

Looking for the best way to determine aerobic performance in futsal: a pilot study

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Abstract:

Problem Statement. The specific characteristics of Futsal require the athlete to have the ability to meet the aerobic requirements either in trainings or during the competitions. To achieve this, it is essential to individualize the training loads for each player. But it is complicated due to training is accomplished with groups of players with different characteristics, and Futsal is an acyclic sport. **Approach.** Heart rate variability (HRV) is currently being used as an indicator of the athlete's recovery after training, as well as their predisposition to face high-intensity stimuli, optimizing adaptations to training and allowing the individual assessment. It has been used in individual resistance sports, and recently in other team sports such as soccer or rugby. According to the previous research, HRV score should be related to the performance profile of athletes but there is no consensus regarding the best measuring parameter. **Purpose.** The objective of this study was to analyze its relationship with the performance of futsal players through the YoYo IR1 test, as well as to determine which HRV measure is capable of predicting the performance of soccer players with greater precision. The design was observational and cross-sectional with a single sample group made up of 15 participants from a cadet futsal team from El Ejido. Resting HRV was measured using the HRV4Training mobile app, and aerobic endurance through distance traveled in the YoYo IR1 test. **Results.** A significant ($p \leq 0.05$) direct correlation was found between the time domain parameters LnrMSSD, SDNN and pNN50 with the YoYo IR1 test, with a coefficient of determination (r^2) of 0.60, 0.42 and 0.57. respectively. **Conclusions.** The HRV is a valid measure to determine the aerobic performance of cadet futsal players, with the LnrMSSD being the most accurate measure.

Key Words: Team sport; Heart Rate Variability; LnrMSSD; soccer player; Yo-Yo test; Correlation

Introduction

Futsal is a sport played on a 40 x 20 meter court where two teams with five players face each other (four court players and one goalkeeper per team), being able to make an unlimited number of substitutions, without the need to stop time, thus favoring the intensity to be very high throughout the match (Ayarra et al., 2018). Moreover, many changes of direction are made with very short recovery periods; this requires great cardiorespiratory endurance and muscle strength (Barbero-Álvarez et al., 2008; Gioldasis, 2016), and the competitive rate is very high, with competitions being held every week, distinguishing it from other similar team sports. Therefore it will have a dynamic and complex context that requires players to be fast and precise in their actions for a successful performance (Iedynak, Galamandjuk, et al., 2019; Iedynak, Marzec, et al., 2019). For this reason, training has to be planned very carefully (Álvarez et al., 2009). Within team sports, it is seen as essential to quantify the training loads, with their control, management and recording being considered very important when planning a season (Cuadrado-Reyes et al., 2012). Consequently, evaluating and determining the training load allows one to obtain useful information that can be used to individualize the loads applied to each player (Campos-Vázquez, 2012). However, controlling the training loads in team sports is complicated since you are working with groups of players with different characteristics. Moreover, one is programming for an acyclic sport (Pascual et al., 2016).

To quantify the training load in team sports, different methods have been used, from recording the heart rate (Tapia-López, 2017) to measuring the maximum oxygen consumption (VO_{2max}) and determining the lactate concentration season (Cuadrado-Reyes et al., 2012). However, these methods require considerable human and material resources that are often not available to clubs (Gómez-Díaz et al., 2013), such as gas analysers and treadmills. For this reason, to quantify the workload of players during training and futsal matches, the subjective rating of perceived effort (RPE) (Tapia-López, 2017) is used. Nonetheless, when using a subjective measurement, the effectiveness of quantifying the training load is diminished; therefore, it is necessary to determine other methods that offer a direct and reliable way to measure the state of the futsal player so as to optimize training planning. Heart rate variability (HRV) is currently used as an indicator of the athletes' physical and psychological state.

HRV is the variation in time elapsed between the different RR waves that occur in each heartbeat over a given time period (Huang et al., 2019; Rodas et al., 2008). This indicator allows the non-invasive analysis of the autonomic nervous system activity in both its sympathetic and parasympathetic branches (Plews et al., 2013). This is relevant when we consider that an important component of interindividual variability in physiological responses to training is related to the balance between the parasympathetic (PNS) and sympathetic (SNS) activity of the autonomic nervous system (ANS) (Chandola et al., 2010). Thus, high HRV values indicate more parasympathetic than sympathetic activation (Márquez et al., 2018), showing better recovery after the training session or a better predisposition to face high-intensity activities. This has been demonstrated in various studies conducted on athletes, in which HRV has been related to elements of training such as intensity, duration, or recovery (Seiler et al., 2007) as well as overtraining (Hedelin et al., 2000), training load (Javaloyes et al., 2019), and psychological (Ortigosa-Márquez, 2017) or performance profiles (Buchheit et al., 2012). Therefore, HRV analysis is a useful method for measuring the heart's ability to adapt to endogenous and exogenous loads (Parrado et al., 2010) and can be used for individual assessment of training load responses and recovery adaptation in young footballers (Williams et al., 2017).

At present, different methods exist for analysing HRV that allow one to obtain multiple and varied parameters. The electrocardiogram has traditionally been used for this purpose, however HRV can currently be obtained through computer programs or validated mobile applications (Rodas et al. 2008), such as Kubios, Elite HRV, Mobile Lab or HRV4Training. According to Rodas et al. (2008) and Shaffer and Venner (2016), time-domain and frequency-domain parameters can be obtained. Time-domain parameters quantify the magnitude of interval variability between successive heartbeats. The most often used measurements are SDNN, SDRR and SDANN, linked to both the sympathetic and parasympathetic mechanisms, and pNN50, HR max-HR min and rMSSD, linked to parasympathetic activation. On the other hand, frequency-domain parameters are the result of HR oscillations, which are divided into four frequency bands: ultra-low (ULF), very low (VLF), low (LF) and high (HF). LF is linked to SNS and PNS activation, as well as to baroreflex. HF inhibits and activates the vagus nerve. Regarding the protocol for recording HRV, it must be taken into account that there is no single procedure among researchers and professionals. The HRV recording can be taken at rest, during or after exercise, depending on its objective (Forner, 2021). Moreover, the body positioning can be considered. Within both amateur and professional sports, the records have been made in a supine position, sitting or standing, while the most used in team sports was the sitting position (Buchheit et al., 2012; Naranjo et al., 2015; Pereira et al., 2016; Proietti et al., 2017; Thorpe et al., 2016) since standing position is more recommended for athletes with a very high level of resistance (Kiviniemi et al., 2007).

Based on the above, this study aims to: i) analyse the relationship between HRV and the aerobic performance of Futsal players; and (ii) determine which HRV measure most accurately predicts the aerobic performance of those players. It is hypothesized that: i) high HRV values will be directly related to better aerobic performance in Futsal players; and ii) the LnrMSSD will be the variable with the highest coefficient of determination. In this way, more information will be provided on the validity of HRV values to gauge the player's performance status; they can be used at various times during the season to adjust individual training loads, allowing more flexibility when conducting performance tests.

Material & methods

Participants

The analysed sample comprised a group of 15 male youth futsal players from a team in El Ejido (Almería). The inclusion criteria were: i) belonging to the team, ii) belonging to the club's youth category, and iii) having the informed consent signed by their parents or guardians. The exclusion criteria were: i) suffering from any injury or pathology that prevented them from carrying out previous training since the beginning of the season, ii) not attending at least 85% of the previous training sessions, and iii) not completing the measurement procedure on the stipulated dates.

Design

The study design was observational and cross-sectional. The study began in November 2021 with the recruitment of the players and the start of taking HRV measurements. In December 2021, familiarization with the Yo-Yo IR1 test was carried out, along with collecting the relative weight data, recording the last HRV, and then undertaking the YoYo IR1 test. All data collection was carried out in the El Ejido Municipal Pavilion (Almería).

Variable

To record the HRV, the HRV4Training mobile application was used, which was validated by Plews et al. (2017). This application uses the plethysmography (PPG) method for recording HRV. In this study the flash on a Xiaomi Redmi 9 s mobile phone was used. The frequency-domain variables LF, HF and LF/HF were collected along with those of the SDNN, pNN50 and rMSSD time domain. The rMSSD was transformed using the natural logarithm for this variable (LnrMSSD) to correct for positive asymmetry, to assume a normal distribution and to allow parametric analysis (Plews et al., 2014). The LF/HF ratio was also calculated to estimate vagal sympathetic equilibrium (Eckberg, 1997) and to use it as an analysis variable. A meeting was held with the players to explain the process for recording the HRV in the study during which they were shown the

HRV4Training application and how the recording of the measurements would be carried out. On the day of the data collection, the players were summoned 30 minutes prior to training. The measurements were taken in the changing room following each player's seating order. The HRV was measured for 1 minute following two minutes of rest to allow the heart rate to stabilize. The obtained data were transferred to Excel for subsequent analysis.

The YoYo IR1 test is a validated test with Krustup et al. (2003) that has been used in several studies on football players (Boullosa et al., 2013 y Buchheit et al., 2014). This test focuses on the ability to perform intermittent exercise that leads to maximal activation of the aerobic system (Bangsbo et al., 2008). It consists of making back and forth sprints over a 20-metre stretch at a speed that increases progressively until exhaustion sets in. The 20-metre length is usually demarcated by two straight parallel lines that the athletes must touch when they hear the sound signal (Krustup et al., 2003). The variable recorded is the total metres travelled by each player. A familiarization session was conducted one week prior to the test in which the data were recorded.

Statistical analysis

The statistical analysis was performed using the IBM SPSS Statistics 27.0 package for Windows. Prior to the data analysis, the distribution (normality) of the variables was determined using the Shapiro-Wilk test. A descriptive analysis of the sample variables was carried out, which is presented as range, mean and standard deviation (SD).

The relationship between the variables in all the sample was calculated using the Pearson's r correlation coefficient. If the correlation was significant, the coefficient of determination (r^2) was used to specify the percentage variation of Y over X. The correlation thresholds were 0.1, small; 0.3, moderate; 0.5, large; 0.7, very large; and 0.9, almost perfect (Hopkins et al., 2009), and the significance level was set at $p \leq 0.05$.

Results

Initially, 15 players were recruited, of which 11 eventually remained, with 4 being excluded. Two players were injured in the match prior to the test (one due to an ankle sprain and the other due to knee dislocation), making it impossible for them to continue participating. Another participant could not participate after being in close contact with a positive Covid-19 case. Finally, one player was excluded from the study because, after the descriptive analysis of the data, his results were considered to be extremely high, which would skew the normality of the sample. Table 1 shows the descriptive statistics for all the variables recorded.

Table 1. *descriptive statistics.*

Variable	N	Min	Max	Mean	SD
Age	11	14,19	15,83	15,07	0,55
Weight (kg)	11	42,60	88,70	62,03	13,36
Height (cm)	11	150	180	169	0,08
BMI (kg/m ²)	11	1580	31,10	21,46	4,55
Basal HR	11	33,30	79,33	51,40	16,21
LnrMSSD (ms)	11	3,94	5,69	5,02	0,58
SDNN (ms)	11	64,45	258,71	139,72	73,79
pNN50 (%)	11	30,36	100	66,77	22
LF (HZ)	11	0,02	0,27	0,11	0,08
HF (HZ)	11	0,06	0,28	0,16	0,07
LF/HF (HZ)	11	0.18	1,67	0,75	0,48
Yo-Yo IR Test (m)	11	600	2640	1518,18	555,87

Note: BMI = body mass index; Basal HR = basal heart rate; LnrMSSD = Natural logarithm of rMSSD; SDNN= standard deviation of all RR intervals; pNN50: percentage consecutive RR intervals; LF= low frequency; HF= high frequency; LF/HF= ratio low frequency and high frequency

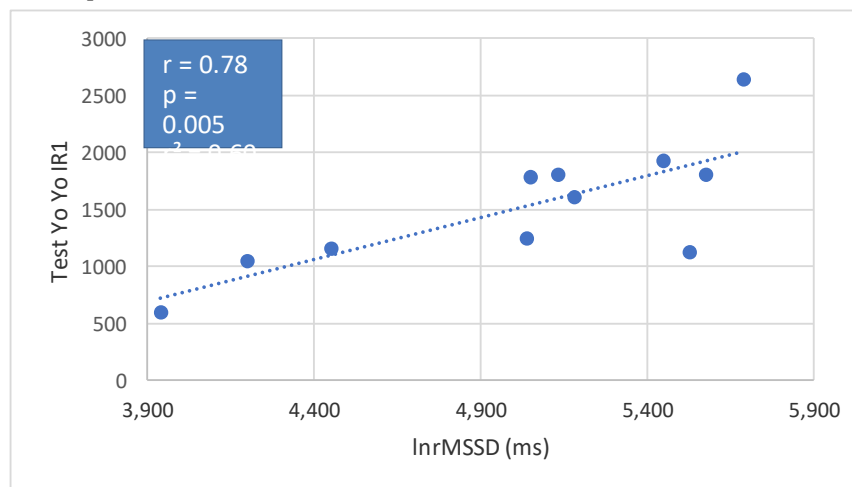
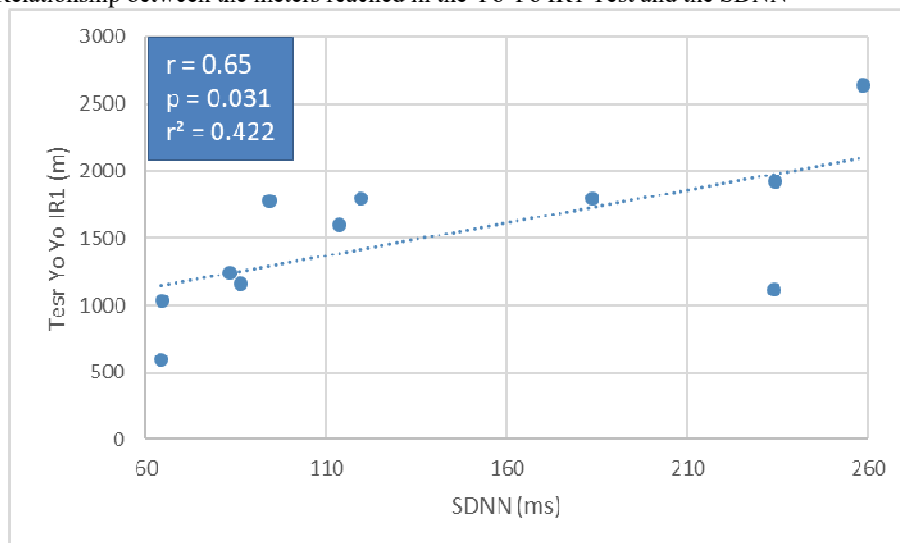
The relationship between variables for the entire sample is shown in Table 2. It indicates that there is a significant direct correlation ($p \leq 0.05$) between the time-domain parameters, such as LnrMSSD, SDNN and pNN50, with the Yo-Yo IR1 test, having coefficients of determination (r^2) of 0.60, 0.42 and 0.57 respectively. No significant correlations were found between the performance test and the frequency-domain parameters or baseline heart rate.

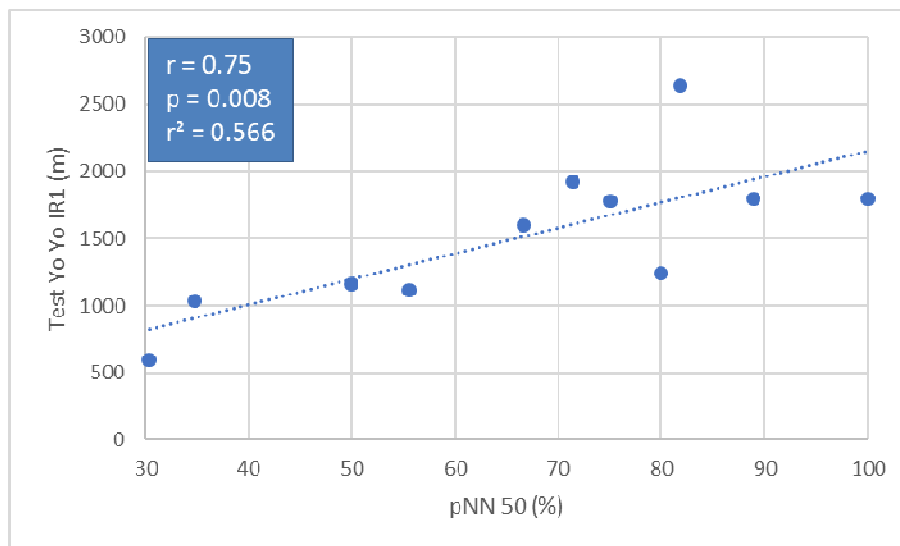
Table 2. Relationship of the variables measured with the Yo-Yo IR1 test

Variable	r	p	R ²
Age	0.58	0.866	0.003
Basal HR	0.36	0.273	0.131
LnrMSSD (ms)	0.78	0.005	0.600
SDNN (ms)	0.65	0.031	0.422
pNN50 (%)	0.75	0.008	0.566
LF (HZ)	0.38	0.248	0.145
HF (HZ)	0.09	0.787	0.009
LF/HF (HZ)	0.36	0.280	0.128

Note: Basal HR = basal heart rate; LnrMSSD = Natural logarithm of rMSSD; SDNN= standard deviation of all RR intervals; pNN50: percentage consecutive RR intervals; LF= low frequency; HF= high frequency; LF/HF= ratio low frequency and high frequency.

The significant correlations of the variables analysed with the Yo-Yo IR1 test are plotted below:

Figure 1. Relationship between the meters reached in the Yo Yo IR1 Test and the LnrMSSD.**Figure 2.** Relationship between the meters reached in the Yo Yo IR1 Test and the SDNN**Figure 3.** Relationship between the meters reached in the Yo Yo IR1 Test and the pNN50.



Dicussion

This study aimed to analyse the relationship between heart rate variability and performance in youth futsal players and to determine which HRV measure predicted performance most accurately. The results show that there is a direct and positive relationship between the YoYo IR1 test and the time-domain parameters analysed (LnrMSSD, SDNN and pNN50), with the LnrMSSD parameter being the most accurate.

According to the results, there is a high probability that the Futsal players who presented high HRV, travelled more meters in the YoYo IR1 aerobic endurance test. Similar results were found in various studies carried out on football players. For instance, one study recorded a correlation of 0.85 between rMSSD and the metres travelled in a YoYo IR1 test conducted on senior players (Oliveira et al., 2012), while another study showed that there was a significant relationship between the measurement of parasympathetic activity at rest and the performance obtained in football players in the novice-junior category during an intermittent endurance test such as the YoYo IR1 (Pereira et al., 2019). Similarly, there is a significant association between another endurance test (Test 5'-5') and the HRV at rest, and with maximum aerobic speed in football players between 13 and 16 years old (Buchheit et al., 2010). Furthermore, in another study by the same author conducted on 15-year-old handball players (Buchheit et al., 2008), a positive relationship was found between the RSA test (the ability to repeat sprints continuously with a reduced recovery time between each of them) and HRV.

According to the results found in this study, and based on the scientific literature, high HRV values are associated with better cardiorespiratory fitness and physical performance (Buchheit et al., 2008; Buchheit et al., 2010; Lamberts et al., 2010; Mandigout et al., 2002), so adequate continuous aerobic demand training is essential for improving cardiac autonomic function, raising HRV indices and optimizing performance, even at a young age. This also highlights the importance of individualized training in team sports, for which HRV-guided training could be a very useful tool, as has been proven in other studies with elite endurance athletes, such as a study on cyclists (Javaloyes et al., 2019) or another on runners (Carrasco-Poyatos et al., 2022).

On the other hand, the measure that presents the greater predictive factor is the LnrMSSD, with a 60% probability that the higher it is, the better the player's performance. Other measures that were also shown to be performance predictors for the players in our sample were SDNN and pNN50, having a 42% and 57% probability, respectively. However, frequency measurements did not yield significant associations. Our study is in accordance with the results of a study conducted on children aged 10 to 11 years old (Mandigout et al., 2002), which showed an improvement in HRV in the time domain, but no major changes in the frequency-domain parameters. Another study determined that the most reliable variable for measuring the HRV of soccer players in pre-season was the SDNN (Boullousa et al., 2013). It is important to note that this measurement was taken at night over 3 hours. However, other studies did find associations between the HRV frequency domains and performance (Bricout et al., 2010; Garet et al., 2004), indicating that a lower LF parameter value was related to higher performance or, conversely, high levels led to early fatigue. These differences in results with other studies may be due to the data recording procedure (Shaffer y Venner, 2016) since 1 minute is sufficient for time domains whereas a 2-to-5-minute range is recommended for frequency domains. According to our study results, and given the fact that it is validated, we recommend using LnrMSSD for its ease of recording and analysis.

The limitations of this study include its sample size - a sample of 11 subjects is not statistically conclusive for establishing correlations. Selection and observation biases must also be taken into account, since the sample was selected for convenience and the data were obtained by the researcher in direct contact with the participants.

As for future research, the sample should be expanded to a statistically significant size. Moreover, it would be interesting to carry out the same research via a cohort study using different measures to determine the influence of certain periods of the season on the variables measured. Determining the HRV normality range in the subjects would provide information on their recovery status on the day of the test; this would complement the information provided from the present study, as well as include different categories and sexes. Our study also indicates that it would be beneficial to include the SDNN and pNN50 variables in the HRV recordings as they also seem to be good performance indicators.

Conclusions

This study demonstrates that the HRV parameters obtained through the HRV4Training application have a direct and significant relationship with aerobic performance in youth futsal players. In addition, the HRV measures that predict performance most accurately for these players are those of the time domain (LnrMSSD, SDNN and pNN50), with LnrMSSD being the most notable of these. Therefore, HRV is a recommended measure for determining the performance of futsal players and can be used to individualize the daily training load in a simple and rapid way. This will allow coaches to make a more accurate intra-session adaptation to optimize the players performance, using recovery if necessary, and avoiding injuries and training overload. Thus, making the planning of the season training more effective.

Conflicts of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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