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Research article

Accelerometer Load Profiles for Basketball-Specific Drills in Elite Players

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Abstract
The purpose of this study was to quantify the workload during basketball-specific drills measured through microtechnology. Twelve professional male basketball players from the Spanish 1st Division were monitored over a 4-week period. Data were collected from 16 sessions, for a total of 95 ± 33 drills per player. Workload data (Acceleration load; AL) were obtained from a tri-axial accelerometer at 100Hz sampling frequency, and were expressed over time ($AL \cdot min^{-1}$). Comparisons among training drills (i.e., 2v2, 3v3, 4v4, and 5v5) were assessed via standardized mean differences. Full-court 3v3 and 5v5 showed the highest physical demand ($AL \cdot min^{-1}$: 18.7 ± 4.1 and 17.9 ± 4.6, respectively) compared with other traditional balanced basketball drills such as 2v2 and 4v4 (14.6 ± 2.8 and 13.8±2.5, respectively). The $AL \cdot min^{-1}$ on half-court showed trivial-to-moderate differences with a likely increase of ~10-20% in 2v2 drill compared with any other formats. This study provides insight into the specific requirements of a range of exercises typically performed in basketball sessions. The use of accelerometer data is presented as a useful tool in assessing the workload.

Key words: Acceleration, physical demands, training drills, monitoring, team sport.

Introduction

Basketball is a stochastic high-intensity sport characterized by high aerobic and anaerobic demands, continuous changes of direction, accelerations and decelerations, jumps, sprints, contacts, and specific skills (Ben Abdelkrim et al., 2007, McInnes et al., 1995). Furthermore, cognitive demands such as perception, decision-making, and anticipatory processes are considered key factors in basketball (Aglioti et al., 2008, Remmert 2003, Stöckel et al., 2013). Thus, there is a challenge in designing training drills to optimize simultaneously physical, specific skills, and cognitive demands which reproduce game requirements, for a greater ecological validity (Reilly et al., 2009).

A common way of simulate game demands during practice sessions is in form of small-sided games (SSG), widely previously described in other team sports (Aguiar et al., 2012, Hill-Haas et al., 2011). Together, these studies have shown that constraints such as number of players involved in the task (i.e., confrontation format), court size, intensity, work-to-rest ratio, and specificity of movement actions influence the physical, physiological, and skill demands during SSG (Klusemann et al., 2012, Schelling et al., 2013, Torres-Ronda et al., 2015). Results essentially reveal the following: a) the greater the number of players, the fewer technical actions; b) the smaller the number of players, while maintaining the relative playing area, the greater the physiological load. Specifically in basketball, previous research has shown that 5v5 open-court drills showed the highest cardiovascular demands, followed by unbalanced SSG (e.g., 2v1, 3v2, etc.) (Torres-Ronda et al., 2015). Results derived from time motion analysis showed that 1v1 is the most demanding basketball drill, regardless of type of court size, in terms of both frequency-of-movements and proportion of high-intensity activities (Castagna et al., 2011, Montgomery et al., 2010, Moreira et al., 2012, Torres-Ronda et al., 2015). However, despite these previous investigations provided important information, they have been mainly conducted with junior or non-elite players. Therefore, there is a limited understanding (or limited scientific literature) of the physical and physiological demands of SSG in elite and professional basketball players. (Castagna et al., 2011, Delextrat et al., 2013, Klusemann et al., 2012, Montgomery et al., 2010, Sampaio et al., 2009, Torres-Ronda et al., 2015). Likely due to their inaccessibility (intellectual property policies), or schedule and logistic constrains. A comprehensive knowledge of the demands of different types of basketball drills in order to have them better described and classified, is crucial for a better understanding of training effects and to optimize the periodization process.

Over the last 10 years, wearable Global Positioning System (GPS) has been more widely used, allowing us a better understanding of sport requirements, being less time-consuming than time-motion analysis. Nevertheless, this technology presents certain limitations: a) it cannot be used by indoor sports (Cummins et al., 2013), b) it shows questionable validity and reliability to accurately assess short, high-intensity movements due to its low sampling rate (1-10 Hz) (Cummins et al., 2013), and c) it is an expensive technology, still not affordable for the general population. Recently, studies reported the usefulness of accelerometer-derived measures, such as the "Player Load" or "Body Load" to describe and quantify athlete's workload (Boyd et al., 2011, Chambers et al., 2015, Cormack et al., 2014, Mooney et al., 2013, Serpiello et al., 2014). Nonetheless, there is a paucity of data analysing basketball drills using microtechnology such as accelerometers (Coe 2001, Montgomery et al., 2010, Scanlan et al., 2014). Due to the nature of the sport, to analyse the behaviour of the loads by using high-sampling-frequency (100 Hz) accelerometer-derived measures could be of great value for a proper training load management.

The aim of this research was therefore to quantify

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the workload using microsensor technology (i.e., accelerometers), in professional male basketball player during basketball-specific training drills, according to different confrontation formats and court size.

Methods

Participants

A convenience sample of twelve professional male basketball players from a single Spanish 1st Division League club (age: 25.0 ± 4.3 y; height: 1.97 ± 0.09 m; weight: 93.4 ± 12.0 kg; fat%: 13.8 ± 2.5 %) participated in the study. At the time of the study (in-season period), the players were training for 12 hours per week ($h \cdot wk^{-1}$). All players and coaches were informed of the research protocol, requirements, benefits and risks, and their written consent was obtained before the study began. There were no players under the age of 18 years old. The local Institutional Research Ethics Committee approved this study, and it conformed to the Declaration of Helsinki (Harriss et al., 2013. 2014 update).

Experimental design

This longitudinal and observational study was conducted during the 2013–2014 Spanish competitive basketball season. Data were collected from basketball team training sessions, performed throughout a 4-week period, during the in-season period (November-December). A total of 16 basketball-specific team-training sessions were chosen for the analysis, where a total of 1139 training observations were analysed, involving a total of 95 ± 33 drills (mean ± SD per player (range: 31 to 123). The mean duration of the drills was 6.3 ± 3.7 minutes. During these practice sessions, groups of teammates, and opponents were varied randomly. These court-based training sessions were designed and supervised by coaching staff to elicit skill, tactical, and physical goals. These were classified according to the confrontation format in terms of the number of players (2v2, 3v3, 4v4, and 5v5) and the court size (full and half court).

Procedures

The team weekly schedule included: ~8 $h \cdot wk^{-1}$ basketball practice [one or two shoot-around sessions (45–90 $min \cdot wk^{-1}$), five or six skill and tactical team sessions (525–625 $min \cdot wk^{-1}$)], ~4 $h \cdot wk^{-1}$ physical conditioning [two or three strength sessions, one high-intensity interval training session], one game, and one recovery session the day after the game. All training sessions started with a standardized warm-up and ended with a standardized cool-down. These periods were excluded from the analysis. All practice sessions were performed on the same regulation court under similarly controlled environmental conditions. The usual verbal encouragement from the head coach was allowed during sessions. Players were allowed to consume water *ad libitum* during recovery periods (see Table 1 for drills description).

Acceleration data, interpreted as external load, were obtained from a tri-axial accelerometer (X8-mini; 16-bit; Gulf Coast Data Concepts, USA). This device is 51 x 23 x 13 mm, weighs 17 g, and was set up at a 100-Hz sampling rate. The accelerometer was located on the player's hip between the belly and the right iliac crest and fixed to the elastic waist of the sport shorts. This location has been shown to provide the best results for whole body movement, as it is close to the player's center of mass (Cleland et al., 2013). Each athlete wore the same device throughout the study.

The instantaneous data from all 3 axes (x, y, and z) were integrated into a resultant vector through the Cartesian formula $\sqrt{[(x_n - x_{n-1})^2 + (y_n - y_{n-1})^2 + (z_n - z_{n-1})^2]}$. The straight addition of the instantaneous change of rates of resultant accelerations (also known as jerk) over time represented the acceleration load for a drill or activity (AL). To reduce the value for ease of use, the result was multiplied by a scaling factor of 0.01. All data were expressed over time, per minute of activity ($AL \cdot min^{-1}$). The validity and reliability of measuring team sport 3-dimensional movements via tri-axial accelerometer has been shown previously (Barrett et al., 2014). Data were downloaded and transferred to a custom built Microsoft Excel spreadsheet for further analysis.

Statistical analysis

Descriptive statistics was performed using mean and standard deviations. Parameters were log-transformed to reduce bias due to the non-uniformity of error and analysed using a customized Excel spreadsheet (Hopkins 2007). Comparisons among training drills were assessed via standardized mean differences and were computed with pooled variance and respective 90% confidence limits (CL) (Cumming 2012, Hopkins et al., 2009). Thresholds for standardized effect size (ES), were as follows: small, >0.2-0.6; moderate, 810.6-1.2; large, >1.2-2.0; and very large, >2.0 (Hopkins et al., 2009). Smallest worthwhile differences were estimated from the standardized units multiplied by 0.2. Uncertainty in the true differences of the scenarios was assessed using non-clinical magnitude-based inferences (Hopkins et al., 2009). Due to the small sample size, the results shown by playing position are just descriptive and exploratory.

Results

The main results of the present study showed that, for all players pooled, the higher values were identified when playing full-court 3v3 and 5v5 scrimmage drills, and the lowest when playing 4v4 (see Table 2). Second, the players showed higher acceleration load per minute when playing 2v2 and 5v5 in half court. Acceleration load differences between basketball drills are presented in Table 2.

First, for full court, differences ranged between small and moderate, most likely with lower values when comparing 2v2 versus 3v3 and 5v5 (~35%), and 4v4 compared with 5v5 (~30%) (see Table 2). Secondly, however, when comparing acceleration load per minute on half court, we found trivial-to-moderate differences with a likely increase of ~10-20% in 2v2 compared with any other formats, but we found unclear differences between other comparisons (see Table 2).

Table 1. Drills descriptions.

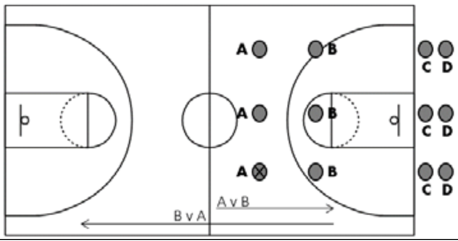
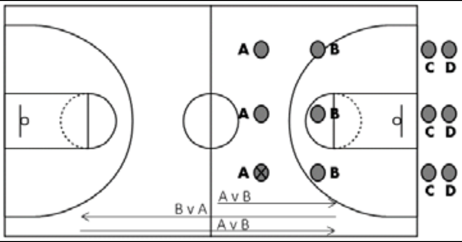
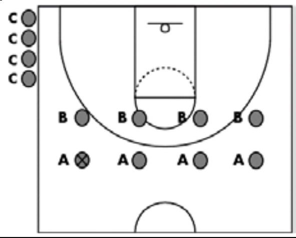
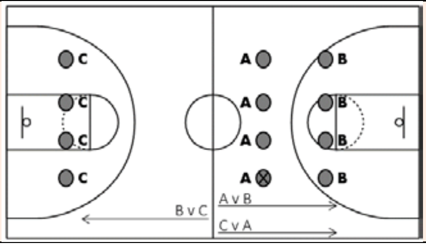
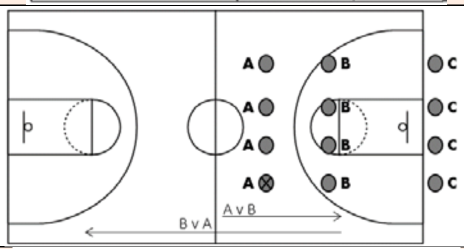
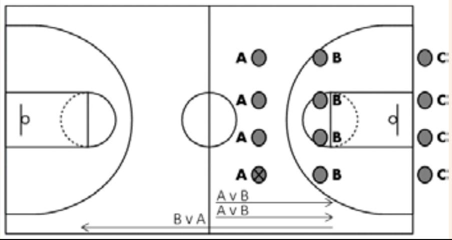
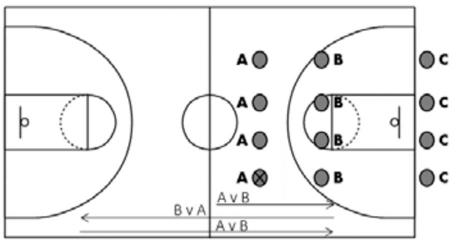
3v3	**Full court**	**3v3-3v3**	Players A attack to players B on half court and will defend players B on transition defense. When A versus B is finished, C and D replace A and B. Next set teams change roles (offense/defense). Rotation work-to-rest ratio: 1:1.	
3v3	**Full court**	**3v3-3v3-3v3**	Players A attack to players B on half court and will defend players B on transition defense. After Bs fastbreak, As will counteraatack Bs once more and Bs will do the transition defense. When A versus B is finished, C and D replace A and B. Next set teams change roles (offense/defense). Rotation work-to-rest ratio: 1:1.	
4v4	**Half court**	**4v4 (half court)**	Players A attack to players B. When the play is over, players B go to rest, players C get in as attackers and players A stay as defenders. Rotation: Offense (A) → Defense (B) → Rest (C). Rotation work-to-rest ratio: 2:1.	
4v4	**Half court**	**4v4v4**	Players A attack to players B in half court. Players B then attack players C, and A rest. Then, players A start the rotation all over again. Usually the duration of the set is based on time (e.g. 3-to-6 minutes), or on a certain number of attacks.	
4v4	**Full court**	**4v4-4v4**	Players A attack to players B on half court and will defend players B on transition defense. When A versus B is finished, players A stay as defenders and players C get in as attackers. Rotation: Starting in Offense → Starting in Defense → Rest. Rotation work-to-rest ratio: 2:1.	
4v4	**Full court**	**2x(4v4)-4v4**	Players A attack to players B on half court two straight offenses and afterwards defend players B on transition defense. When A versus B is finished, players A stay as defenders and players C get in as attackers. Rotation: Starting in Offense → Starting in Defense → Rest. Rotation work-to-rest ratio: 2:1.	
4v4	**Full court**	**4v4-4v4-4v4**	Players A attack to players B on half court and will defend players B on transition defense. After Bs fastbreak, As will counteraatack Bs once more and Bs will do the transition defense. When A versus B is finished, players A stay as defenders and players C get in as attackers. Rotation: Starting in Offense → Starting in Defense → Rest. Rotation work-to-rest ratio: 2:1.	

Table 1. Continued.

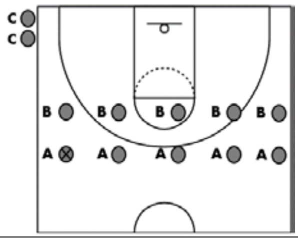
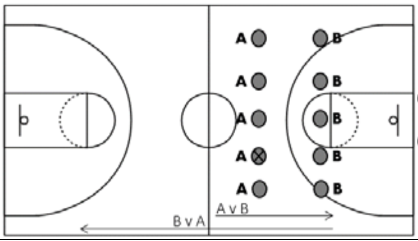
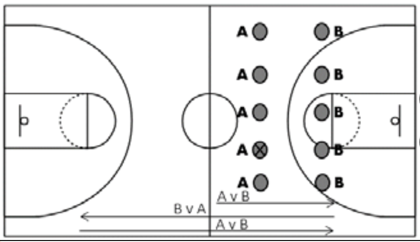
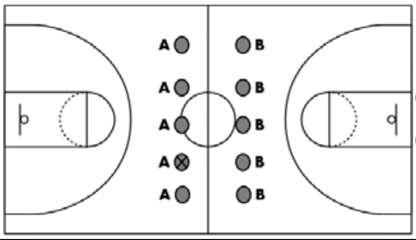
5v5	**Half court**	**5v5 (half court)**	Players A attack to players B. The resting time between sets will depend on coach explanations.	
5v5	**Full court**	**5v5-5v5**	Players A attack to players B on half court and will defend players B on transition defense. When A versus B is finished, the resting time between sets will depend on coach explanations.	
5v5	**Full court**	**5v5-5v5-5v5**	Players A attack to players B on half court and will defend players B on transition defense. After Bs fastbreak, As will counteraatack Bs once more and Bs will do the transition defense. When A versus B is finished, the resting time between sets will depend on coach explanations.	
5v5	**Full court**	**5v5 Scrimmage**	5 on 5 game simulation. Usually the duration of the set is based on time (e.g. 3, 5, 6, 10 minutes).	

Table 2. Descriptive AL/min. Differences in means (%) ± 90% Confidence Limits and uncertainty in the true differences. All players pooled.

	Confrontation format (mean±SD)					
Court	**2v2 (n = 22)**	**3v3 (n = 42)**	**4v4 (n = 42)**	**5v5 (n = 42)**	**Difference in means (%); ±90% CL**	**Uncertainty in the true differences**
Full	14.6±2.8	**18.7±4.1**	13.8±2.5	**17.9±4.6**	a) -31.1; ±12.7	most likely
					b) 9.7; ±5.6	likely
					c) -29.3; ±10.6	most likely
					d) 25.9; ±4.2	most likely
					e) 4.2; ±6.2	possibly
					f) -29.5; ±7.3	most likely
	2v2 (n = 40)	**3v3 (n = 16)**	**4v4 (n = 30)**	**5v5 (n = 42)**		
Half	12.7±2.7	10.9±1.8	10.8±2.3	12.0±5.6	a) 15.9; ±13.7	Likely
					b) 13.5; ±9.8	Likely
					c) 9.4; ±10.0	Likely
					d) 3.1; ±9.6	Unclear
					e) -3.5; ±20.9	Unclear
					f) -7.0; ±15.8	Unclear

Differences in means ((%); ±90% CL) are identified as: a) 2v2-3v3; b) 2v2-4v4; c) 2v2-5v5; d) 3v3-4v4; e) 3v3-5v5; f) 4v4-5v5.

Discussion

The aim of this research was to objectively quantify the workload using microtechnology (i.e., accelerometers) during basketball-specific training drills, according to different confrontation formats, and court size, in professional male basketball players. Our results revealed that full-court 3v3 and 5v5 have the highest physical demand (external load) compared to other traditional balanced basketball drills (2v2 and 4v4). Moreover, visual inspections in the descriptive analysis by playing position showed that guards reached the highest acceleration load results, irrespective the drill performed.

The present findings confirm previous results reported by Montgomery et al. (2010) with junior basketball players. Furthermore, similar conclusions were reached by our group when we analysed drills in an elite basketball team through time motion analysis (Torres-Ronda et al., 2015). Consistently with previous studies, 3v3 full-court drill seems to be a good drill to develop a higher 'game pace' (intensity) through increased frequency of movements, due to a smaller number of players on the court (Castagna et al., 2011, Torres-Ronda et al., 2015). Our data, however, did not show higher acceleration loads during full-court 2v2 as previous research did (Klusemann et al., 2012). This could be explained because of the drill design. In this regard, we have to take into account that within any drill design we can find two differentiated resting periods: intra-set pauses and inter-set pauses. Intra-set pauses refer to the time that the drill design allows to the player to rest within a set. Inter-set pauses refer to the time that the coaches give to the player to rest between different sets of the same exercise. These pauses, which determine the work-to-rest ratio, will affect both the total and the relative load or intensity. In Table 1, one can see the particularities on the design of the 2v2 exercises analysed. The two of them performed on full court have fairly long intra-set pauses, which may lead to lower average relative loads (lower work-to-rest-ratio). Thus, when thinking on drills' load and intensity, not only the confrontation format (1v1, 2v2, 3v3, 4v4, or 5v5) nor the space (half court, full court) have to be considered, but also the rotations and the subsequent intra- and inter- set pauses. In this regard, it is necessary to remind the reader that the research group did not interfere with the team routine throughout the data collection.

When we considered the drills on half-court, 2v2 and 5v5 showed the highest acceleration loads. Taking into account that in this study 1v1 drills were not analysed because they were not included over the data sampling period, having the 2v2 as the drill with higher acceleration load matches with the small-sided game principle that states the relationship between having a fewer number of players involved in a drill and a higher intensity (Castagna et al., 2011). Regarding half-court 5v5, a possible explanation for its high $AL \cdot min^{-1}$ could be its ecological validity, since the cognitive and physical requirements are closer to an actual basketball game (Reilly et al., 2009), as well as it may help players to maintain higher levels of motivation in comparison with less specific training scenarios.

In our exploratory data by playing position, our descriptive results showed higher acceleration loads for point-guards. These results would match two logical principles: 1) the smaller the player, the lower the body mass, and the easier to accelerate with less applied force (force = mass $\cdot$ acceleration; acceleration = force $\cdot$ mass^{-1}). In this regard, it seems reasonable to use a scaling factor such as body mass or body mass index to minimize those differences between players, and to obtain an individualized external load; and 2) the tactical principles of basketball usually imply that playing zones for big players are more reduced than the ones for small players, meaning that small players usually have to cover more distance per play or possession for tactical reasons. As previously reported in other team sports such as Australian Football, the identification of position-specific acceleration profiles would assist coaches and staff members, as well as sports scientist, to develop position-specific dependent drills aimed to improve players conditioning (Varley et al., 2013).

Previous research reported that internal training load model (i.e. based on physiological variables) measures largely different than the accelerometer-based training load model in basketball players (Scanlan et al., 2014). Scanlan's research group suggested to include the use of accelerometer-derived measures in team sports, such as basketball, in order to achieve a more integrative and ecological picture of the workloads. From a practical point of view, using accelerometer technology in official competitions, currently not allowed in top-level competitions (e.g., the NBA League in the US, or the ACB League in Spain), may allow a more precise control of the individual external load per game, which represents our main reference for training prescription, and our final goal to be improved. Indeed, the game-reference would have two main practicalities: a) from a periodization point of view, it would be useful to know whether the practice workload has been below or above game-reference loads, and to periodize the training cycles (e.g., microcycles) according to individual needs (e.g. recovery or extra-workouts); and b), from a return-to-play perspective, it would be useful to periodize the workload progression to achieve the individual game-reference, before the injury occurred. Thereby, if the player is able to cope with its game loads during practice (e.g., during 5v5 full-court or scrimmage), in conjunction with information from other training tasks, it would mean he/she is physically ready to compete. Furthermore, using accelerometer technology systematically, in every practice session, may let us to build a drill database, which could be used by coaches and staff to prescribe drills knowing ahead of time which exercise may suit different training workloads. All this information from competition and workouts could simplify, and objectivize, the way we periodize our training cycles (e.g., practice sessions, microcycles) with individualized data.

Further research should investigate whether data obtained from wearable microtechnology (i.e., accelerometers, gyroscopes, and magnetometers) can be used to classify and quantify basketball activities, such as running activities, jumps, and potential asymmetries (Wundersitz et al., 2015). A limitation of external load quantification through accelerometers is the lack of information regarding isometric muscle contractions or the physical effort during static fights/contacts between players; for instance, low post situations could imply low acceleration loads but high physical expenditure due to isometric contraction or almost-static movements.

A potential limitation of the current study is the sample size; however, subjects were recruited from the Spanish 1st Division (ACB League), which constitutes a small exclusive convenience sample. The study results are unique in professional basketball players of this level, and it should be taken into account that the training procedures were not modified in any way during the present investigation.

Conclusion

In conclusion, the results of this study revealed full-court 3v3 and 5v5 showed the highest external workload, measured by tri-axial accelerometer. According to playing position, and commonly related to body size, the smaller the player, the higher the acceleration load, which could be explained by the fact that the lower the body mass, the easier to accelerate with less applied force. Further studies with a larger sample are required to verify these findings. Systematic monitoring of the physical demands during both training and competition would likely improve basketball drill description and classification, as well as a more accurate training periodization.

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Key points

- Full-court 3v3 and 5v5 showed the highest external workload.
- The smaller the player, the higher the raw acceleration load.
- Systematic monitoring during training and competition would likely improve training prescription and periodization.

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