The physiological load experienced during basketball drills is crucial to understand players’ adaptation to team-sport training and plan physical-conditioning programs. **Purpose:** To compare mean heart-rate (HR_{mean}) responses by playing position during 2-a-side (2v2) and 3-a-side (3v3) ball drills in male junior basketball players and explore the relationship between HR_{mean} and repeated-sprint ability (RSA).

**Methods:** Thirty-one players volunteered to participate in this study. On separate occasions, they performed 2v2 and 3v3 ball drills and 6 repetitions of shuttle-run sprints of 20 m (10+10 m), departing every 20 s (RSA). Ball drills took place on the full length but only half the width of the court and were three 4-min bouts separated by 1-min rest periods. An analysis of variance (ANOVA) assessed the effect of the number of players on court (2v2 vs 3v3) and playing position (guards vs forwards vs centers) on HR_{mean}, and a Pearson correlation coefficient evaluated the relation between HR_{mean} and RSA. **Results:** The main results showed greater HR_{mean} in 2v2 than in 3v3 ball drills (P < .001) in all playing positions (90.7% ± 1.3% vs 87.6% ± 3% of HR_{peak} in guards, 91.3% ± 2.1% vs 87.5% ± 3.7% of HR_{peak} for forwards, and 88.2% ± 3.5% vs 82.2% ± 5.6% of HR_{peak} in centers, respectively, for 2v2 and 3v3). In addition, centers were characterized by lower HR_{mean} than guards and forwards in 3v3 only (P = .018). **Conclusions:** These results suggest that 2v2 drills should be preferred to 3v3 drills for aerobic conditioning, in particular for centers. Finally, RSA does not seem to influence players’ acute responses to ball drills.

**Keywords:** 2-a-side, 3-a-side, heart-rate zones, aerobic conditioning

Basketball relies mainly on high-intensity runs, jumps, and lateral displacements, repeated with an average work-to-rest ratio of 1:3.6 during competition. Analysis of the physiological determinants of success in basketball reveals the importance of both aerobic and anaerobic pathways. Mean heart rates (HR_{mean}) recorded during matches range from 87.0% to 89.0% and are 91.0% and 94.4% of players’ maximal HR (HR_{peak}) in nonelite and elite male players, respectively. The HR_{mean} reported for elite players are within the range of training intensities suggested to improve aerobic fitness in team-sport players. However, nonelite players experience lower match HR_{mean} and training volume than elite players, and many authors have highlighted the need to train aerobic fitness during practice sessions for this population.

Ball drills are a popular method to improve the aerobic characteristics of basketball players because they improve physical fitness while maintaining technical skills. Precise knowledge of the physiological load represented by these types of sessions is particularly useful to plan physical-conditioning programs and optimize training periodization. However, in basketball only 2 studies have investigated these aspects. Castagna et al reported that full-court 2-a-side (2v2) drills elicited a greater HR_{mean} than 3-a-side (3v3) and 5-a-side (5v5) drills (92.0% ± 5.6% vs 88.0% ± 8.4% vs 84.0% ± 9.2% of HR_{peak}, respectively, for 2v2, 3v3, and 5v5). Montgomery et al observed that offensive and defensive drills with a reduced number of players represented, respectively, 90.7% and 93.8% of HR_{mean} observed in competition. These studies showed that both 2v2 and 3v3 drills could be used to improve aerobic fitness. However, the main limitation evoked by these authors is the small participant samples used, which did not allow any analysis by playing position. It is crucial to establish whether ball drills represent an adequate stimulus to develop aerobic fitness in each playing position. Indeed, some players might not reach a high-enough HR during these types of drill due to the technical or strategic constraints imposed by their playing position, in particular at nonelite level. If this were observed, athletic-based conditioning could be more beneficial for these players. It is well established that centers are characterized by lower HR than guards and forwards during competitive matches. However, a recent study reported similar maximal oxygen-consumption (VO_{2max}) values between shooting guards, forwards, and centers, suggesting that...
centers might develop their aerobic fitness during drills in practice sessions.

Aerobic fitness has been identified by many authors as one of the limiting factors for repeated-sprint ability (RSA). Indeed, in their recent review, Bishop et al. highlighted that fatigue during repeated sprints could be attenuated by factors such as increased mitochondrial density, faster oxygen-uptake kinetics, faster postsprint muscle reoxygenation rate, and VO2max. In basketball, only a few studies have focused on these aspects, showing either low correlations or no relationship between VO2max and RSA parameters or the frequency of sprints during a match. However, it has been emphasized that aerobic factors other than VO2max could be associated with RSA, and further research is therefore needed in this area. In particular, acute training responses have received little attention, and it could be useful to investigate the link between RSA performance and HR responses during ball drills. This could help determine if players with a better capacity to repeat sprints achieve higher HRmean or, in contrast, work at a lower percentage of their HRpeak during ball drills than players with a poorer capacity to repeat sprints, as it has been recently suggested.

Therefore, the main objective of the current study was to compare HRmean responses by playing position during 2v2 and 3v3 ball drills in male junior basketball players. The second objective was to investigate the relationship between HR recorded during these ball drills and RSA.

Methods

Subjects

Thirty-one male junior basketball players volunteered to participate in this study. They were randomly selected from 3 teams involved in the same Under 17 regional championship. Their characteristics are described in Table 1. They undertook 240 minutes of practice and 1 match per week. Their typical warm-up for practice sessions consisted of 5 minutes of aerobic activity with the ball, followed by 2 minutes of joint-mobility exercise, 2 minutes of neuromuscular exercise (3 s of skipping followed by 10-m sprint and 3 countermovement jumps followed by 10-m sprint, repeated for 2 min), and 2 minutes of passive recovery (free throws). None of these players was performing additional strength and conditioning at the time of the study. Selection criteria included the absence of injury in the past 6 months. Before testing, the participants and their legal guardians were fully informed of the aims, risks, and benefits of the study and provided written informed consent. The local ethics committee approved the study, in accordance with the Helsinki declaration.

Overview

The study used an observational within-subject repeated-measures design. It was conducted during the first phase of the season, to ensure that an optimal level of fitness had been reached by the players. Subjects took part in 6 testing sessions involving an assessment of maximal aerobic performance, 4 ball-drill sessions, and an RSA test. Testing sessions were undertaken on separate occasions, at the same time of the day (6–7 PM) and with at least 48 hours rest between sessions. Familiarization was not needed for the fitness test and drills because these were regularly used on this team as part of their preseason and in-season practice sessions. Players performed each type of ball drill twice, on separate days (2 sessions for 2v2 and 2 sessions for 3v3), and within-subject reliability between trials was very good (kappa correlation coefficients of .88 and .87 for 2v2 and 3v3, respectively). Players were instructed to refrain from eating or consuming caffeine at least 2 hours before each testing session.

Preliminary Session

Subjects took part in the 30-15 Intermittent Fitness Test (30-15IFT) to assess their maximal aerobic performance (VIFT, km/h) and HRpeak (beats/min). This test has a very good test–retest reliability (ICC of .96). Recent studies on team-sport players have used it. It consists of 30-second bouts of 20-m shuttle running at increasing speeds, separated by 15 seconds of passive recovery. The test ended when the subject could no longer maintain the speed, and the speed and HR attained in the last fully completed stage were recorded as VIFT and HRpeak, respectively.

Ball Drills

Ball drills were 2v2 and 3v3 on the full length (28 m) but only half the width (7.5 m) of the court. This...
configuration is different from previous research, where full court (28 × 15 m) is commonly used, but it is often used by coaches, since more players can exercise simultaneously. In addition, this choice is linked to our purpose to analyze the effects of playing position, because players have to work in specific spaces of the court that involve technical abilities specific to their playing position. Ball drills were presented in a random order and consisted in three 4-minute bouts, separated by 1-minute rest periods. This is similar to exercise durations used in previous studies on basketball, while a shorter recovery was allowed because of the smaller space used. They were played like a competition, with only man-to-man defense allowed. There were no free throws or time-outs allowed during the 4-minute periods to avoid excessive stops. Players could only recover passively in a standing position during rest periods. They were given strict guidelines for starting positions, but they could then move freely. Starting positions are detailed in Figure 1. Ball drills always took place at the start of the practice session, immediately after a standardized warm-up.

RSA Test

The RSA test involved 6 repetitions of shuttle-run sprints of 20 m (10+10 m), departing every 20 seconds. This RSA protocol was adapted (ie, distance made shorter) from a test previously used in handball and field hockey, characterized by a good test–retest reliability. Each subject performed 3 maximal 20-m shuttles before the RSA test to ensure familiarization and determine a criterion score. During the first sprint of the RSA test, each player was required to achieve at least 95% of their own criterion score. If this was not achieved, they had to repeat the first sprint until achievement of the criterion score after 3 minutes of recovery. Subjects were instructed to avoid pacing during the RSA test and produce a maximal effort during each sprint. The researchers provided verbal encouragement throughout each attempt to help achieve this goal.

During the RSA and criterion-score tests, photocells (Wireless speedtrap2, Brower timing systems, Draper, UT, USA) located at the starting line recorded sprint times. Players started each sprint from a line placed 50 cm before the starting line, and timing started when they broke the light beam. The following parameters were calculated from each of the RSA tests:

- Total time (TT), defined as the sum of the 6 sprint times
- Ideal time (IT), calculated as the best sprint time multiplied by 6
- Performance decrement (PD, %), determined according to the following equation:

\[
PD = \left( \frac{TT}{IT} \times 100 \right) - 100
\]

HR Measurements

During the 30-15IFT and all the ball drills, HR monitors (Suunto Pro Team Pack, Vantaa, Finland) continuously monitored HR. HR_{mean} was calculated as the average of the values recorded from the start to end of ball drills. It was expressed in absolute values (beats/min), as well as relative (%) to HR_{peak} measured during the preliminary session. In addition, 4 HR zones were established, and the time spent in each zone during ball drills was calculated as a percentage of total time. The HR zones were defined as low (<75% of HR_{peak}), moderate (75–85% of HR_{peak}), high (85–95% of HR_{peak}), and maximal (>95% of HR_{peak}), according to previously established criteria in basketball.

Statistical Analyses

All parameters were expressed as mean ± SD. Shapiro–Wilk tests assessed the normality of distributions, revealing parametric data. Subsequently, a mixed-design factorial analysis of variance (ANOVA) examined the effects of the number of players on court (2v2 vs 3v3, within subjects) and playing position (guards vs forwards vs centers, between subjects) on absolute and relative HR_{mean}. Where differences were identified,
Bonferroni-corrected pairwise comparisons identified where they lay. Statistical significance was set as \( P < .05 \). In addition, a Pearson correlation coefficient assessed the relation between HR measures and RSA. Effect sizes were calculated using partial eta squared (\( \eta^2 \)). Since this measure is likely to overestimate effect sizes, values were interpreted according to Ferguson\(^26\) as no effect if \( \eta^2 \) was between 0 and .04, a minimum effect if \( \eta^2 \) was between .04 and .25, a moderate effect if \( \eta^2 \) was between .25 and .64, and a strong effect if \( \eta^2 \) was greater than .64.

Results

Preliminary Session

The main results of the 30-15\(_{IRT} \) were an HR\(_{peak} \) of 204 ± 4 beats/min and a V\(_{IFT} \) of 17.3 ± 1.4 km/h. There was no difference between playing positions for these variables (95% CL: −5 to 1.5, −3 to 4.4, and −1.4 to 6.2, respectively, for guards vs forwards, guards vs centers, and forwards vs centers; \( \eta^2 = .23; P = .359 \) for HR\(_{peak} \), 95% CL: −1.6 to −1.7, −0.6 to −3.2, and −0.7 to 3.2, respectively, for guards vs forwards, guards vs centers, and forwards vs centers, \( P = 311; \eta^2 = .27 \) for V\(_{IRT} \)).

Ball Drills

The statistical analyses showed an effect of the number of players on court on HR\(_{mean} \), with the 2v2 ball drill characterized by greater absolute HR\(_{mean} \) (95% CL: 6–11; \( P < .001 \)), \( \eta^2 = .73; \) Figure 2[a]) and relative HR\(_{mean} \) (95% CL: 3.1–5.5; \( P < .001 \); \( \eta^2 = .72 \), Figure 2[b]) than with the 3v3 ball drill.

There was an effect of playing position on absolute HR\(_{mean} \) (\( P = .041 \), \( \eta^2 = .33 \); Figure 2[a]) and relative HR\(_{mean} \) (\( P < .018 \), \( \eta^2 = .40 \); Figure 2[b]). However, post hoc analyses demonstrated differences in the 3v3 ball drills only, with lower HR\(_{mean} \) in centers than in guards (95% CL: −1.5 to 21.0 and 0.05–10.8, respectively, for absolute and relative HR\(_{mean} \); \( P = .048 \); Figures 2[a] and 2[b]) and in centers than in forwards (95% CL: −1.7 to 21.3, and 0.1–10.6, respectively, for absolute and relative HR\(_{mean} \); \( P = .034 \); Figures 2[a] and 2[b]). There was no difference between playing positions in the 2v2 drill (\( P = .726 \)). Values were 185 ± 3 beats/min (90.7% ± 1.3% of HR\(_{peak} \)), \( 187 ± 5 \) beats/min (91.3% ± 2.1% of HR\(_{peak} \)), and \( 181 ± 6 \) beats/min (88.2% ± 3.5% of HR\(_{peak} \)), respectively, for guards, forwards, and centers in the 2v2 drill and \( 179 ± 8 \) beats/min (87.6% ± 3.0% of HR\(_{peak} \)), \( 179 ± 7 \) beats/min (87.5% ± 3.7% of HR\(_{peak} \)), and \( 170 ± 13 \) beats/min (82.2% ± 5.6% of HR\(_{peak} \)), respectively, for guards, forwards, and centers in the 3v3 drill.

Figure 3 shows an example of HR responses to the 2v2 and 3v3 drills in a center player. There were differences between ball drills in the time spent in the different HR zones (\( P < .05 \); Figure 4). More specifically, players spent more time in low and moderate zones in the 3v3 than in the 2v2 drill (\( P < .001 \) and \( \eta^2 = .63 \) for low HR zone, and \( P < .01 \) and \( \eta^2 = .53 \) for moderate HR zone).

Differences were observed in guards and centers for the low HR zone (8.8% ± 4.4% vs 2.7% ± 2.3% in guards and 16.6% ± 11.9% vs 7.1% ± 2.5% in centers; 95% CL: 4.3–10.6; \( P < .001 \)) and for all players in the moderate HR zone (26.0% ± 19.8% vs 9.2% ± 5.2% in guards, 15.0% ± 8.3% vs 8.5% ± 2.2% in forwards, and 37.8% ± 31.0% vs 16.8% ± 7.4% in centers; 95% CL: 9.1–28.5; \( P = .009 \)). No effect of ball drills was found on the time spent in the high HR zone (\( P = .538 \)). However, compared with the 2v2 drill, the 3v3 drill elicited a lower percentage of total time spent in the maximal HR zone in guards and forwards (11.8% ± 22.5% vs 29.5% ± 28.3% in guards and 16.9% ± 26.1% vs 44.7% ± 25.3% in forwards; 95% CL: 1.9–37.9; \( P = .032 \)).

There was an effect of playing position on the time spent in the low and moderate HR zones only (\( P = .001 \) and \( \eta^2 = .61 \) for low HR zone, and \( P = .05 \) and \( \eta^2 = .51 \) for moderate HR zone, Figure 4). Guards spent less time than centers in the low HR zone in both ball-drill types (2.7% ± 2.3% vs 7.1% ± 2.5% in the 2v2 drill and 16.6% ± 11.9% vs 7.1% ± 2.5% in the 3v3 drill; 95% CL: −3.3 to −15.9; \( P = .005 \)). In addition, guards spent less time than centers in the moderate HR zone in both ball-drill types (9.2% ± 5.2% vs 16.5% ± 7.4% in the 2v2 drill and 26.0% ± 19.8% vs 37.8% ± 31.0% in the 3v3 drill; \( P = .003 \)), and forwards spent less time in the moderate HR zone than centers in the 3v3 drill only (15.0% ± 8.3% vs 37.8% ± 31.0%; CL: −6.8 to −38.6; \( P = .005 \)).

RSA Test

Performance indicators achieved by players in the RSA test were 27.8 ± 1.9 seconds, 29.0 ± 2.1 seconds, and 4.0% ± 2.7%, respectively, for ideal time, total time, and performance decrement. There were no differences between playing positions (\( P = .596 \)) and no correlation between RSA parameters and any of the HR variables measured (correlation coefficients ranging from −.273 to .483, \( P = .628 \)).

Discussion

The main results of this study showed that in junior players, 2v2 ball drills elicited greater absolute and relative HR in all playing positions than the 3v3 ball drills. In addition, centers were characterized by lower HR than guards and forwards in the 3v3 drill only. Finally, there was no relationship between acute HR responses to ball drills and RSA. This is the first study to show HR responses of the 3 main playing positions during basketball drills. While our findings confirm those already published in basketball, they add useful information for strength and conditioning coaches.

The relative HR achieved by players of the current study ranged from 88.2% to 91.3% of HR\(_{peak} \) in the 2v2 drill and from 82.2% to 87.6% of HR\(_{peak} \) in the 3v3 drill. Only 1 previous study has described basketball players’ HR during 2v2 and 3v3 ball drills.\(^3\) Our results are
slightly lower than those observed by those authors in male junior players of the same level (92.0% and 88.0% of \( \text{HR}_{\text{peak}} \), respectively, for 2v2 and 3v3).\(^3\) The lower HR observed in the current study could be explained by the reduced playing area used compared with previous studies (full-court length but only half the width, compared with full-court length and width in the study of Castagna et al\(^3\)). Indeed, many authors in basketball and other team sports have observed that reducing the number of players for the same area or increasing the area for the same number of players results in substantially greater HR.\(^8\) For example, Montgomery et al\(^7\) observed that offensive and defensive drills with a reduced amount of players represented, respectively, 90.7% and 93.8% of \( \text{HR}_{\text{mean}} \) observed in competition.

Basketball coaches commonly use 2v2 or 3v3 full-court ball drills to train physical, tactical, and technical skills during practice sessions.\(^14\) These drills are believed to be as efficient as generic running-based interval training to improve aerobic fitness.\(^8\)\(^,\)\(^11\) In the
Figure 3 — Individual heart-rate responses of a center player to the 2-a-side (2v2) and 3-a-side (3v3) ball drills.

Figure 4 — Percentage of total time spent in low (<75% of HRpeak), moderate (75–85% of HRpeak), high (85–95% of HRpeak), and maximal (>95% of HRpeak) heart-rate zones by playing position during the 2-a-side (2v2) and 3-a-side (3v3) ball drills, % of total time. *Different from 2v2, $P < .05$. †Different from centers, $P < .05$. 
2v2 ball drills, although the HR were slightly lower than those measured during full-court drills in basketball, they are still within the range recommended to improve aerobic fitness.\(^{27,28}\) HR were substantially lower in the 3v3 than with the 2v2, as shown by strong effect sizes (.72–.73). This is in accordance with the results of Castagna et al.\(^3\) Although the intensities experienced during 3v3 (82–87% of HR\(_{\text{peak}}\)) could enhance aerobic fitness by inducing mostly central adaptations,\(^29\) most physical-conditioning drills used by team-sport coaches are performed at greater intensities (88–94% of HR\(_{\text{peak}}\)).\(^{13,30}\) These greater intensities have been associated with central, as well as peripheral, adaptations such as muscle capillarization, oxidative enzyme activity, mitochondrial volume, and myoglobin.\(^{31–33}\) In addition, although blood lactate levels were not measured in the current study, a recent investigation reported that blood lactate was significantly lower in 3v3 than in 2v2 drills (6.2 ± 2.3 vs 7.8 ± 1.2 mmol/L).\(^3\) Therefore, our results suggest that 2v2 drills should be preferentially used to train team-sport-specific aerobic fitness because of the greater average physiological load and the greater range of adaptations. To gain a greater insight into the exact cardiovascular breakdown into HR zones and thus would present a different training goal. It is well established that physiological responses to competitive basketball vary according to playing position. Ben Abdelkrim et al\(^2\) reported greater HR during male junior competition in guards than in forwards and centers. Other authors showed greater HR in guards than other positions and in forwards than in centers.\(^{15,16}\) In our study, no difference was observed among playing positions during 2v2, while centers reached a lower HR\(_{\text{mean}}\) than guards and forwards during 3v3. Therefore, while 3v3 seems to be closer to the reality of the competition in terms of cardiovascular stress, the 2v2 offers the possibility to create a greater aerobic training stimulus than competition or 3v3 for centers. Indeed, in our study the difference in relative HR\(_{\text{mean}}\) between 2v2 and 3v3 drills was 5.6% in centers and only 2.6% and 2.7% in guards and forwards. However, moderate effect sizes were associated with these results, suggesting that further studies are needed to strengthen our findings. There are 2 main elements of explanation for the lower HR experienced by centers in the 3v3. The first is that they might have covered more distance at a high speed during the 2v2 than the 3v3. Indeed, centers and forwards both started outside the 3-point line in the 2v2, while centers started closer to the basket in the 3v3 (Figure 1). It is likely that the starting position was reached at a slow or moderate speed, whereas centers then had to sprint toward the basket to post in the 2v2 but not in the 3v3. Although no time–motion analysis was performed in the current study, a recent study on ball drills in soccer showed a greater HR in the drills where players had to cover more distance at a high speed.\(^{14}\) The second explanation is related to the specific actions performed by players. The 3v3 condition might have led to more postplay by the centers, given the restricted area used. The specific actions related to postplay were listed by Trinic and Dizdar\(^{34}\) and included rebounding, inside shots, dribble penetration, and screening. While these actions are physically demanding, they rely mostly on isometric strength. In contrast, the 2v2 might have involved more running-based effort, which is more likely to result in high HR.

The relationship between aerobic fitness and RSA has been studied in several investigations, and various authors mentioned that aerobic fitness could be a limiting factor for RSA.\(^{8,10,11,13,17}\) Since most studies have used VO\(_{\text{2max}}\) as an indicator of aerobic fitness, it was suggested to consider other variables. Therefore, a secondary aim of the current study was to focus on the relationship between RSA and acute HR responses during ball drills. From the past literature in team sports, 2 possible links between these variables could be expected. The first is a positive association, with players with the greatest RSA also capable of reaching a greater HR during ball drills. This is based on a study reporting that soccer players with a greater capacity to repeat sprints during an RSA test were also capable of producing greater sprint speed during a game,\(^{19}\) although no direct relation between sprint speed and HR has been demonstrated. The second possible link is a negative association, with players with a greater RSA showing the lowest physiological load during ball drills, as shown in another study on soccer players.\(^{13}\) This latter possibility would suggest that ball drills...
are less demanding for fitter players than for less fit players. In the current study, none of these hypotheses was confirmed, as we did not observe any relationship between acute HR responses to ball drills and RSA. This suggests that other parameters might play a role during ball drills, such as technical or strategic aspects. In accordance with our findings, Castagna et al.18 did not show any correlation between aerobic fitness and RSA performance in male junior basketball players.

The main limitations of this study are the limited number of players to compare playing positions and the absence of time–motion analysis during ball drills. In addition, our results could only be applied to junior basketball of regional level. Further studies are necessary to investigate these aspects in adult players and/or elite players.

Practical Application

The high HR observed in this study suggests that ball drills can be used by coaches to train physical fitness and technical and tactical skills. In particular, 2v2 ball drills should be selected by coaches, rather than 3v3, to focus on maximal HR zones and/or when short rest periods are targeted (little time spent in low and moderate HR zones). The 2v2 would be particularly useful to enhance the aerobic fitness of centers, who are not subjected to these high intensities during competition.

In conclusion, the current study showed that greater HR are achieved by junior basketball players during 2v2 than during 3v3 ball drills. In addition, centers were characterized by lower HR than guards and forwards in the 3v3 drill only. These results suggest that 2v2 drills should be preferred to 3v3 drills for aerobic conditioning, in particular for centers. Finally, RSA does not seem to influence players’ acute responses to ball drills. Further studies should be undertaken to clarify the link between these variables, which would be very helpful in planning physical-conditioning sessions.

References