INFLUENCE OF ENVIRONMENTAL CONDITIONS ON PERFORMANCE AND HEART RATE RESPONSES TO THE 30-15 INCREMENTAL FITNESS TEST IN RUGBY UNION ATHLETES

ABSTRACT

The purpose of this study was to examine the differences in performance and heart rate responses between a high heat outdoor condition (34.0°C, 64.1% humidity) and a temperate indoor condition (22.0°C, 50.0% humidity) during the 30-15 intermittent fitness test (30-15$_{IFT}$). Eight highly trained Rugby Union players (28.1 ± 1.5 years, 181.4 ± 8.8 cm, 88.4 ± 13.3kg) completed the 30-15$_{IFT}$ in two different temperature conditions. Dependant variables recorded and analysed included; final running speed of the 30-15$_{IFT}$, heart rate (HR) at rest (HR rest), maximum HR (Max HR), HR recovery (HRR), average HR (HR ave) and sub-maximal HR corresponding to 25%, 50% and 75% of final test speed (HR 25%, HR 50% and HR 75%) and HR at 13 km·h^{-1} (HR 13 km·h^{-1}). Greater running speeds were achieved when the test was conducted indoors (19.4 ± 0.7 km·h^{-1} vs. 18.6 ± 0.6 km·h^{-1}, p = 0.002, d = 1.67). HR ave and HR 13 km·h^{-1} were greater when the test was conducted outdoors (p < 0.05, d > 0.85). Large effect sizes were observed for the greater HR at submaximal intensities (d > 0.90). The results of this study highlight the influence of temperature on 30-15$_{IFT}$ performance and cardiac responses. It is recommended that prescription of training based on 30-15$_{IFT}$ results reflects the temperature that the training will be performed in and that practitioners acknowledge that a meaningful change in assessment results can be the result of seasonal temperature change rather than training induced change.

KEY WORDS 30-15, fitness testing, rugby union, heat, heart rate, ambient conditions

INTRODUCTION

To date, a large body of research exists investigating the influence of high ambient temperatures on physical performance (9,14,15). Many of the world's major sports are played in challenging environmental conditions. Furthermore, a number of 'seasonal sports' may actually span over summer and winter depending on the continent. Rugby Union, now played the world over, will generally involve long seasons and fixtures spanning winter and spring months and extended pre-season training phases spanning summer and autumn months (11). Consequently, across the duration of the season, there can be large variation in ambient temperatures in which athletes train and compete. Emerging Rugby regions such as Asia can be exposed to high temperatures year round. Therefore, it is vital to understand the effects of environmental conditions and their impact on physical performance. Indeed, it has been demonstrated that cardiovascular responses may be affected when exercising in the heat, contributing to a decrease in physical performance (12,15,16).

Whilst the majority of research investigating physical performance in high heat has been performed utilizing sub-maximal aerobic exercise, given what is known about physiological strains incurred as intensity increases, certain inferences can be drawn (9). For example, at a given sub-maximal intensity, as ambient temperature increases there is an increase in the thermoregulatory response with blood flow being diverted towards the peripheries to allow for greater heat dissipation. Consequently, stroke volume is reduced and heart rate increases to compensate. As intensity of exercise increases and cardiac output reduces, aerobic metabolism and the delivery of oxygen to working muscles becomes inadequate with a greater contribution from anaerobic metabolism required. High ambient temperatures advance these processes causing earlier onset of fatigue and more acute reductions in physical performance (14).

Given the changes in ambient temperatures in many regions across the course of the year, testing environment may be hard or impossible to control. One example of a variable environment could be the Middle East. The rugby season in the Middle East spans August to April with temperatures ranging from above 40°c down to approximately 20°c and use of both indoor and outdoor facilities for training occurs. Some other environments that experience large disparities in temperatures are Australia, America, South Africa and Europe. Prescription of exercise based off testing results in highly variable environments could result in inaccurate or undesirable outcomes and these implications need to be understood and accounted for. Presently there is no literature detailing the effects of high ambient temperatures on aerobic intermittent test performance in the 30-15 Intermittent Fitness Test ($_{IFT}$) (3), a commonly performed test in many team sports. Results of the 30-15_{IFT} may be used to prescribe aerobic and anaerobic running loads in team sports (6,10). As such, if training occurs across multiple environments such as indoor and outdoor in which large temperature variations occur, training prescription needs to take this into account in order to prescribe adequate overload or avoid overloading.

The aim of this study was to investigate the performance implications of ambient temperature variations between outdoor (at high heat) and indoor (at a moderate temperature) performance testing on two separate occasions in the 30-15_{IFT}. It was hypothesized that there would be a decrease in test performance and an increase in cardiac strain when performed outdoors in high ambient temperature compared to indoors.

METHODS

Experimental Approach to the Problem

Data collection was conducted during the 4th week of pre-season. The subjects had undertaken the 30-15_{IFT} previously and were familiar with the test procedures. The tests were performed as part of routine sport science support during the pre-season programme. All subjects performed the test on 2 occasions; first outdoors on a grass pitch in high heat (34.0°C, 64.1% humidity, 0.5 $m{\cdot}s^{-1}$ wind speed) in the first training session of the week (1900 h) and then again 86 h later indoors on a 4G artificial pitch (Astro Turf GT+1 (TM 2012), AstroTurf Corporation)) at moderate environmental conditions (22.0°C, 50.0% humidity, 0.0 $m{\cdot}s^{-1}$ wind speed) on the last training session of the week (0900 h) as dictated by the weekly training programme. The indoor testing occurred 36 hours after the previous training session. Subjects performed no other exercise on testing days. As data were collected as part of routine sport science service diet and fluid consumption were not controlled for during testing but the subjects were asked to maintain a normal diet and had previously been given information on pre training nutrition. No warm up was conducted prior to testing other than individual stretching.

Subjects

Eight highly trained Rugby Union players (mean ± standard deviation, 28.1 ± 1.5 years, 181.4 ± 8.8 cm, 88.4 ± 13.3kg) from a West Asian Premiership Rugby team participated. The subject pool consisted of one second row (28 years, 190.5 cm, 91 kg); 2 back row (30 ± 1.4 years, 189 ± 1.4 cm, 104.8 ± 1.8 kg); 3 half backs (27.7 ± 0.6 years, 178.3 ± 9.5 cm, 85.3 ± 6.5 kg) and 2 outside backs (27 ± 1.4 years 174 ± 4.2 cm, 75.5 ± 3.5kg).

Data were collected as a part of the routine sport science support provided to the players during the season which all players had consented to. Therefore, usual appropriate ethics committee clearance was not required (21). Nevertheless, to ensure confidentiality, all physical performance data were anonymized before analysis.

Procedures

The 30-15 Intermittent Fitness Test

The $30\text{-}15_{IFT}$ consisted of 30-second shuttle runs over a 40 m distance, interspersed with 15-second walking recovery periods. The test began at 8 $km \cdot h^{-1}$ and increased 0.5 $km \cdot h^{-1}$ for every stage thereafter. The speed of the test was controlled by a pre-recorded audio signal that helped the subjects adjust their running speed by entering into 3-m zones in the middle and at each extremity of the field while the short beep sounded. At the end of each 30-second stage the subjects were instructed to walk forward to the nearest line, at either the middle or end of the running area depending on where the last stage ended, within the 15-second recovery period. Subjects were instructed to complete as many stages as possible. The test ended when a subject could no longer maintain the imposed running speed or when they were unable to reach a 3-m zone around each line at the moment of the audio signal consecutively 3 times. The velocity attained during the last completed stage was recorded as their maximal $30\text{-}15_{IFT}$ running velocity (V_{IFT}).

Heart Rate Measurement

Heart rate (HR) was recorded using Polar RS800CX monitors (Polar Electro, Kempele, Finland). Heart rate was continually recorded at 1Hz throughout both outdoor and indoor trials.

HR data were split into separate variables for analysis; the average of the last 30 s of 120 s supine rest prior to the 30-15$_{IFT}$ (HR rest), maximum HR achieved during the test (Max HR), the average of the last 30 s of 120 s supine rest following test cessation (HRR), average of the last 15 s of each stage corresponding to 25%, 50% and 75% of individual test cessation speed (HR 25%, HR 50% and HR 75%) and average HR over the duration of the test (HR ave). Additionally the average of the last 15 s of the 13 km·h^{-1} stage (HR 13 km·h^{-1}) was included, this was selected as it represents the mid-point between the start of the test and what is considered high intensity running in Rugby Union (18 km·h^{-1}) (19).

Statistical analysis

Data are presented as mean ± standard deviation. Prior to analysis, dependant variables were verified as meeting required assumptions of parametric statistics. Time course HR data were analysed using mixed model repeated measures ANOVA tests (SPSS, version 20, Chicago, IL). ANOVA analysed differences between 2 conditions (outdoors and indoors) and 6 time points of; HR rest, HR 25%, HR 50%, HR 75%, HR max and HRR. Time course data including final running speed, HR ave and HR 13 km·h^{-1} were analysed using a student's T-test. The alpha level of 0.05 was set prior to data analysis. Assumptions of sphericity were assessed using Mauchly's test of sphericity, if the assumption of sphericity was violated Greenhouse Gessier correction was employed. If significant effects between conditions or over time were observed *post-hoc* differences were analysed with the use of Bonferroni correction. Statistical power of the study was calculated post-hoc using G*Power statistical software (v3.1.3, Düsseldorf, Germany) using the effect size, group mean, SD and sample size of the primary outcome measures, in this case being final running speed and none time course HR variables. Power was calculated as between 0.8 and 1 indicating sufficient statistical power (7).

In addition, probabilistic magnitude-based inferences about the true value of outcomes were employed (1). Dependent variables were analyzed to determine the effect of the designated condition as the difference in change following each condition. To calculate the possibility of benefit, the smallest worthwhile effect for each dependent variable was the smallest standardized change in the mean – 0.2 times the between-subject SD for baseline values of all participants. This method allows practical inferences to be drawn using the approach identified by Batterham and Hopkins (1). Furthermore, standardized effect size (Cohen's d) analyses were used to interpret the magnitude of any differences.

RESULTS

Participants reached significantly greater running speeds when the test was conducted indoors (p = 0.002, d = 1.67; Figure 1, Panel A). Inferential statistical analyses indicated this difference was very likely practically relevant (Table 1).

HR ave and HR 13 km·h^{-1} were significantly greater when the test was conducted outdoors (p = 0.004, d = 0.87 and p = 0.038, d = 1.15 respectively; Figure 1, Panels B and C), with both differences being likely practically relevant (Table 1).

No time x condition interaction was observed for HR responses over the time course of the observations, including; HR rest, HR 25%, HR 50%, HR 75%, HR max and HRR ($F_{(5, 70)}$ = 0.559, p = 0.632). A significant time effect was observed with both conditions eliciting changes in HR across the aforementioned time course ($F_{(5, 70)}$ = 663.451, p < 0.001; Figure 2, Table 2). Despite the absence of a time x condition interaction large effect sizes were observed for the greater HR observed outdoors at HR 25% and HR 50% (d = 0.92 and d = 0.93 respectively; Figure 2). Inferential analysis also indicated the greater HR observed outdoors at these time points was likely practically relevant (Table 1). A large effect size was also observed for the difference in HRR between conditions (d = 1.42; Figure 1, Panel C). The greater HRR outdoors was also very likely practically relevant (Table 1).

DISCUSSION

The primary finding of this study is that performance of the 30-15$_{IFT}$ was worse when performed outdoors at a high ambient temperature. The typical error of measurement for the 30-15$_{IFT}$ is 0.36 km·h^{-1} (17); this value represents less than one complete stage (0.5 km·h^{-1}) of the assessment. The present study observed test performance to be greater by ~2 stages (0.81 ± 0.46 km·h^{-1}) when performed indoors at moderate environmental conditions. As such the greater performance at moderate environmental conditions should be considered a true increase in performance. This is re enforced by inferential statistical analysis indicating that the decrease in performance when the test was performed outdoors in high heat was “very likely” practically relevant.

This current study demonstrated cardiac strain to be greater when the $30\text{-}15_{IFT}$ was performed outdoors in high heat, observing a 3.1-7.4 % increase in HR at submaximal intensities and 5.5 % increase in HR during recovery. The cardiac strain associated with exercise in the heat is a product of thermoregulatory processes combined with the working muscles demand for oxygen (9). Consequently there is a diversion of blood to the body’s periphery in order to dissipate heat and because of this central blood flow is reduced. In the present study, a significant elevation in heart rate at submaximal intensities was found in the outdoor condition. This may be indicative of increases in heart rate compensating for reductions in stroke volume (14). This finding has important practical relevance in the prescription of training to enhance cardiorespiratory fitness and the interpretation of test results, in different ambient temperatures.

An increase in HR at submaximal intensities and a decrease in HRR is evidence of the greater cardiac strain imposed by performing the test in high heat. However, during intense exercise cardiac output may start to decline as heart rate reaches near maximal values and can no longer compensate for a potential reduction in stroke volume (13). However, it is important to note that there are conflicting findings with regards to the effect of exercise intensity on changes in stroke volume (20). Stroke volume was not measured in the present study but significant differences in heart rate response between the indoor and outdoor conditions become less apparent at 75% HR and at Max HR. It is at this stage that oxygen delivery and the subsequent aerobic contribution to energy supply is likely to become compromised in high temperature conditions. Hence, there becomes a greater reliance on anaerobic energy contribution in the heat and it is this reliance which may cause the earlier onset of fatigue and the concomitant reduction in performance found in the $30\text{-}15_{IFT}$ (8).

In the current study there was a greater reliance on anaerobic processes, which is also likely to have contributed to the increases in HRR that was observed outdoors (5). HRR is controlled by the autonomic nervous system and post-exercise parasympathetic reactivation. The slower HRR found outdoors is likely reflective of a higher oxygen debt brought about by the more anaerobically demanding work (18).

Results of the $30\text{-}15_{IFT}$ are often used to prescribe high intensity interval training. The $30\text{-}15_{IFT}$ is effectively an incremental running test utilising 180˚ changes of direction. The V_{IFT} attained at the end of the test is approximately 120 % of maximal aerobic speed and it is this result that is used in the prescription of high intensity interval training (3,4). In the current study a need to establish running intensities that account for fluctuations in ambient temperature have been highlighted. There was a 12°C difference in the outdoor vs. indoor conditions, representing differences in ambient conditions that may be witnessed across a season. As such the over or underestimation of training intensities in different ambient temperatures, the interpretation of the results of the $30\text{-}15_{IFT}$ and therefore the training completed leading up to the assessment may be misleading. Considering that a 0.21 $km{\cdot}h^{-1}$ increase has been identified as the smallest worthwhile change for the $30\text{-}15_{IFT}$ (Scott et al., 2015), the performance change found in the present study (0.81 ± 0.46 $km{\cdot}h^{-1}$) could easily be misinterpreted as a training effect rather than an effect of temperature or seasonal change.

The prescription of cardiorespiratory training based off of either high heat or moderate heat conditions is very likely to either overestimate or underestimate training intensities respectively. This is an important finding as prescription of cardiorespiratory training that is underestimated may not apply enough stress to provoke adaptations to the metabolic, neuromuscular or musculoskeletal systems (4). Furthermore, when intermittent fitness testing is conducted in different seasonal weather temperatures, such as late summer and early winter, performance change may actually be a result of reduced cardiac strain rather than exercise induced adaptations *per se*.

Although this study was conducted as routine sport science delivery, and therefore potentially not as well controlled as other investigations, it is important to acknowledge that there may have been diurnal effects on the assessment results. Future studies should look to control the time of day that each test is conducted in order to avoid diurnal effects. Future work should also look to further elucidate if there may be a threshold at which ambient temperature influences intermittent physical performance.

PRACTICAL APPLICATIONS

Sport science practitioners and coaches should account for changes in temperature when prescribing cardiorespiratory training between seasons and between outdoor and indoor conditions. Prescribing outdoor running intensities based on indoor results could lead to an overestimation of intensity, failure to complete the proposed training and maladaptation of targeted physiological systems.

A high intensity training session, described by Buchheit and Laursen (2013) (4), may encompass 3 series of 12 repetitions of 20 seconds of running at 14 km·h^{-1}; passive recovery between repetitions could be 20 seconds and recovery between series could be 4 minutes in duration. Using the indoor performance results of one participant in the present study the prescribed intensity would represent 70% of his indoor 30-15$_{IFT}$ result (approximately 90% of velocity at VO_{2max}). The cardiac response at this particular intensity in the indoor vs. the outdoor condition was 163 beats per minute vs. 176 beats per minute respectively. This response represents two different training zones with the indoor response equating to a classification of ‘training zone 3’, described as heavy aerobic work, and the outdoor response equating to a classification of ‘training zone 5’, described as maximal aerobic work (2). These training zones represent a very different perception of effort and concomitant blood lactate response (2). The training protocol suggested may be highly appropriate indoors but may be too strenuous to be completed outdoors (in high heat), unless a lower running intensity is used or longer recovery periods are prescribed.

An overestimation of training intensity may come at a significant metabolic, neuromuscular and musculoskeletal cost. The cost of intensity overestimation may mean a) higher levels of fatigue, with a greater anaerobic demand, and therefore the need for longer recovery times within and between training sessions; b) maladaptation in the desired physiological system, for example, blunted development of the aerobic system in favour of enhancing glycolytic metabolism and c) higher musculoskeletal loads and an inherent risk of soft tissue injuries (4).

In order to match indoor and outdoor intensities in the present example, 70% of the outdoor 30-15_{IFT} result should be used (running speed of 13.5 km·h^{-1}). This intensity would result in a reduction of running distance by 3 metres per repetition (from 77.8 metres indoors vs. 75.0 metres outdoors) and a reduction in total distance of 100 metres for the session (2800 metres indoors vs. 2700 metres outdoors). Despite the difference in mechanical loading, the physiological cost of exercise, in terms of cardiac response, is likely to be similar.

It is important that practitioners prescribe training according to temperature changes. Practitioners should be aware that performance changes of almost two stages in the 30-15_{IFT} assessment may be due to seasonal temperature change rather than training induced change.

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Figure Legends

Figure 1. Heart rate (BPM) responses at 25, 50, 75 and 100% of test cessation during the 30-15$_{IFT}$ (22.0°C and 50.0% RH) and outdoors (34.0°C and 64.1% RH). †Effect size of *d* > 0.90.

Figure 2. Final running speed (Panel A), HR ave (Panel B), HR 13 km·h^{-1} (Panel C) and HRR (Panel D) during the 30-15$_{IFT}$ indoors (22.0°C and 50.0% RH) and outdoors (34.0°C and 64.1% RH). Dashed lines are individual data and solid line represents the mean. *Significant difference ($p < 0.05$), †effect size of $d > 0.90$.

Table 1. Summary of inferential analysis of dependant variables in response to performing the 30-15$_{IFT}$ indoors (22.0°C and 50.0% RH) and outdoors (34.0°C and 64.1% RH).

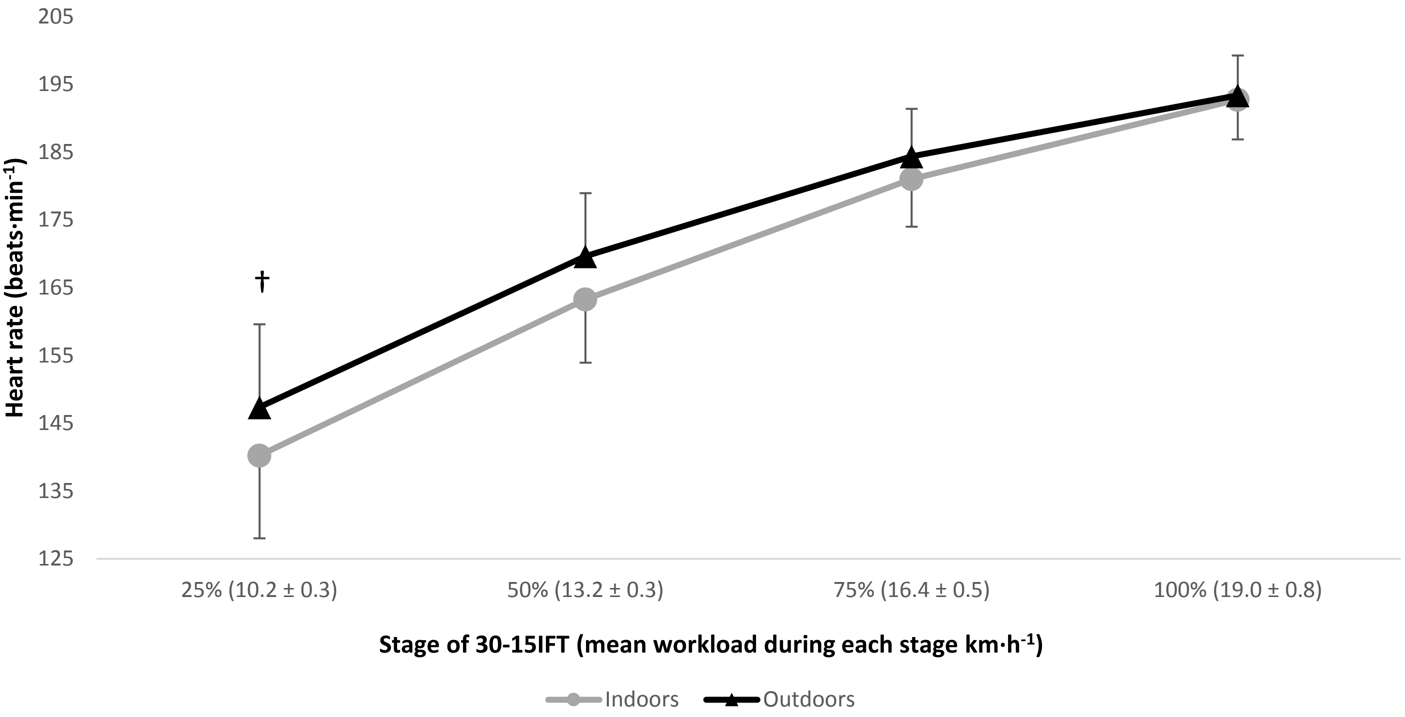
Variables	Mean effect±90% CI	Qualitative inference
Change between indoors and outdoors		
Final running speed	1.30±0.51	Decrease very likely
HR rest	0.64±0.80	Increase possible
HR 25%	0.92±0.63	Increase likely
HR 50%	0.93±0.63	Increase likely
HR 75%	0.69±0.75	Increase possible
HR max	0.16±0.91	Trivial
HRR	1.40±0.76	Increase very likely
HR ave	0.87±0.39	Increase likely
HR 13 km·h^{-1}	1.10±0.87	Increase likely

Note: Mean effect refers to the indoor condition minus the outdoor condition. For the ±90% CI, add and subtract this number to the mean effect to obtain the 90% confidence intervals for the true difference.

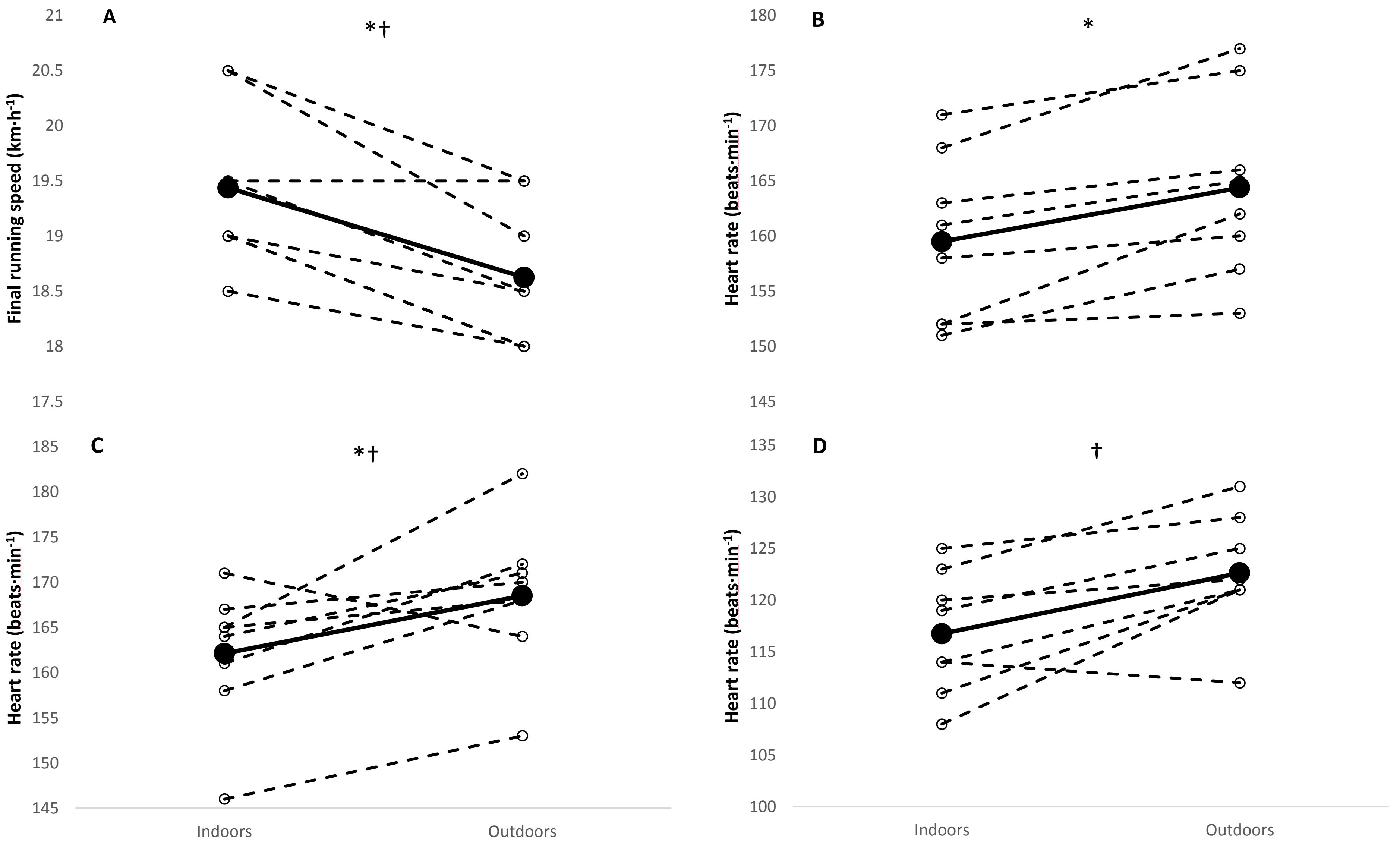
Table 2. Heart rate (BPM) responses prior to, during and after the 30-15$_{IFT}$ indoors (22.0°C and 50.0% RH) and outdoors (34.0°C and 64.1% RH).

Time point	**Indoors**	**Outdoors**
HR rest	75.8 ± 8.8	80.3 ± 11.0
HR 25%	140.3 ± 9.5	147.4 ± 12.2†
HR 50%	163.3 ± 10.1	169.6 ± 9.3†
HR 75%	181.0 ± 6.7	184.4 ± 7.0
HR max	192.8 ± 4.8	193.4 ± 5.9
HRR	116.8 ± 5.9	122.6 ± 5.7†

†Effect size of $d > 0.90$.


205
195
185
175
165
155
145
135
125
Heart rate (beats·min-1)
†
25% (10.2 ± 0.3)
50% (13.2 ± 0.3)
75% (16.4 ± 0.5)
100% (19.0 ± 0.8)
Stage of 30-15IFT (mean workload during each stage km·h-1)
Indoors
Outdoors

1


A
*†
Final running speed (km·h-1)
21
20.5
20
19.5
19
18.5
18
17.5
B
*
Heart rate (beats·min-1)
180
175
170
165
160
155
150
145
C
*†
Heart rate (beats·min-1)
185
180
175
170
165
160
155
150
145
Indoors
Outdoors
D
†
Heart rate (beats·min-1)
135
130
125
120
115
110
105
100
Indoors
Outdoors

1