12. https://doi.org/10.5093/rpadef2017a8

Sanders, G. J., Boos, B., Rhodes, J., Kollock, R. O., & Peacock, C. A. (2021). Competition-Based Heart Rate, Training Load, and Time Played Above 85% Peak Heart Rate in NCAA Division I Women's Basketball. *Journal of Strength and Conditioning Research*, *35*(4), 1095–1102. https://doi.org/10.1519/JSC.0000000000002876

Sansone, P., Gasperi, L., Tessitore, A., & Gomez, M. (2021). Training load, recovery and game performance in semiprofessional male basketball: Influence of individual characteristics and contextual factors. *Biology of Sport*, *38*(2), 207–217. https://doi.org/10.5114/biolsport.2020.98451

Santos, L., González, V., Iscar, M., Brime, J. I., Fernández-Río, J., Rodríguez, B., & Montoliu, M. A. (2012). Physiological response of high-level female judokas measured through laboratory and field tests. Retesting the validity of the Santos test. *The Journal of Sports Medicine and Physical Fitness*, *52*(3), 237–244.

Sawada, Y., Ichikawa, H., Ebine, N., Minamiyama, Y., Alharbi, A. A. D., Iwamoto, N., & Fukuoka, Y. (2023). Effects of High-Intensity Anaerobic Exercise on the Scavenging Activity of Various Reactive Oxygen Species and Free Radicals in Athletes. *Nutrients*, *15*(1), 222. https://doi.org/10.3390/nu15010222

Stojanović, E., Stojiljković, N., Scanlan, A. T., Dalbo, V. J., Berkelmans, D. M., & Milanović, Z. (2018). The Activity Demands and Physiological Responses Encountered During Basketball Match-Play: A Systematic Review. *Sports Medicine*, *48*(1), 111–135. https://doi.org/10.1007/s40279-017-0794-z

Takahashi, H., Yoshika, M., & Yokoi, T. (2015). Validation of three automatic devices for the self-measurement of blood pressure according to the European Society of Hypertension International Protocol revision 2010: The Omron HEM-7130, HEM-7320F, and HEM-7500F. *Blood Pressure Monitoring*, *20*(2), 92–97. https://doi.org/10.1097/MBP.0000000000000096

Warr-di Piero, D., Valverde-Esteve, T., Redondo-Castán, J. C., Pablos-Abella, C., & Sánchez-Alarcos Díaz-Pintado, J. V. (2018). Effects of work-interval duration and sport specificity on blood lactate concentration, heart rate and perceptual responses during high intensity interval training. *PLOS ONE*, *13*(7), e0200690. https://doi.org/10.1371/journal.pone.0200690

Weichenberger, M., Esefeld, K., & Müller, S. (2023). Kardiopulmonale Leistungsdiagnostik beim Spitzensportler. *Herzschrittmachertherapie + Elektrophysiologie*. https://doi.org/10.1007/s00399-022-00916-1

Wilson, D. F. (2016). Regulation of metabolism: The work-to-rest transition in skeletal muscle. *American Journal of Physiology-Endocrinology and Metabolism*, *310*(8), E633–E642. https://doi.org/10.1152/ajpendo.00512.2015

Wu, J., Han, X., Sun, D., Zhang, J., Li, J., Qin, G., … Xu, H. (2023). Age-specific association of stage of hypertension at diagnosis with cardiovascular and all-cause mortality among elderly patients with hypertension: A cohort study. *BMC Cardiovascular Disorders*, *23*(1), 270. https://doi.org/10.1186/s12872-023-03250-7

Yanci, J., Granados, C., Otero, M., Badiola, A., Olasagasti, J., Bidaurrazaga-Letona, I., … Gil, S. (2014). Sprint, agility, strength and endurance capacity in wheelchair basketball players. *Biology of Sport*, *32*(1), 71–78. https://doi.org/10.5604/20831862.1127285

Yang, P., Jang, E., Yu, H. T., Kim, T., Pak, H., Lee, M., & Joung, B. (2021). Changes in Cardiovascular Risk Factors and Cardiovascular Events in the Elderly Population. *Journal of the American Heart Association*, *10*(11), e019482. https://doi.org/10.1161/JAHA.120.019482

Submitted: May 8, 2024
Accepted: September 30, 2024

Correspondence to:
Jose Vicente Beltran-Garrido, Ph.D.
Department of Education Science
School of Humanities and Communication Sciences,
CEU-Cardenal Herrera University,
12006 Castellón de la Plana, Spain
Email: josevicentebelga@gmail.com