



Original research

Physical and physiological demands and hormonal responses in basketball small-sided games with different tactical tasks and training regimes

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ABSTRACT

Objectives: To evaluate external and internal training load (TL) and hormonal responses in basketball 3-versus-3 small-sided games (SSGs).

Design: Randomized repeated-measures study.

Methods: Twelve male basketball players participated to four 3-versus-3 SSGs characterized by different tactical tasks (offensive; defensive) and training regimes (long-intermittent: three 4-min bouts with 2' rest in between; short-intermittent: six 2-min bouts with 1' rest in between). Variables measured were: PlayerLoad (PL); percentage of maximal heart rate (%HR_{max}); Edwards' TL. Before and after the SSGs, saliva samples were collected to measure cortisol (C) and testosterone (T). Two-way (task; regime) repeated-measures ANOVA was performed for PL and %HR_{max}; C concentrations were analysed with a three-way (task; regime; time: pre/post) repeated-measures ANOVA; non-parametric analyses were performed for Edwards' TL and T.

Results: PL was moderately higher in offensive task (148.0 ± 16.8 AU) compared to defensive (137.1 ± 15.5 AU), and short regime (147.0 ± 18.2 AU) compared to long (137.9 ± 14.6 AU). %HR_{max} was moderately higher in offensive task (91.1 ± 4.1%) compared to defensive: (88.7 ± 5.4%), while it did not differ between regimes (long: 90.0 ± 5.6%) (short: 89.8 ± 4.2%); additionally, an interaction (task*regime) effect was found (ES: strong). Edwards' TL was moderately higher in offense-long SSG (56.6 ± 2.4 AU) compared to defense-short (52.4 ± 4.4 AU). C increased after the SSGs (ES: strong). T decreased after offense-short (ES: moderate) and increased after defense-long (ES: moderate) SSGs.

Conclusions: Tactical tasks and training regimes influence external and internal demands of basketball SSGs. Steroid hormones respond in SSGs.

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1. Introduction

Basketball is an intermittent-based, stochastic team sport¹ characterized by neuromuscular efforts (jumps, sprints, shuffling),¹ considerable cardiorespiratory requirements (81–95% of the peak heart rate during live time),¹ and frequent changes of activity (one every 1–3 s).¹

During training, coaches can manipulate several factors, such as playing area, number of players involved, rules, regimes and work:rest ratios to determine the demands of small-sided games (SSGs).^{2–4} Considering the multi-faceted nature of basketball, SSGs have been proposed as effective for improving physical capacities^{2,3,5} and technical-tactical abilities.^{2,3,5} A review of Clemente et al.² on basketball SSGs indicates that smaller formats (lower number of players) and larger court areas per player determine higher internal training load (TL) (cardiovascular responses, blood lactate accumulation).² Regarding training regime, a study by Conte et al.⁶ found that, for the same total work time, continuous regimes (longer bout duration) induced higher internal responses

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than intermittent regimes (shorter bouts) in youth players⁶; conversely, Klusemann et al.⁷ did not find differences for peak heart rate (HR) between continuous and intermittent regimes in elite youth players.⁷ Thus, there is need for further investigations on training regimes, considering their physiological importance.^{2,3}

Another feature which is usually manipulated by coaches during SSGs is tactical task. For example, players can be alternatively assigned to the offensive or defensive tasks to selectively train the specific skills and capacities required for each phase of the game. A study by Montgomery et al.⁸ involving professional players quantified external and internal TLs of offensive and defensive training drills; however, drills evaluated were unstructured. Therefore, performance profiles of different tactical tasks in structured basketball drills have still to be defined.

The physical work performed by athletes on court can be quantified by measuring external TL. Time-motion analysis (TMA) of basketball SSGs highlighted that smaller formats induce more physical (sprints, jumps, shuffling)⁷ and technical (dribbling, passing, shooting) actions.^{6,7} However, TMA is very time-consuming. Physical load in basketball can be more efficiently monitored by means of accelerometers, considering their validity and practicality.^{9,10,11} While external loads of competition and weekly training have been previously quantified,⁸ only one study measured it in structured ball-drills.¹¹ In the work by Schelling and colleagues,¹¹ factors investigated were format and court area. Thus, there is no information on the influences of tactical tasks and regimes on physical load of basketball SSGs.

To have a more comprehensive picture of TL, useful information can be gathered by measuring exercise-related bio-markers.^{12–14} Among the available methodologies, the non-invasiveness and practicality of saliva collection makes it a favourable choice. Steroid hormones have been widely investigated in Sport Science.^{12,15,16} Cortisol (C) is the primary hormone involved in responses to psychophysiological stressors, and is thus considered a marker of acute and chronic training stress.^{14,15,17} Also, increases in C levels have been suggested to be beneficial for physical and behavioural outcomes during competition.^{17,18} Testosterone (T) plays a central role in anabolic processes,¹⁸ and has been associated with training stress and fitness status.^{12,15} Variations in T levels have been reported both before¹⁵ and after acute exercise,^{15,16} suggesting its implication with performance. Previous studies have investigated steroid hormones' responses in basketball players during official and simulated games,^{17,19} while to the best of our knowledge only one recent study by Moreira et al.²⁰ evaluated salivary C and T responses in youth players during SSGs. Thus, further investigations are necessary to understand how steroid hormones respond in basketball SSGs, especially in adult players.

Therefore, the aim of this study was to measure physical and physiological demands and salivary hormones' responses in basketball SSGs played with different tactical tasks and training regimes.

2. Methods

Twelve male basketball players (age: 21 ± 2 y; stature: 193.9 ± 7.0 cm; body mass: 84.8 ± 6.6 kg; playing experience: 12 ± 3 y) from a team playing in the Lithuanian National League (NKL) participated in this study. NKL is the national second-tier basketball championship, organized by the Lithuanian Basketball Federation and considered of semi-professional level. Players were informed about the study aims and procedures, and provided written informed consent to participate. Ethical approval was received by the local Institutional Review Board (code: BEK-TRS(B)-2018-30). The team schedule comprised 5 training sessions and one official match per week. Training sessions primarily consisted of

full-court ball-drills, SSGs, tactical drills and metabolic conditioning, while lower time was dedicated to skills development and strength-power training. The study was performed during the competitive phase of the season; thus, players were in appropriate fitness status.

The study consisted of five experimental sessions. In the first one, players familiarized with the entire experimental setup and were tested with the Yo–Yo Intermittent Recovery Test (Level 1) to assess their maximal HR (HR_{max}). Following familiarization, four experimental sessions were conducted over four weeks, each scheduled at the same time of the day (5.00 PM) and following 48 hours of rest.

The SSGs format was 3-versus-3, played on half-court (14×15 m). The team's head coach allocated players in four balanced teams. In all sessions, each team always played against the same opponent (Team A vs Team B; Team C vs Team D). Training factors investigated were:

- tactical task: offense or defense;
- training regime: long-intermittent (three 4-min bouts interspersed by 2 min of passive recovery) or short-intermittent (six 2-min bouts interspersed by 1 min of passive recovery). Total work time was equated (12'), while work:rest ratios were similar (long-intermittent: 3:1; short-intermittent: 2.4:1).

Therefore, players underwent, in a randomized order, the following four experimental conditions:

- Offense-long;
- Offense-short;
- Defense-long;
- Defense-short.

Players were accustomed with the SSGs' characteristics as they were commonly used in their training sessions. Regarding tactical task, one team was playing only the offensive task and the other team was only involved in the defensive task for all the duration of the SSG. The defensive strategy chosen was man-to-man (with switch allowed). Each ball possession was considered finished after a basket made, foul, rebound (offensive or defensive), steal, turnover, and when ball went out of bounds. In order to restart playing, the ball had to be passed to the assistant (positioned centrally at half court), who rapidly returned it to the offensive team to start a new possession; in case the offensive team collected an offensive rebound, game continued without the assistant's check. Considering the reduced court area, shot clock was set at 12 s, similarly to a previous study.⁷ No free throws were allowed; in cases of fouls committed while an offensive player was in shooting motion, 1 point was awarded to the offensive team.⁷ Two referees regulated the SSGs. Score was constantly showed; encouragement was offered by coaches and researchers to maintain high motivation.^{6,7} During the pauses between bouts, players passively recovered (sitting or standing).

Before each session, players underwent an 8-min standardized warm-up, which included mobility exercises, running, basketball-specific movements, jumps and sprints.

Before the warm-up, and 15 min after completion of the SSGs, saliva samples were collected. Players actively produced at least 1.5 ml of saliva over 5 min,^{17,19,20} collecting it in 2-ml tubes which were subsequently stored at -20° .²¹ Samples were analysed using enzyme-linked immunosorbent assays (Labor Diagnostika Nord, Germany) to measure C (ng/ml) and T (pg/ml) concentrations. Coefficient of variations of C and T intra-assays were 4.2% and 5.5%, respectively.

External TL was assessed using Catapult OptimEye S5 devices (Catapult Innovations, Australia), which provide the indicator

PlayerLoad (PL) (in arbitrary units, AU). PL is calculated as the instantaneous rate of change in accelerations in the anteroposterior, mediolateral and craniocaudal axes, and thus quantifies the physical loads placed on the athletes.^{8,22}

Internal TL was assessed by collecting players' HR responses during the SSGs. Each player wore a Polar H7 monitor belt (Polar Electro, Finland), which was connected wireless with his respective S5 device. Indicators measured were: the peak HR reached during the SSGs, calculated in percentage of the maximal HR recorded during the Yo-Yo test (%HR_{max}); and Edwards' TL,²³ calculated by multiplying the time (in minutes) spent by the player in each HR zone by the relative zone coefficient (50–59.9% HR_{max} = 1, 60–69.9% HR_{max} = 2, 70–79.9% HR_{max} = 3, 80–89.9% HR_{max} = 4, 90–100% HR_{max} = 5) and summing these scores, finally obtaining the TL value (in AU).²³

Statistical analysis was performed using SPSS 25.0 (SPSS, USA). A two-way (tactical task: offense/defense; training regime: long/short) repeated-measures ANOVA was performed for PL and %HR_{max}. Edwards' TL was not normally distributed, and thus analysed using Friedman test and subsequent Wilcoxon post-hoc (Bonferroni correction).

Regarding salivary hormones (C, T), due to an inconvenience in the storage process samples were analysed for 10 of the 12 participants. To ensure players entered the four experimental sessions in similar conditions, pre-SSGs values of C and T were compared via repeated-measures ANOVA. Three-way (task; regime; time: pre-SSG/post-SSG) repeated-measures ANOVA was performed to analyse C concentrations. Post-SSGs T concentrations were not normally distributed; therefore, non-parametric analysis was performed using Friedman test. Then, two Wilcoxon post-hoc tests (Bonferroni correction) were performed: one to evaluate whether there was a difference in T due to the SSG's condition by comparing T post concentrations; another one to assess if there was a general effect of exercise on T, by comparing pre versus post T levels in each of the four SSGs.

Significance was set at $p < 0.05$. Effect sizes [ES; partial eta squared (η_p^2)] of the ANOVA analyses were interpreted as: ≤ 0.039 — no effect; 0.04 to 0.24— minimum; 0.25 to 0.63— moderate; ≥ 0.64 strong.²⁴ In case of interaction effects, mean (M) and standard error (SE) were presented. For the non-parametric analyses, ES was calculated as r ,²⁵ and interpreted as: 0.1— small; 0.3— moderate; 0.5— large.²⁵

Table 1
Results for PlayerLoad (PL) and percentage of maximal heart rate (%HR_{max}).

	Task					Regime				
	Offense	Defense	Mean diff. (95% CI)	p	ES (η_p^2)	Long	Short	Mean diff. (95% CI)	p	ES (η_p^2)
PL	148.0 ± 16.8	137.1 ± 15.5	11.0 (3.5; 18.4)	0.008	0.517 - moderate	137.9 ± 14.6	147.0 ± 18.2	-9.1 (-16.8; -1.3)	0.026	0.404 - moderate
%HR _{max}	91.1 ± 4.1	88.7 ± 5.4	2.4 (0.5; 4.4)	0.020	0.433 - moderate	90.0 ± 5.6	89.8 ± 4.2	0.2 (-2.5; 2.8)	0.893	0.002 - no effect

Results presented as mean, standard deviation, mean difference and 95% confidence interval of the differences. ES = effect size. p-value and ES of significant differences in bold.

Table 2
Salivary hormonal concentrations before and after each SSG typology.

	Offense-long		Offense-short		Defense-long		Defense-short	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
C ^a (ng/ml)	6.7 ± 4.7	12.4 ± 3.4	7.3 ± 2.2	11.1 ± 4.2	8.1 ± 4.3	11.4 ± 4.3	6.6 ± 1.4	10.5 ± 3.7
T (pg/ml)	200.7 ± 86.7	239.4 ± 122.2	260.5 ± 155.9	192.2 ± 152.9 [#]	159.3 ± 94.7	251.8 ± 104.3 [#]	175.1 ± 183.1	249.0 ± 130.22

Data presented as mean and standard deviation.

^a Significant effect for time [$p = 0.001$; mean difference (95% CI): -4.19 (-6.24; -2.13); $\eta_p^2 = 0.702$, strong].

[#] Significantly lower than Pre ($p = 0.028$; $r = 0.49$, moderate).

^{*} Significantly higher than Pre ($p = 0.037$; $r = 0.47$, moderate).

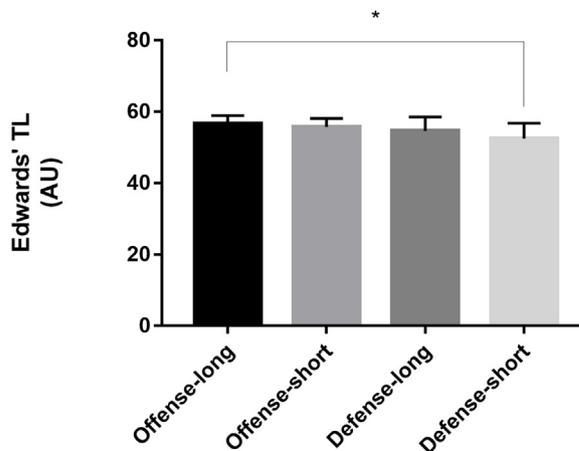


Fig. 1. Edwards' TL of the four SSGs.

Data presented as mean and standard deviation.

*Offense-long higher than defense-short ($p = 0.004$; $r = 0.25$, moderate).

3. Results

Data and main effect results for PL and %HR_{max} are presented in Table 1. There was no interaction (task*regime) effect for PL ($p = 0.374$), while it was found for %HR_{max} (offense-long: M: 90.6, SE: 1.6; offense-short: 91.7 ± 0.8; defense-long: M: 89.4, SE: 1.9; defense-short: M: 88.0, SE: 1.4) ($p = 0.002$, $\eta_p^2 = 0.632$, strong).

Regarding Edwards' TL, Friedman test was significant ($p = 0.008$); results of the Wilcoxon post-hoc are presented in Fig. 1.

There were no differences between pre-SSGs salivary hormones in the four sessions (C: $p = 0.599$, $\eta_p^2 = 0.054$, minimum; T: $p = 0.227$, $\eta_p^2 = 0.154$, minimum). C and T concentrations before and after the SSGs are shown in Table 2. Regarding C, no interactions were found (time*task*regime: $p = 0.350$, $\eta_p^2 = 0.098$, minimum; task*regime: $p = 0.295$, $\eta_p^2 = 0.121$, minimum; task*time: $p = 0.485$, $\eta_p^2 = 0.056$, minimum; regime*time: $p = 0.757$, $\eta_p^2 = 0.011$, no effect); a significant effect was found for time [$p = 0.001$; pre-post difference (95% CI): -4.19 (-6.24 - -2.13); $\eta_p^2 = 0.702$, strong]; no differences were found for task ($p = 0.694$, $\eta_p^2 = 0.018$, no effect) or regime ($p = 0.128$, $\eta_p^2 = 0.238$, minimum). Regarding T, Friedman test was significant

($p = 0.030$). Wilcoxon test between T post concentrations of the four SSGs found no differences ($p > 0.05$). Results of the Wilcoxon test between pre and post T levels in each SSG are presented in Table 2.

4. Discussions

This study aimed at evaluating physical and physiological demands and steroid hormones' responses in basketball 3-versus-3 SSGs played with different tactical tasks and training regimes. Results show that the offensive task elicited higher external and internal TLs. Shorter regimes induced higher external, but not internal loads. Cortisol significantly increased after the SSGs. Testosterone increased after the defense-long SSG, decreased following the offense-short one, and did not change in defense-short and offense-long conditions.

To the best of our knowledge, this was the first study measuring the effect of tactical tasks (offense/defense) on external TL in structured basketball drills. Higher PLs ($\eta_p^2 = 0.517$, moderate) were assessed in the offensive task. It is possible that, while in the offensive task players continuously produced efforts to beat the defense and score, in the defensive one they might have played mostly within the 3-point line to protect the basket, thus covering lower distances. Additionally, defensive strategy (man-to-man with switch allowed) might explain the lower PLs accumulated. In fact, in picking situations defensive players could decide to switch, leaving their assigned opponent to the defensive teammate involved in order not to leave any space advantage to the opponents. In this way, defensive players could reduce physical efforts and distance to cover by switching, thereby accumulating lower PLs.

Regarding training regimes, moderately higher PLs ($\eta_p^2 = 0.404$) were registered in the short regimes (2') compared to long ones (4'). While total work time was equated (12'), the regimes featured slightly different work:rest ratios (2.4:1 in short-intermittent; 3:1 in long-intermittent). Shorter bouts and lower work:rest ratios may allow for phosphocreatine resynthesis, reduce metabolic stress and, in turn, neuromuscular fatigue^{26,27}; thus, our players might have perceived less fatigue in the short regimes. In fact, as total work time was equated, the higher PLs assessed suggest that the short regimes were played at a higher pace. In line with our findings, Klusemann et al.⁷ reported more moderate-to-high-intensity movements in short-regime basketball SSGs. Therefore, shorter bouts and lower work:rest ratios can elicit higher physical loads and work rates, thus resulting more similar to competition demands.⁷

For internal load, the SSGs elicited cardiovascular responses (mean and SD of %HR_{max} in the four conditions: 89.9 ± 4.9) in the range of those documented in basketball competition (81.8–94.6%).¹ Regarding tactical tasks, moderately higher ($\eta_p^2 = 0.433$) %HR_{max} were measured in offense, in line with the findings for PL. As proposed above, the possibility to switch given to defensive players possibly allowed them to reduce physical efforts and distance to cover, thus determining lower workloads and also %HR_{max}. Differently from PL results, no difference was found for %HR_{max} between regimes. This discrepancy is plausible, considering that external and internal TLs are different constructs, and in fact have only moderate to large relationships in basketball training ($r = 0.38–0.61$).²⁸ The absence of difference for %HR_{max} between our regimes is in line with previous findings by Klusemann et al.⁷; conversely, Conte et al.⁶ reported differences in internal load between continuous and intermittent regimes. These different findings might be explained considering work:rest ratios adopted. In the study of Klusemann et al.⁷ and our investigation, work:rest ratios of the intermittent regimes were higher (3.3:1 and 2.4:1, respectively) than in the intermittent regime used by

Conte et al.⁶ (1:1 ratio), which in fact found lower HR responses. Collectively, our results confirm the importance of monitoring and evaluating external and internal TLs as separate constructs in basketball²⁸; additionally, work:rest ratios should be specified when designing SSGs, as also recommended in a previous review on football SSGs.³ Furthermore, the strong interaction effect ($\eta_p^2 = 0.632$) found for %HR_{max} and results for Edwards' TL (higher in offense-long compared to defense-short) suggest that cardiovascular demands can be manipulated by combining tactical tasks and training regimes. For example, the combination of longer bouts and offensive task could be designed to increase internal load, and vice versa.

To the best of our knowledge, this was the first study investigating salivary hormones' responses to basketball SSGs in adult athletes. C levels we measured before and after the SSGs (pre: 7.2 ± 0.7 ng/ml; post: 11.4 ± 0.8 ng/ml) were higher than those reported by Moreira et al.¹⁹ before and after official basketball games (pre: 1.9 ± 0.3 ng/ml; post: 4.0 ± 0.7 ng/ml).¹⁹ As competitive level has been shown to influence C responses in football players,¹⁶ the higher C levels in this study could be attributed to the sample involved (semi-professional players in our study; elite players in the study by Moreira et al.)¹⁹. Additionally, a recent study by Moreira et al.²⁰ involving youth basketball players did not register changes in C after SSGs, further suggesting the influence of competitive level on C responses. Nevertheless, considering that C has been shown to increase in official but not simulated basketball games,^{17,19} the strong ($\eta_p^2: 0.702$) increase of C assessed in this study suggests that the SSGs were considerable training stimuli. Therefore, as SSGs are utilized in team sports training because they mimic the physical, physiological and technical-tactical demands of competition,^{2,3,5} our study supports their usefulness to prepare players for competition also from an endocrinological perspective.

Regarding testosterone, no previous study assessed its acute responses in SSGs in adult male basketball players. We found moderate increases after the defense-long SSG, which had the lowest PL (132.8 ± 15.0 AU), and moderate decreases after the offense-short condition, which had the highest PL (151.9 ± 18.8 AU); T remained stable in the defense-short and offense-long SSGs, which had intermediate PLs (139.4 ± 15.9 AU and 141.4 ± 13.3 AU, respectively). Therefore, it appears that T responses were influenced by external TL. A recent study by Moreira et al. proposes that T responses in basketball SSGs are attenuated by mental fatigue.²⁰ It could be speculated that in offense-short players had to continuously find a solution to score at a high pace, which might have increased demands on the central nervous system²⁰ and thus reduced T levels, while defense-long was the opposite, least demanding condition, resulting in increases of T. Nevertheless, further studies are necessary to understand the influence of physical and tactical constraints on T responses in basketball SSGs.

Limitations of this study are the lack of assessment of perceived exertion and technical-tactical parameters, which future studies could investigate in order to have a comprehensive picture of basketball SSGs' demands.

5. Conclusions

Tactical tasks and training regimes influence physical and physiological demands of basketball SSGs. Cortisol increased after the SSGs, while testosterone responses differed depending on SSGs conditions. Considering the heart rate responses assessed (comparable to those of official competitions)¹ and the significant increases in cortisol, which can induce benefits in performance,¹⁷ our findings posit for the utilization of SSGs to prepare basketball players for competition.

Practical implications

- External and internal TLs can be increased or decreased by allocating players to offensive or defensive tasks, respectively.
- Players who are exposed to high training stress, such as starters,²⁹ can be allocated to defensive tasks to reduce their TL; vice versa, offensive tasks can be used to increase TL of bench players.
- Shorter bouts induce higher physical demands, and thus appear more similar to competition.⁷
- SSGs can induce significant variations in cortisol and testosterone, which might be considered when designing daily and weekly training programs.³⁰

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