Sports Training

Different methods to determine maximum heart rate and its influence on internal training load in futsal players

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Abstract - Aims: The purpose of this study was to compare maximal heart rate (HR_{max}) determined in official match (OM), Yo-Yo intermittent recovery test level 1 (YYIR-1), and age-predicted equations in futsal players, also assessing the effects of using these HR_{max} approaches on internal training load (TL) outcomes since HR_{max} influences the TL internal calculation. **Methods:** HR_{max} of professional male futsal players (n=8) was determined in OM, YYIR-1 and by four age-predicted equations: Fox-HR_{max}; Hossack-HR_{max}; Tanaka-HR_{max}; Nikolaidis-HR_{max}. Additionally, the internal TL of seven training sessions was calculated individually each day for each of the six HR_{max} approaches using Edwards's method. Statistical analysis comprised ANOVA for repeated measures ($p < 0.05$) and Cohen's *d* effect size (ES). **Results:** Fox-HR_{max} overestimated all other HR_{max}-equations and YYIR-1 HR_{max}, and Nikolaidis-HR_{max} overestimated Tanaka-HR_{max} and Hossack-HR_{max} ($p = 0.01$; $\eta_P^2 = 0.496$). TRIMP statistical results were statistically like HR_{max} but underestimated ($p = 0.008$; $\eta_P^2 = 0.513$). Pairwise inferences showed that OM HR_{max} presented a large effect (d: 0.83) in comparison to the YYIR-1 and a moderate effect (*d*: -0.35 to 0.35) in comparison to the Fox-HR_{max}, Tanaka-HR_{max} and Hossack-HR_{max}. Nikolaidis-HR_{max} presented a lower difference with OM, HR_{max} (*d*: -0.13, *trivial*) and TRIMP (*d*: -0.09, *trivial*). **Conclusion:** HR_{max} from OM presented a higher effect in comparison to the YYIR-1, while the Nikolaidis-HR_{max} equation was lower and differed from OM HR_{max}. Futsal coaches are encouraged to use OM to determine HR_{max} and Nikolaidis-HR_{max} equation when maximal efforts are not possible, avoiding overestimated TRIMP that may impair training load prescription and physical gains.

Keywords: Age-related equations, official match, team sport, training impulse, Yo-Yo intermittent recovery test..

Introduction

The use of heart rate (HR) as a method for training control consists of establishing maximum heart rate (HR_{max}) and then prescribing training sessions over a range of HR_{max} percentages, which varies according to the desired exercise intensity[1,2]. Currently, in team sports, the most useful approaches for internal training load (TL) quantification reported in the literature involve calculating the training impulse (TRIMP) through HR-based methods, which, in addition to the duration of the exercise session, requires HR at rest, mean HR, and HR_{max}[3,4,5]. The main approaches to calculate the TRIMP consider the HR_{max} as the reference to establish submaximal intensity zones based on the percentage of maximum HR (%HR_{max}), by which the session TRIMP is calculated by multiplying the time spent in each %HR_{max} intensity zone by a pre-established factor, such as the approach proposed by Edwards (1993)[6]. Therefore, accurately establishing HR_{max} seems to be a key factor in properly prescribing training intensity and quantifying internal TL, optimizing fitness and performance gains, and avoiding overtraining[4].

In practice, HR_{max} can be determined in different ways, measured in maximum physical effort tests[7-10] and, specifically in team sports, measured in official match[11-13], in which the player seeks his maximum performance to win against the opponent. However, although most HR monitors available on the market allow measuring and storing HR values with high reliability[14] and have become popular, in practice, not all teams have the equipment to determine HR_{max}. Alternatively, HR_{max} can be estimated through age-predicted equations, which have been tested in comparison to the HR_{max} response in maximum physical effort tests and matches[11,12].

In studies on the determination of HR_{max} in team sports, several maximal physical tests have been used, i.e., laboratory tests on the treadmill[10,15,16]; continuous running field tests[9,11] and intermittent running field tests[8,12,15,16], which have ecological validity, as for example, the Yo-Yo intermittent recovery level 1 test (YYIR-1), a test with high reproducibility, sensitivity, validity to access HR_{max}, indicate to intermittent sports[15]. However, the HR_{max} determined in soccer official matches[7,11,12] and basketball simulated match[17] has shown higher values in comparison to physical tests, while only one study with futsal players reported similarity between match and physical test HR_{max}[18].

Although HR measured at maximal physical exertion is more trustworthy in establishing HR_{max}, a better way to determine HR_{max}, in the absence of equipment to determine the HR_{max} at maximum effort, the use of age-predicted equations should be cautious, considering that there are many age-predicted HR_{max} equations validated for distinct populations[9,16,17], and the use of general age-predicted equations may generate an important prediction error when utilized in specific sports, jeopardizing training prescription[3,17]. HR_{max} obtained by age-predicted equations has shown inconsistent results for team sports players of different ages, underestimating or overestimating the HR_{max}[8-10,12]. For example, the age-predicted equation proposed by Tanaka et al. (2001)[19] (Tanaka-HR_{max}) did not differ from the HR_{max} of the match and physical test in young soccer players[12], while the age-predicted equation proposed by Fox et al. (1971)[20] (Fox-HR_{max}) tested in soccer players was similar to the HR_{max} measured in physical test only to adults, but not to adolescents and the total, leading the Nikolaidis to propose specific equations for adult and youth soccer players (Nikolaidis-HR_{max})[9]. Testing the Nikolaidis-HR_{max} age-predicted equation proposed for young soccer player[9], Nikolaidis-HR_{max} and Fox-HR_{max} overestimated, and Tanaka-HR_{max} underestimated the measured HR_{max}, while this trend was not consistent when groups were analyzed separately by age, i.e., Tanaka-HR_{max} was similar with measured HR_{max} in U-12 and U-15, and Nikolaidis-HR_{max} was similar with measured HR_{max} in U-15 and U-18[8].

Inconsistent HR_{max} results obtained by age-predicted equations may influence the TRIMP calculation. To our knowledge, only one study, with basketball players, investigated this issue, and the authors found that the use of HR_{max} measured by age-predicted equations influenced the quantification of TL by TRIMP's calculation in comparison to the use of the HR_{max} measured in field physical test and in match[3]. The age-predicted HR_{max} equation has already been studied in some intermittent sports such as soccer[8-10,12,13] and basketball[3,17], but this knowledge remains unclear in futsal players. Considering the intermittent characteristic and high intensity of futsal, superior to soccer, handball and basketball[21,22] make futsal a great context for the study of different methods of determination of HR_{max} and its influence on the TRIMP determination. In this context, the aims of this study were: i) to compare HR_{max} measured in two effort situations, YYIR-1 and futsal official match (OM), and three age-predicted HR_{max} equations; ii) to determine the effects of using these different approaches on internal TL outcomes in futsal players. Our hypothesis was that the direct methods of measuring HR_{max} and the equations used to estimate it would provide different outcomes in professional futsal players, leading to different TRIMP values calculated based on HR_{max}.

Methods

Participants

Eight professional futsal outfield players from the same team competing in the São Paulo State League composed the sample of the study (21.1±3.1 years). The players presented more than 2 years of competitive experience, training 6-7 days a week, 1-2 times a day with a session duration of 1.5 hours and 1-2 matches in competition by week (data collection was carried out during state competition). The sample was chosen for convenience (n = 8), getting a sampling power above 0.80 (see statistical analyses for more information). The criteria for inclusion in the sample were to have performed the anthropometric and physical (YYIR-1) evaluation and to have participated at least 8 min in one of two matches since futsal substitutions are unlimited. Among 10 outfield players evaluated, two did not satisfy the minimum stay on the court. Participants were informed of the risks and benefits of taking part in the study and signed a free informed consent form. All procedures were conducted according to the Declaration of Helsinki and were approved by the ethics committee of the School of Science, São Paulo State University (CAAE: 41515915.5.0000.5398).

Procedures

The current investigation is a quantitative, descriptive, and comparative study. Data were collected during the competition period. In the first week of the study, anthropometric measurements and YYIR-1 were performed to physically characterize participants (Table 1). In the next two weeks, the HR of the players was monitored in seven training sessions and two OM. All measures of HR and other proceedings were taken on the same indoor court where players trained (11:30 a.m. to 1:30 p.m.), except the two OM (8:00 p.m.). The temperature and

Table 1 - Characteristics of participants.

Parameters	Mean ± SD
Body mass (kg)	71.7 ± 9.2
Stature (cm)	175.0 ± 5.0
Fat (%)	11.6 ± 2.9
YYIR-1 (m)	1185 ± 257

SD: standard deviation, (n = 8).

humidity during data collection by a digital Thermo-Hygrometer model 7427.02.0.00 (Incoterm, Porto Alegre, Brazil). Before the beginning of each training, match and evaluation, the equipment was reset and placed on a table next to the court, and for each of the situations, the result was the average between the initial and final registration (YYIR-1 = 25.8º C and 55 %, OM = 23.8º C and 70 %, training sessions = 22.6±1.3º C and 55±9 %). During all procedures, the players had free access to water only. The training sessions involving agility, acceleration, tactical and technical drills lasted between 60-90 min and were performed on the same indoor court as the team played their matches at home. Training characteristics are in Table 2.

All HR measures, OM, YYIR-1, and training sessions were performed using a POLAR Team2 Pro system (Polar Electro Oy®, Oulu, Kempele, Finland). Data was recorded every second, and the manufacturer's program error corrector was activated to eliminate outliers. In addition, a second error filtering was done by visual inspection through the analysis of the curve of the HR graph of each player in the manufacturer's own program since the Software allows the correction of errors manually. After that inspection, the data were exported to an Excel spreadsheet (Microsoft®, Redmond, Washington, USA) for further analysis.

Anthropometric measurements of body mass and height were taken on an anthropometric balance (Welmy, Santa Barbara d'Oeste, São Paulo, Brazil) and body fat percentage was determined through the equation of 7 skinfolds (triceps, subscapular, pectoral, abdominal, supra iliac and medial thigh) for the calculation of body density and Siri equation for fat percentage[23].

Prior to the YYIR-1 test, players performed a 20-minute general warm-up (i.e., self-select light running and dynamic general stretching). The YYIR-1 reproducibility was previously demonstrated (coefficient of variation = 4.9 % and r = 0.98)[15], and the YYIR-1 test has been widely used in futsal studies with U-18 players[24] and professional players[25–28]. YYIR-1 test consisted of a 20 m shuttle run with 10 s active recovery between runs, which started at a running velocity of 10 $Km{\cdot}h^{-1}$ and increased according to broadcasted sound beeps until voluntary exhaustion or twice failing to reach the finish line in time. All players were already familiarized with the test, and the total distance covered was recorded and used as a performance indicator. Prior to OM, they also performed a 20-minute general warm-up (i.e., self-select light running, dynamic general stretching, and specific exercise with the ball). The OM consisted of two halves of 20 minutes clocked with an interval of 10 minutes to recovery

Table 2 - Characteristics of seven training sessions.

	Description
Warm-ups models	- Jogging, variates dynamic exercises.- Muscle activation and balance circuit.- Short acceleration movements- Technical exercises: varied passes with change of direction, in pairs changing distances and in small groups, dribbling, driving the ball, and small game.
Sessions	
Session 1	- Ball out: defensive organization leaving the 2×2 defensive court.- Variation 1: 3×3.- Variation 2: and 4×4.
Session 2	- Game situations: the main team trains positioning without the opposing defence;- 4 × 4: individual marking on line 4. The defence taking possession of the ball attacks against 3 + 1 behind (1 defending player must run to the area opposite his defence to return to the defence), thus creating a counter-attack situation, 4×3.
Session 3	- Specific exercises of agility, reaction time and speed with the ball.- 6 × 4 (4 × 4 + 2 joker players): 2 joker players participate when the team passes the half court, attacking with 6 players, the defence marking 4 players in line 4. The defence retook the ball and started to attack with 4+2 × 4.- Three teams with 3 players each (3×3×3). Offensive organization and counterattack. Team A attacked B, and team C participated when the competition between A and B was concluded with one goal.
Session 4	- Defensive system: 3 × 3 all court. Defensive players are fixed all the time (4min), while the 3 attackers change with the other outside players when the defence takes the ball.- Offensive system: 4 × 4 all court. Attacking players are fixed at (4 min), varying the ball exit location in 3 positions (defence, midfield, attack).
Session 5	- Counterattack: 2 × 1 + 1 (one player is late - he runs/sprints forward and back to restore the 2nd defender (2 × 5 min);- Variation from the previous activity: 3 × 2 + 1 player-late.- 4 × 4: defence remains on the court, and players from the attacking change with others outside the players' team (ball possession maintenance).
Session 6	- Numerical superiority training in reduced space (small sty- 5×3), using 3 quintets.- 5×4 half court. The defence remains and the attack changes.- Rehearsed fouls: 10 plays for each quartet.
Session 7	- Numerical superiority training with goalkeeper-line (5×4).- Training of rehearsed plays / stop ball (side, corners, and fouls).

Session training started with a warm-up. The main part of the session consisted of 2-3 different training units/models, which were interspersed with periods for coach orientation, hydration, and rest.

between the halves, following the other official rules. The players in the same team remained on the court during the entire game. The higher value observed was established as HR_{max}.

Four age-related equations were used to estimate HR_{max}. They are described below with the rationale for use in the study.

Equation 1 - Fox-HR_{max} equation = (220 - age)[20]. The equation is widely used as a basis for exercise prescription and as one of the criteria for completing the maximum effort test19; it has been used in several studies of team sports, such as soccer[8-10,12,13] and basketball[3,17].

Equation 2 - Hossack-HR_{max} equation = 206 - (0.597 x age)[29]. The most accurate age-based approach to predict HR_{max} in basketball players in comparison to the simulated match HR_{max}[17] was analyzed in a study like the present study, which compared the influence of several HR_{max} approaches on TRIMP calculation[3].

Equation 3 - Tanaka-HR_{max} equation = 208 - (0.7 x age)[19]. The authors reviewed the Fox-HR_{max} equation with cross-validation, including elderly subjects in the sample, and obtained the equation based on maximum testing in the laboratory in healthy individuals, in addition to a meta-analysis, in which there was no difference between men and women, nor between active and aerobic trained individuals and Tanaka-HR_{max} equation has been evaluated in studies which to compare the different approaches to determine HR_{max} in team sports, as soccer[8-10,12,13] and basketball[3,17].

Equation 4 - Nikolaidis-HR_{max} equation = 213.2 - (0.78 x age)[9]. The equation was proposed by soccer players[9] and used in comparing to the two equations used in the present study, Fox-HR_{max} and Tanaka-HR_{max}[8,10].

Internal TL was calculated using Edward′s TRIMP method[6], which had been previously applied in other intermittent sports[30]. This method determines the internal load by calculating the TRIMP by stratifying the exercise time in minutes in which the athlete remains in each of five intensity zones based on $\%HR_{max}$ and multiplying the time spent in each of those five $\%HR_{max}$ intensity zones by a corresponding coefficient (1-5) at each respective intensity zone. Session TRIMP considers the accumulated values of the five intensity zones. Thus, TRIMP = $\sum$ (time [min] in zone 50-60 $\times$ 1 + time [min] in zone 60-70 $\times$ 2 + time [min] in zone 70-80 $\times$ 3 + time [min] in zone 80-90 $\times$ 4 + time [min] in zone 90-100% HR_{max} x 5). Results were then summed, and internal session TL was expressed in arbitrary units (A.U.).

Statistical analysis

All data were checked for normality using the Shapiro-Wilk test and are presented as means ± standard deviation and 95% confidence interval (95% CI). For comparing the effects of the different approaches to establish HR_{max} (YYIR-1, OM and age-predicted HR_{max} equations) and their influences on internal TL outcomes, an analysis of variance (ANOVA) for repeated measures was used, completed by the pairwise comparison with Sidak test. Once Mauchly's test revealed that the sphericity was violated ($p < 0.001$), the data were corrected by Greenhouse-Geisser. Both HR_{max} and TRIMP calculations obtained sampling power > 0.80 (HR_{max}: $F_{1.87,\ 13.09} = 6{,}880$; $p = 0.01$; $\eta_P^2 = 0.496$; power = 0.832) and (TRIMP: $F_{1.89,\ 13.15} = 7.366$; $p = 0.008$; $\eta_P^2 = 0.513$; power = 0.859). Furthermore, Cohen's d effect sizes (ES) for pairwise comparisons were calculated between the result from each age-predicted equation with each of the measured HR_{max} (YYIR-1 and OM), and the magnitude of the ES was interpreted using previously established criteria[31]: *trivial* ≤ 0.20; *small* = 0.21-0.5; *moderate* = 0.51-0.79; *large* = 0.80-1.29; *very large* ≥ 1.30. IBM® SPSS 20 software (Chicago, IL, USA) was used for statistical analysis and in all cases, a 5% level of significance was considered.

Results

The HR_{max} obtained values, and the internal TL outcomes are shown in Table 3 and Table 4, respectively. The measured HR_{max} and TRIMP calculated by YYIR-1 and OM did not differ from each other. HR_{max} and TRIMP obtained by the age-predicted equations presented differ among them, Fox-HR_{max} overestimated the Tanaka-HR_{max}, Hossack-HR_{max} Nikolaidis-HR_{max} and the measured HR_{max} by YYIR-1, while the TRIMP obtained by Fox-HR_{max} underestimated the TRIMP measured by those approaches. In addition, Nikolaidis-HR_{max} also overestimated Tanaka-HR_{max} and Hossack-HR_{max} and underestimated the TRIMP measured by those approaches (Tables 3 and 4).

The ES was analyzed between the two objective measures of HR_{max} (YYIR-1 and OM) and the respective TRIMPs, and both objective measures were also compared with the equations age-predicted equations (Figure 1). In comparison to the OM, all age-predicted equations presented *trivial* and *small* ES, while TRIMP's ES was *trivial* and *moderate*. Compared to the YYIR-1, Tanaka-HR_{max}, Hossack-HR_{max} Nikolaidis-HR_{max} equations presented small and moderate ES, while compared to the Fox-HR_{max}, the ES was *large*. On the other hand, TRIMP calculated by HR_{max} from YYIR-1 resulted in ES higher in comparison to the age-predicted equations, *large* and *very large* ES. It should be noted that although the HR_{max} measured in the YYIR-1 and in the OM, and the respective TRIMP values did not differ from each other (Table 3 and 4), ES between the two approaches presented a *large* difference, with the higher HR_{max} values recorded in the OM in comparing to the YYIR-1 (d = 0.98) (Figure 1). HR_{max} of five players was higher in OM, while one player presented higher HR_{max}

in YYIR-1, and for one player, the result was similar. That HR_{max} result led to the lower TRIMP calculated by OM HR_{max} in relation to TRMP from YYIR-1 HR_{max} (d = -0.83, *large* ES) (Figure 1).

Table 3 - HR_{max} values determined by the different approaches and the comparison between the measures HR_{max} (YYIR-1 and OM), and the HR_{max} determined by the age-predicted equations (Hossack, Tanaka and Nikolaidis), expressed in of percentage of the HR_{max} (%HR_{max}).

Approach to establish HR_{max}	HR_{max} (beats/min) Mean ± SD [95 % CI]	ANOVA *p*-value	%HR_{max} (%) in comparison to the YYIR-1	%HR_{max} (%) in comparison to the OM
			Mean ± SD [95 % CI]	Mean ± SD [95 % CI]
YYIR-1	189.88 ± 6.03 [184.83-194.91]		–	96.89 ± 4.01 [93.54-100.25]
OM	196.13 ± 6.66 [190.55-201.69]		103.25 ± 4.53 [99.46-107.04]	–
Fox	198.88 ± 3.09**^{Y,H,T,N} [196.29-201.46]	^{Y}, $p = 0.018$ ^{H}, $p < 0.001$ ^{T}, $p < 0.001$ ^{N}, $p = 0.003$	104.75 ± 2.76 [102.44-107.06]	101.49 ± 3.42 [98.63-104.35]
Hossack	193.38 ± 2.07 [191.65-195.10]		102.00 ± 2.93 [99.55-104.45]	98.69 ± 3.20 [96.02-101.37]
Tanaka	193.38 ± 2.07 [191.65-195.10]		101.88 ± 2.75 [99.58-104.17]	99.62 ± 3.58 [96.63-102.61]
Nikolaidis	196.63 ± 2.26**^{F,H,T} [194.73-198.52]	^{F}, $p = 0.003$ ^{H}, $p < 0.001$ ^{T}, $p < 0.001$	103.88 ± 2.75 [101.58-106.17]	100.40 ± 3.01 [97.63-103.16]

Data are described as mean and standard deviation (mean ± SD) and 95% confidence interval [95 % CI].
*Significant difference (ANOVA for repeated measures) in relation to the HR_{max} approach: the difference is represented by the initial letters of each approach (YYIR-1: ^{Y}; Fox: ^{F}; Hossack: ^{H}; Nikolaidis: ^{N}). HR_{max} = maximal heart rate; YYIR-1 = Yo-Yo intermittent recovery test leve1-1; OM = official futsal match; ES = effect size; %HR_{max}= percentage of maximal heart rate.

Table 4 - Edward′s training impulse (TRIMP) calculated by different approaches to determinate HR_{max}, and the comparison between the TRIMPs calculated by measured HR_{max} (YYIR-1 and OM) and the TRIMPs from of age-predicted equations (Hossack, Tanaka and Nikolaidis), expressed in percentage of the TRIMP (%TRIMP).

Approach to establish HR_{max}	Edward's TRIMP (A.U.) Mean ± SD [95 % CI]	ANOVA *p*-value	%TRIMP (%) in comparing to the YYIR-1	%TRIMP (%) in comparing to the OM
			Mean ± SD [95 % CI]	Mean ± SD [95 % CI]
YYIR-1	160.38 ± 17.11 [146.07-174.68]		–	109.04 ± 11.68 [99.27-118.80]
OM	147.38 ± 13.71 [135.91-158.84]		92.50 ± 9.55 [84.52-100.48]	–
Fox	141.50 ± 19.88**^{Y,H,T,N} [124.87-158.13]	^{Y}, $p = 0.013$ ^{H}, $p < 0.001$ ^{T}, $p < 0.001$ ^{N}, $p = 0.005$	88.25 ± 6.20 [83.06-93.44]	95.90 ± 9.14 [88.25-103.54]
Hossack	153.38 ± 20.40 [136.32-170.43]		95.62 ± 6.97 [89.80-101.45]	103.79 ± 8.40 [96.77-110.81]
Tanaka	153.50 ± 20.64 [136.24-170.76]		95.75 ± 7.05 [89.86-101.64]	100.82 ± 9.00 [93.29-108.35]
Nikolaidis	146.13 ± 20.65**^{F,H,T} [128.86-163.39]	^{F}, $p = 0.005$ ^{H}, $p < 0.001$ ^{T}, $p < 0.001$	91.25 ± 6.69 [85.65-96.85]	98.85 ± 9.19 [91.17-106.54]

Data are described as mean and standard deviation (mean ± SD) and 95% confidence interval [95 % CI].
*Significant difference (ANOVA for repeated measures) in relation to the HR_{max} approach: difference is represented by initial letters of each approach (YYIR-1: ^{Y}; Fox: ^{F}; Hossack: ^{H}; Nikolaidis: ^{N}). HR_{max} = maximal heart rate; YYIR-1 = Yo-Yo intermittent recovery test leve1 1; OM = official futsal match; ES = effect size; %TRIMP= percentage of training impulse.

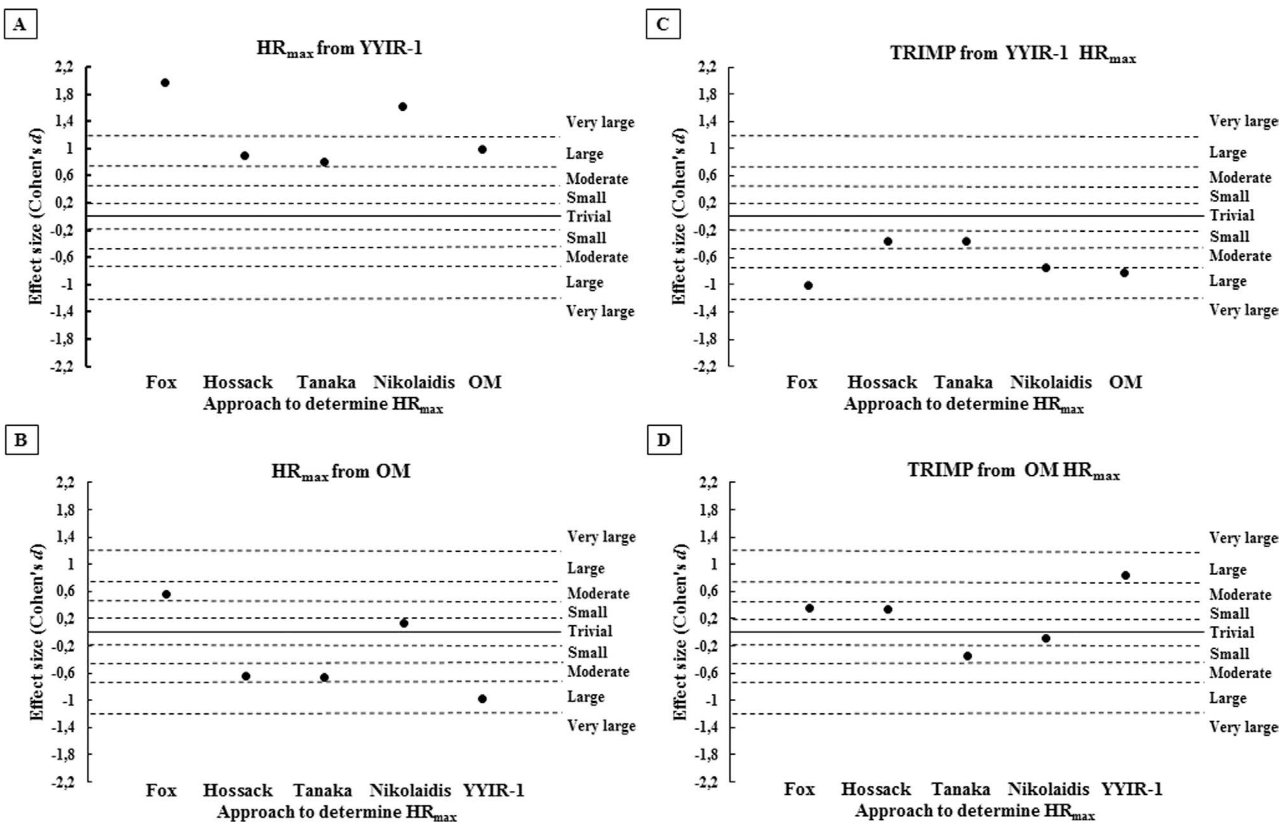

Figure 1 - Effect size (ES, Cohen's *d*) calculated between the measured HR_{max} and TRIMP from YYIR-1 and OM with the results from age-predicted equations approach (Fox, Hossack, Tanaka and Nikolaidis). A: YYIR-1 HR_{max}; B: OM HR_{max}; C: YYIR-1 TRIMP; B: OM TRIMP, all compared with results from age-predicted equations from HR_{max} and TRIMP, respectively. Considered ES: *trivial* ≤ 0.20; small = 0.21-0.5; *moderate* = 0.51-0.79; large = 0.80-1.29; very large ≥ 1.30.

Discussion

This is the first study to compare the use of OM, YYIR-1 and age-related equations to determine HR_{max} in futsal players and the impact of using these distinct methods on internal TL outcomes (TRIMP). The age-predicted equations of Fox-HR_{max} and Nikolaidis-HR_{max} overestimated Tanaka-HR_{max} and Hossack-HR_{max}, while Fox-HR_{max} also overestimated Nikolaidis-HR_{max}. These results were like the TRIMP. There were no differences between HR_{max} and TRIMP from two objectively measured approaches (YYIR-1 and OM). Although there were no significant differences in HR_{max} and TRIMP between YYIR-1 and OM approaches, the practical significance of qualitative inferences showed *large* ES. OM presented higher HR_{max} and lower TRIMP (*d*: 0.98 and -0.83, respectively), which warn coaches and physical trainers to choose the best method to determine HR_{max} carefully in futsal players, aiming not to jeopardize training prescription and monitoring. Simultaneously, the *trivial* to *moderate* differences between data obtained from direct measures and age-related equations provide sound knowledge that scientifically supports the use of these indirect approaches to futsal players in circumstances in which direct assessments are not possible.

Considering those direct measure methods, HR_{max} showed higher values in OM than YYIR-1, 3.25% ($d = 0.98$), with most players having higher HR_{max} in OM (5/8); this trend has also been observed in professional adult[11], junior[11]and juvenil[11,12] male soccer players, and in semi-professional adult male[3] and juvenile female basketball players[17]. The higher HR_{max} values during OM have been commonly attributed to psychological aspects such as motivation and competitiveness, as well as due to different activities present in the matches but not in the tests (i.e., tactical activities, challenge for the ball), encouraging players to reach their truly maximum performance[13,32]. Therefore, as the intensity of exercises is prescribed based on HR_{max}, using HR_{max} established by OM appears to be more suitable for not overestimating training load intensity in futsal players.

All age-predicted equations presented results like the OM, varying between 98.7% to 101.5% and *trivial* to *moderate* ES. However, HR_{max} values estimated by Nikolaidis-HR_{max} showed a lower difference between HR_{max} established by OM, 100.4% ($d = 0.13$, *trivial*). The Nikolaidis-HR_{max} equation was concerned recently for soccer players[9], and it has been tested in some studies with soccer players and other team sports. In a study with young and adult soccer players, the results differed from the present study, i.e., Fox-HR_{max}, Tanaka-HR_{max}, and Nikolaidis-HR_{max} overestimated the measured HR_{max}; however, Nikolaidis-HR_{max} showed a lower difference in comparison to the measured HR_{max} (2 bpm)[10]. Other contradictory results were observed in adult soccer players. Fox-HR_{max} was like the measured HR_{max} in Conconi's test carried out in the field, while Tanaka-HR_{max} underestimated measured HR_{max}[9]. On the other hand, Fox-HR_{max} overestimated the measured HR_{max} in OM, while Tanaka-HR_{max} was like the OM HR_{max}[12]. Comparing HR_{max} results from age-predicted equations with physical testing or matches can explain the difference between the results. In this context, when we analyzed the contradictory results, results from the present study with futsal players and with soccer players10,12 indicate that Nikolaidis-HR_{max} Tanaka-HR_{max} equations appear to be more reliable since their results have been closer to the measured HR_{max} in-match an objective approach which has shown higher results than physical tests[3,11,12,17].

Other variables that should be observed when comparing different approaches to determine HR_{max} are the age of the population studied and the characteristics of sport. For example, Nikolaidis (2015)[9] proposed equations from a sample of young and adult soccer players and tested the young's equation in a study[8] with a group of athletes from various team sports (soccer, futsal, basketball and water polo) comparing the HR_{max} determined during the 20m shuttle run endurance test with the HR_{max} age-predicted equations and the analysis of the whole sample show that HR_{max} from the equations differed of the measured HR_{max} in physical test (Nikolaidis-HR_{max} and Fox-HR_{max} overestimated and Tanaka-HR_{max} underestimated measured HR_{max}). However, analysis by age group revealed that mean HR_{max} in U-12 and U-15 were like Tanaka-HR_{max}, in U-15 and U-18, measured HR_{max} were like Nikolaidis-HR_{max}, while Fox-HR_{max} was higher in the three groups of age compared to measured HR_{max}. Since the equations take age into account, it is suggested that equations be created for each age group, as already suggested by Nikolaidis[8]. Regarding the specificity of the sport, Abad et al.[17] comparing HR_{max} directly measured by OM and YYIR-1 with HR_{max} predicted by age-relation equations in basketball noticed that, in comparing to the OM, Hossack's equation (*trivial* ES) and Tanaka′s equations (*trivial* ES) appear to be the best choice to estimate HR_{max} in female young basketball players. In this sense, although there is no doubt about the prediction error when using age-related equations, if HR_{max} needs to be estimated, a specific equation for each sport should be used, seeking to reduce error prediction as much as possible.

The use of the equation created from an exclusive sample of soccer players can cause bias when used in other sports. However, considering the similarity between the technical and movement actions of soccer and futsal, we understand that the Nikolaidis-HR_{max} equation[9] created by soccer players can be used in futsal players due to the similarity between the technical and movement actions. Soccer and futsal are commonly considered related-team sports, and although some differences in match requirements21, anthropometric[33] and physiological characteristics[34] between professional futsal and soccer players have been described, using the Nikolaidis-HR_{max} age-predicted equation appears to be the best choice to estimate HR_{max} in players of these two sports, as well as the Tanaka-HR_{max}. This idea is supported by results of the present study with futsal players (Nikolaidis-HR_{max} showed a lower difference in comparison to the measured HR_{max}, i.e., +0.5 bpm), and two studies with soccer players, in which Tanaka-HR_{max} was similar to the OM HR_{max}[12], in U-18 and U-12 players, Nikolaidis-HR_{max} and Tanaka-HR_{max} did not differ of measured HR_{max}, respectively, and both equations were also similar to the measured HR_{max} in the U-15 players[8], while Fox-HR_{max} overestimated the measured HR_{max} in all those categories (U-12 to U-18). Furthermore, in a study in which those three equations differed from the measured HR_{max}, Nikolaidis-HR_{max} and Tanaka-HR_{max} showed a lower difference with the measured HR_{max} (-2 and +3 bpm, respectively) compared to Fox-HR_{max} which overestimated the measured HR_{max} by 9 bpm[10].

As previously suggested[2,3,13], underestimated or overestimated HR_{max} may jeopardize internal TL outcomes, and this influence appears to be inversely proportional, meaning that underestimating HR_{max} leads to overestimating internal TL outcomes. Between the direct methods, the mean TRIMP during training sessions were higher, 9.0% (d = 0.83, *large* ES) for HR_{max} based on YYIR-1 than HR_{max} based on OM. This same trend, higher HR_{max} values during OM, and higher internal TL outcomes using HR_{max} based on YYIR-1, was also found by Berkelmans et al.[3] investigating the impact of different approaches to establish HR_{max} on Edward′s TRIMP or, as called by authors, Summated-Heart-Rate-Zones (SHRZ) in semi-professional male basketball players.

In fact, Edward′s TRIMP method6 is used to measure internal TL by multiplying the duration (min) in five different zones of HR_{max} by a coefficient equivalent to each zone, which simultaneously increases from 1 to 5 with HR values. If the HR_{max} was underestimated, the higher coefficients, as zones 4 and 5, will be composed by lower HR values, leading athletes to reach them faster and spending more time in these zones, eliciting higher internal TL outcomes. The higher daily internal TL may provide misleading knowledge to coaches and physical trainers, leading to errors in training load adjustments throughout the season.

About the internal TL outcomes obtained using HR_{max} values from direct measures and age-related equations, Nikolaidis-HR_{max}, as well as what occurred with HR_{max} values, showed the lowest difference when compared with the internal TL outcomes obtained using HR_{max} values established by OM (d = -0.09, *trivial* ES). To date, only Berkelmans et al.[3] performed a similar investigation, which was performed on semi-professional male basketball players. These authors found the lowest difference between internal TL outcomes using Nikolaidis-HR_{max} and Fox-HR_{max} age-predicted equation, *small* and *trivial* ES, mean TRIMP = 323.5 ± 35.0 and 312.6 ± 35.7 A.U., respectively, while Tanaka-HR_{max} and Hossack-HR_{max} presented *moderate* ED (335.3 ± 35.6 and 333.6 ± 34.1 A.U., respectively) when compared with outcomes using HR_{max} established by OM (307.6 ± 43.4 A.U.). In comparing the TRIMP calculated by YYIR-1 HR_{max}, our results presented a difference in relation to the TRIMP calculated by age-predicted equation (small to large ES) and comparing it to the OM effect size was *large*. A higher result of the TRIMP calculated by YYIR-1 HR_{max} was also observed in a study with basketball players3, which reflects the lower HR_{max} in YYIR-1 compared to HR_{max} from matches and trainings[3] or only match[17]. From a practical perspective, the determination of HR_{max} during matches and specific training can prevent and avoid underestimating TRIMP.

According to our results, although the YYIR-1 test has been widely used to evaluate endurance performance in futsal[24-28] and soccer[15,35] players, and the HR_{max} can be measured in the YYIR-1 test, the determination of HR_{max} in the OM is very important to determine the training load correctly, avoiding TRIMP overestimation. In the impossibility of measuring HR_{max} objectively, although the HR_{max} determined by the equations of FOX-HR_{max}, Tanaka-HR_{max}, Hossack-HR_{max} did not differ from the OM HR_{max} (*small* ES), Nikolaids-HR_{max} should be the choice of coaches and physical coaches to ensure adequate quantification and control of training load in futsal players since it presented the smallest difference compared to the TRIMP calculated by OM HR_{max} (*trivial* ES), which can be explained by the fact that Nikolaidis-HR_{max} equation was the result of the evaluation of soccer players. In addition,

Some limitations of the present study must be acknowledged. First, just a small sample size (n=8) of male professional futsal players was available to participate in the present study, however, the sampling power was higher than 0.80. Therefore, our findings may not be transferable to female players. Second, the absence of metabolic measurements, such as blood lactate and oxygen consumption during YYIR-1, does not allow us to ensure that players reached maximal oxygen uptake and, thus, HR_{max}. Notwithstanding, this is the first study to compare HR_{max} values obtained by age-predicted equations, YYIR-1 intermittent field test and OM in futsal players; still investigating the impact of these different data on internal TL outcomes, and we believe that, despite such limitations, the current study provides useful insight for coaches and conditioning professionals in futsal environment.

Conclusions

In conclusion, our findings show that HR_{max} established by OM presented higher values than HR_{max} established by YYIR-1 (i.e., *large* effect). Conversely, internal TL outcomes calculated using HR_{max} established by YYIR-1 were higher than outcomes calculated using HR_{max} established by OM (i.e., *large* effect). In addition, between age-related equations, the Nikolaidis-HR_{max} equation shows the lowest difference (i.e., *trivial* effect) when compared with HR_{max} established by OM. Simultaneously, internal TL outcomes calculated by Nikolaidis-HR_{max} also presented the lowest difference (i.e., *trivial* effect) when compared with the outcomes calculated using HR_{max} established by OM. Therefore, for prescription and monitoring of the training in male futsal players, coaches and physical trainers are encouraged to use HR_{max} established during OM to avoid underestimating training intensity and overestimating internal TL outcomes. When maximal efforts are unfeasible, Nikolaidis-HR_{max} should be chosen to accurately predict, as much as possible, HR_{max} and calculate internal TL in Futsal.

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