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LOAD MONITORING AND MANAGEMENT IN ELITE BASKETBALL

Doctoral thesis

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‘Travel and change of place impart new vigor to the mind.’

Seneca

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CHAPTER 1

INTRODUCTION

Basketball is one of the most popular team sports in the world. Several competitions are well recognized regarding the quality of players and teams where National Basketball Association (NBA) and NCAA are the most famous competitions in the USA, followed by two competitions on the European soil – Euroleague and Eurocup. In the last decade, Spain has been a leading European country with number of teams participating in the most elite basketball competitions in Europe, where in the season 2017/2018, five teams (FC Barcelona Lassa, Baskonia, Unicaja Malaga, Real Madrid and Valencia Basket) took place in Euroleague, three teams (Morabanc Andorra, RETABet Bilbao Basket and Herbalife Gran Canaria) joined the Eurocup and three teams (Movistar Estudiantes, Iberostar Tenerife and UCAM Murcia) are competing in Basketball Champions League. Therefore, it could be concluded that the greatest challenge in Europe could be expected for Spanish teams who compete for Euroleague trophy, therefore having two of the most demanding competitions to play concurrently (Euroleague and domestic ACB Liga Endesa).

Knowledge of basic and specific endurance development and strength training has been well recognized in basketball for many years where physical conditioning coaches have been important members of coaching staff, especially during the pre-seasonal training camps where gains in physical qualities are of utmost importance. However, novelty research on importance of players' recovery, load monitoring, and travel-management has increased interest of clubs' owners, sport directors and head coaches where it is becoming very obvious that in modern congested fixture, where teams play around 80 games per season (2-3 games per week), scientific and professional knowledge is immensely important for performance improvements and overall teams' success. High level of competition and growth of knowledge in the field of sport science allowed sport coaches, performance specialists and physical conditioning experts to improve and apply their knowledge in challenging seasons of elite basketball teams.

One of the clubs that has recognized the importance of comprehensive knowledge in physical conditioning and high-performance is a Spanish club Saski Baskonia S.A.D. from Vitoria-Gasteiz where I was hired as a physical conditioning coach in the summer of 2016. Besides the regular physical conditioning work, my role in the team is to monitor training and game loads, recovery and well-being of the players. Moreover, travel management and nutrition on the road are also major part of my responsibilities. In order to upgrade the system of load monitoring, the club has provided micro-technology. Having the micro-technology available for daily use, one of the most important tasks was to establish comprehensive system of load monitoring, together with Igor Jukić (head of performance) and Julen Castellano (sport scientist).

During the 2016 pre-seasonal training camp data derived from micro-technology was well analyzed regarding the training and game parameters, various training drills demands, playing positions differences etc. as previous research in the field of elite basketball basically did not offer any valuable information about the use and application of micro-technology. Moreover, training and game load data was related to other methods of load monitoring, especially internal subjective markers such as rating of perceived exertion and session rating of perceived exertion (i.e. RPE and sRPE). By the end of 2016, with the background in elite team sports such as rugby, Australian football and soccer, the system of load monitoring and application of collected data was established for periodization and training design. This creative practical work has encouraged me to apply for PhD studies at the University of Basque Country at the Faculty of Physical Activity and Sport Sciences in Vitoria-Gasteiz.

After a systematic revision of the scholar literature about load monitoring in basketball, we detected lack of information not only regarding the use of micro-technology but also insufficient information about external/internal weekly training loads, short-term tapering models and training games (such as small-sided games) among elite players. Eventually, the revision gave us directions to prepare the whole PhD project. The main intention of this project was to investigate team practices and match-play, in order to contribute to scientific field of elite basketball, especially due to the fact that only paucity of research has focused on use of modern micro-technology. The whole project was divided into four parts, all of them around the same topic: external and internal load monitoring (Figure 1).

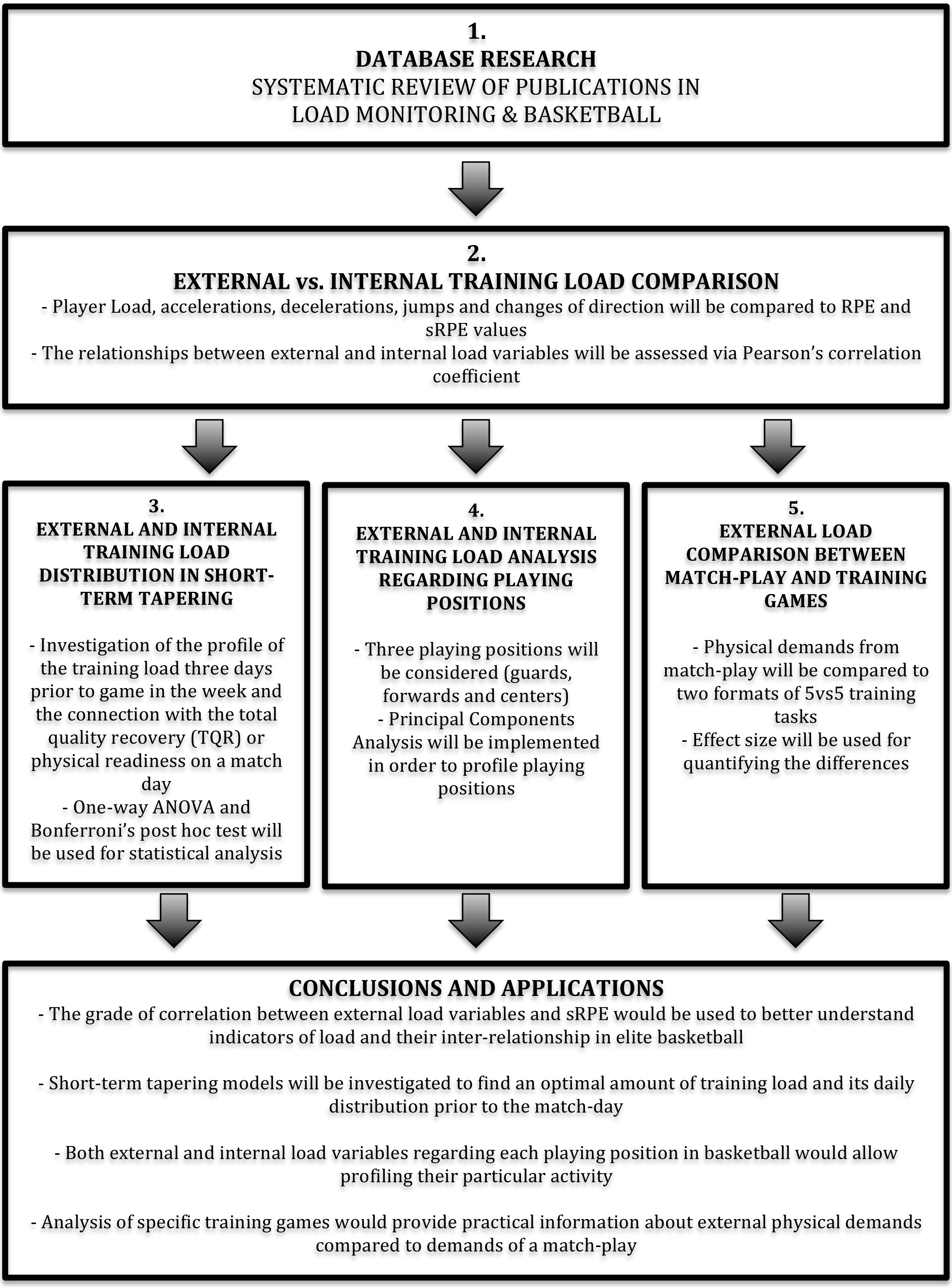
The first focus was on the analysis of relationship between various external (e.g. Player Load, accelerations, decelerations, jumps, changes of direction) and two internal training load measures (e.g. RPE and sRPE). Even though these two methods are of different construct, their complementary use is advised. In practice, it is important to understand the relationship between training dose (e.g. Player Load) and internal response (i.e. RPE and sRPE).

The second part also investigated both external and internal load measures but considering the training proximity to the match day and application of short-term tapering. In this study, for the period of three days prior to the game, progressive decrease in training load was investigated. Moreover, use of Total Quality of Recovery (TQR) questionnaire was presented as a marker of physical condition on the match day. Finally, the relationship between training load and TQR scores could help to understand the connection between accumulated training loads and players' physical response on a match day.

The third part has been focused on the external and internal training load analysis between three playing positions (i.e. guards, forwards and centers). In team sports, it is well known that different playing position elicit particular physical and physiological responses in both game and training settings, but still there is a lack of information using micro-technology. Therefore, data presented in this study could help coaches to better understand both external and internal training demands of each playing position in elite basketball.

The forth part aimed to compare external load demands between match-play and two training games used in team trainings. Match-play was recorded during pre-seasonal training camp and compared with regular-stop and no-stop training games. The results from this study can help coaches who are looking for specific constraints in training drills that can elicit similar or greater physical demands as in basketball game.

Figure 1. Doctoral project scheme.



CHAPTER 2

LOAD MONITORING IN BASKETBALL

The competition schedule for professional Spanish teams who compete in Euroleague is very demanding where they play at least two, sometimes even three, games per week, including the domestic, ACB games. However, in order to compete in the best way, teams need to devote time for practice. Thus, it is immensely important to find appropriate training stimuli (i.e. the dose) that facilitate optimal individual response for competition. The team settings during competitive season require use of various training drills for enhanced individual conditioning and improved teamwork. For that reason, training loads need to be well planned and monitored in accordance to both team and individual needs. Adequate load management in team sports could show less number of injuries (Akenhad & Nassis, 2015; Budgett, 1998; Drew & Finch, 2016; Gabbett, 2004; Gabbett, 2016; Halson, 2014; Putlur et al., 2004; Urhausen & Kindermann, 2002; Weiss et al., 2017) and improved performance (Akenhad & Nassis, 2015; Budgett, 1998; Drew & Finch, 2016; Foster et al., 1996; Gabbett, 2004; Gabbett, 2016; Putlur et al., 2004; Urhausen & Kindermann, 2002). Moreover, Coutts et al. (2004) suggest that training load monitoring serves as a stable platform for optimal periodization and gives a coach better understanding of individual tolerance to training since it is influenced by many factors such as fitness level, previous experience, age, nutrition and recovery practices.

Therefore, it is crucial to employ an individual approach in setting training loads. There are two main reasons for that. The first one is based on finding that the right amount of acute and chronic training load potentially leads to positive physical changes (Gabbett, 2016), while the second reason is based on fixture congestion and inconsistent playing time, where players accumulate different amounts of game load on weekly basis. The latter is of paramount importance, since, in some weeks, top-level players might participate in an equal number of games as training sessions. With that in mind, coaches are able to determine training loads for each player on the team in order to prevent overloading and injuries. However, in case of injuries, monitoring of load progression is one of the most important factors for safe return-to-play process. In order to establish an effective load monitoring system in basketball team it is important to consider all training and game activities. The team basketball sessions are just one part of load monitoring system where coaches need to implement other training activities such as individual basketball sessions, strength trainings, basic conditioning trainings and active recovery sessions to get the total workload values for each player on the team. Furthermore, playing time in the season of professional basketball player can never be well estimated since it largely depends on the coaches' tactical settings before and during the game (i.e. substitutions). Therefore, after each game physical conditioning coaches, performance specialists and/or sport scientists need to consider the impact of the game load on player's physical and mental status and deliver optimal recovery and training activities for the following days until the next game. Moreover, when tracking the total load of each player on the team, strength coaches could be more aware of the potential overload and react accordingly by talking to head coaches, especially about playing time in the following basketball trainings and games.

For all aforementioned reasons, every sport scientist/performance specialist should devote time to investigate each training drill that head coach applies, as well as demands of (friendly) games. With the use of modern micro-technologies, very quick turnaround of training/game data is possible. With accumulated data from games, coaches are able to design various drills that can replicate game demands and establish adequate amount of training load. Additionally, one of the greatest benefits of its use is the fact that collected data from friendly games does not represent only the team and playing positions demands but demands of every player what finally enables individual profiling in team-training settings. Therefore, special focus in investigations in training should be on drills that have the highest impact on success in games (e.g. 4vs4, 5vs4, 5vs5 etc.). Additionally, scientific literature should be an important asset when analyzing and comparing training and game loads.

To sum up, here are the key reasons why monitoring of load should be an important part when working with (elite) basketball teams:

- Use of micro-technology in (friendly) games provides information about individual load and physical demands
- Use of micro-technology gives information if training drills are replicating game demands
- Monitoring of load can be used for general periodization and planning of adequate training load
- Monitoring of load provides database to establish acute:chronic load relationship that protects players from overload and injuries
- In case of any injury, individual load progression monitoring serves as a safe return-to-play process

2.1. BACKGROUND OF LOAD MONITORING – SYSTEMATIC PAPER REVISION

In the search for publication about load monitoring in basketball two electronic databases were used, PubMed and Web of Knowledge (WOK), prior to January 15th 2018. The following search terms were used in the papers' titles: 'basketball' was associated with the terms 'training' or 'games' or 'load' or 'demands' or 'GPS' or 'accelerometry', or 'physical' or 'physiological' or 'time-motion' or 'monitoring' or 'activity' or 'small-sided games' or 'RPE' or 'lactate' or 'heart rate'. The database search was limited to articles in English and Spanish without limitations in year-of-publishing. Study participants included players of both genders and all playing levels. Studies that considered other team sports, referees, basic physiology testing in laboratory, wheelchair or recreational basketball, were excluded. On the following page, figure 2 presents a systematic review flow diagram. Finally, 78 publications from basketball were included in this project (complete list is presented in Appendix 1).

Figure 2. Systematic review flow diagram.

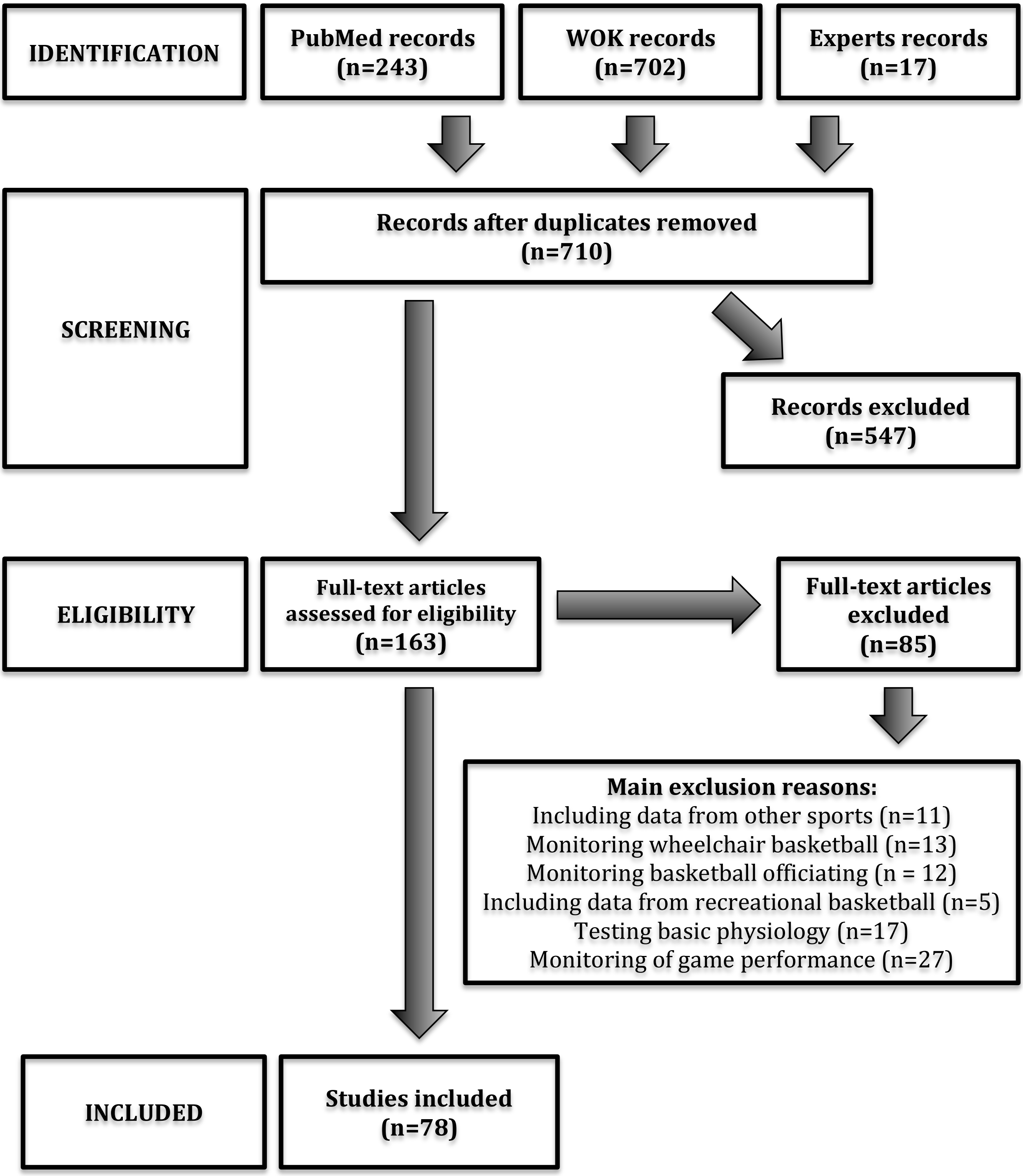
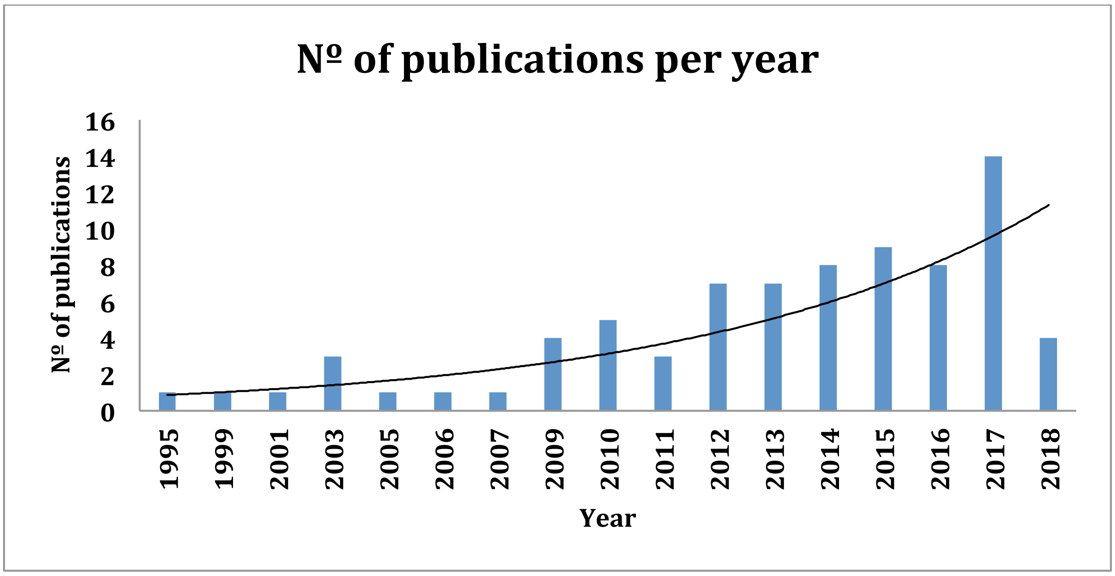


Figure 3 presents the current 78 publications in basketball load monitoring by the year of publishing. It can be observed that in recent years, monitoring of load in basketball has gained greater scientific interest.

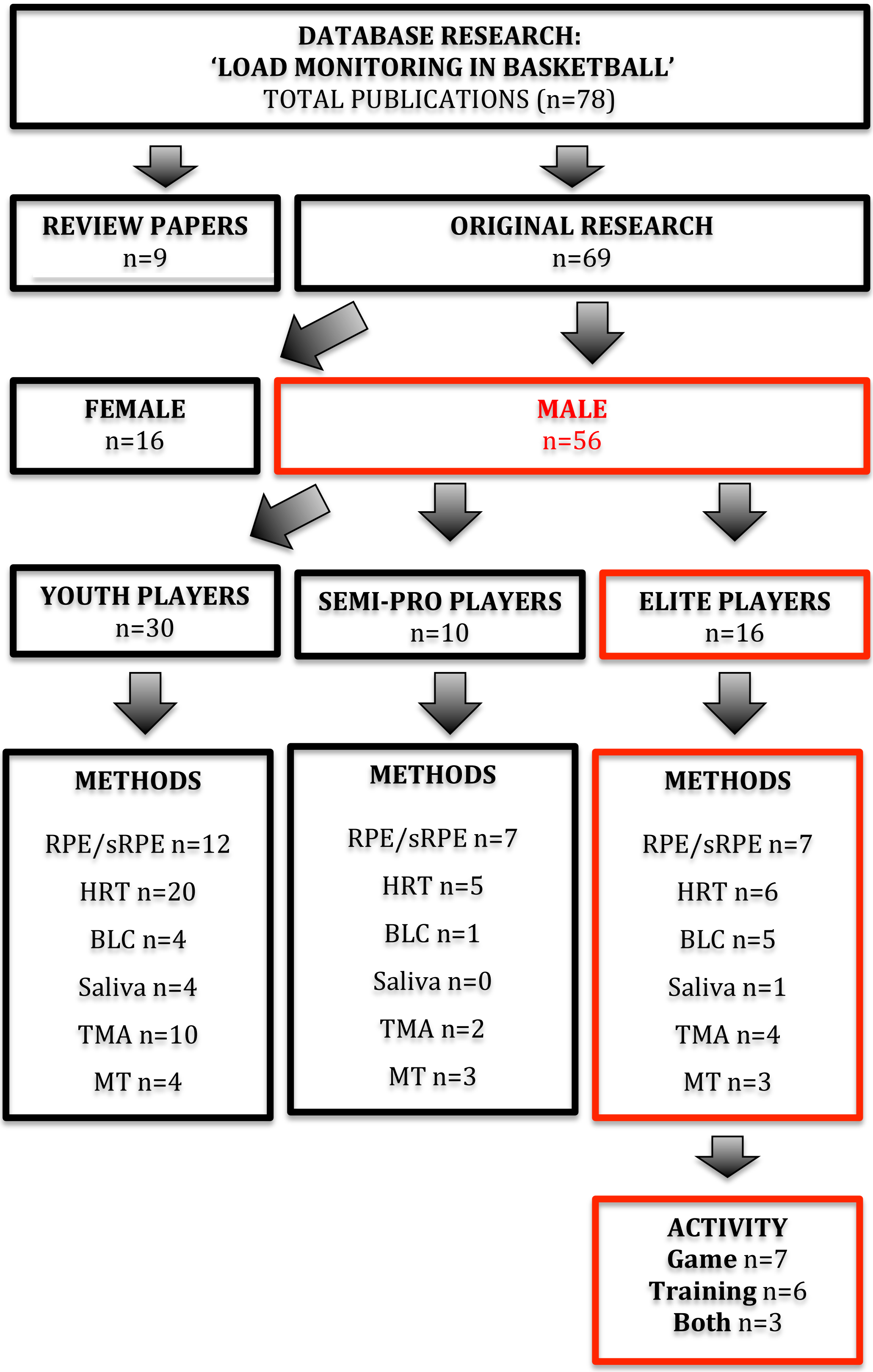
Figure 3. Load monitoring publications in basketball by year.



Load monitoring in elite basketball training, as in other team sports, has been mainly focused on use of technologies such as heart rate telemetry (Conte et al., 2016, Torres-Ronda et al., 2016), measurement of blood parameters such as blood lactate concentration (Castagna et al., 2011; Marcelino et al., 2016), testosterone and cortisol (Hoffman et al., 1999; Schelling et al., 2015) and creatine kinase (Hoffman et al., 1999; Schelling et al., 2015) and rating of perceived exertion (RPE) (Arruda et al., 2014; Freitas et al., 2013). However, all of aforementioned methods consider only internal (both objective and subjective) players' responses with lack of external (objective) workload quantification. In order to examine external training load (eTL) parameters, coaches have been using multi-camera technology and lately, micro-technologies (i.e. global positioning systems and inertial sensors). The major part of external load research in basketball has been based on video analysis (Abdelkrim et al., 2010b; Delextrat et al., 2015; Klusemann et al., 2013; Scanlan et al., 2011) while only paucity of research has been focused on micro-technology (Aoki et al., 2016; Fox et al., 2018; Leite et al., 2013; Montgomery et al., 2010; Puente et al., 2016; Scanlan et al., 2014; Schelling & Torres, 2016; Staunton et al., 2017). The use of micro-technology allows coaches to record events related to changes in velocity (e.g. accelerations, decelerations and changes of directions) and events derived from the inertial sensors/accelerometers (Buchheit & Simpson, 2016). It is consisted of tri-axial accelerometer, gyroscope and magnetometer located in a small device attached to players' body via custom-made shirt. These sensors allow inertial movement analysis (IMA) and registration of different data about physical effort (i.e. Player/Body Load, accelerations, decelerations, jumps and changes of direction). The micro-sensor devices can capture the changes in players' movements instantly, what makes them user-friendlier to other time-consuming technologies such as time-motion analysis. Moreover, the micro-technology supports the use of HR monitors and provides information about physiological stress elicited in training drills. The complementary use of HR monitors and micro-sensors could be the most useful practical method as potential limitation of accelerometers is lack of information regarding physical effort in isometric muscle contractions during static movements between players, such as low-post play situations.

On the following page, figure 4 distributes all 78 publications by gender, playing level and methods used to monitor load. As it can be observed by highlighted part (red colour), the main focus of the classification is on the elite-level publications in male basketball. In the end, by presenting all of the methods that are used to monitor load, the main idea is to show that the elite-level of basketball clearly lacks scientific research and publications, especially when micro-technologies are used.

Figure 4. Load monitoring publications in basketball by gender, playing level and methods used.



Note: n means number, RPE is rating of perceived exertion, sRPE is session RPE, HRT is heart rate telemetry, BLC is blood lactate concentration, TMA is time-motion analysis, MT is micro-technology.

2.2. MONITORING OF LOAD IN YOUTH AND SEMI-PROFFESIONAL BASKETBALL GAMES AND TRAINING

Monitoring and analysis of basketball games explain the physical, physiological, technical and tactical demands for each player on the team during competition. With this data, coaches are able to better understand individual patterns and design effective training programs with various training drills. As an example of very useful and practical investigation we can mention study of Delextrat and Martinez (2014), which showed that greater improvements in aerobic capacity and technical skills can be obtained by using small-sided games during the season, rather than high-intensity interval training.

In the study on junior basketball players, Abdelkrim et al. (2010a) found that during the game players covered 7558 ± 575 m where sprinting accounted for 763 ± 169 m and high-speed shuffling for 218 ± 117 m. The overall covered distances in the first and the second halves were not significantly different, but there was an evident 16% decrease in the distance of high intensity activities. Mean work-to-rest ratio for the players was 1:3.6 with a higher value recorded in the first half compared to the second (1:3.2 vs. 1:4.1).

When considering playing positions, various studies (Abdelkrim et al., 2007, Ben Abdelkrim et al., 2009, Hulka et al., 2013, Rodriguez-Alonso et al., 2003, Scanlan et al., 2012 and 2015, Vaquera Jimenez et al., 2008) that analyzed physical and physiological demands in games found significant differences between guards, forwards and centers. Additionally, it is important to note that monitoring of demands in basketball showed differences between genders (Abdelkrim et al., 2007, 2010a and 2010b; Matthew & Delextrat, 2009; Scanlan et al., 2015) as well as among elite, semi-professional and junior male players (Abdelkrim et al., 2007; Abdelkrim et al, 2010a; Abdelkrim et al, 2010b; Ben Abdelkrim et al., 2009; McInnes et al., 1995; Narazaki et al., 2009; Rodriguez-Alonso et al., 2003; Scanlan et al., 2011, 2012 and 2015).

With aforementioned data, coaches have better insight in basketball game demands and therefore more accurate information for designing of training plans. Regarding wearable technologies (e.g. micro-technology and heart rate monitors), the rules of domestic, regional and European competitions until current date unfortunately do not allow teams to use it during official games like it is common in other team sports (Gabbett et al., 2012, Suarez-Arrones et al., 2015, Wisbey et al., 2010). In future research, it will be important to collect these data with permission, as these data will be of great importance to all coaches who use micro-technology in their clubs.

When monitoring basketball trainings, scientists and coaches are able to compare it to demands of game and objectively conclude if training goals have been well accomplished (Mujika, 2013). Therefore, it is very important to analyze each training session demands, especially small-sided and 5vs5 games where each player could have similar, but yet different amount of physical demands and total workload. Various authors (Castagna et al., 2011; Clemente et al., 2017; Conte et al., 2016; Conte et al., 2017; Torres-Ronda et al., 2016) state that constraints such as number of players, court size, work-to-rest ratios and coach intervention are the key factors influencing cardiovascular responses and time-motion demands during basketball training sessions.

Conte et al. (2016) found that 2vs2 game elicited higher load demands with respect to 4vs4. Moreover, Delextrat and Kraeim (2013) suggested that 2vs2 drills elicit greater heart rate response than 3vs3, and therefore should be prioritized for aerobic conditioning. In this line, both Klusemann et al. (2012) and Castagna et al. (2011) found that 2vs2 drill showed the greatest physiological response for improving aerobic and anaerobic fitness. Sampaiao et al. (2009) showed that 3vs3 game has a greater physiological load based on heart rate compared to 4vs4 format. Similar finding were found it the study of Castagna et al. (2011), that showed that 3vs3 format induces higher cardiovascular response as well as a higher lactate concentration compared to 5vs5. Finally, Conte et al. (2015) found that no-dribble game drill elicits greater physiological demand than the regular drills.

2.3. LOAD MONITORING IN ELITE BASKETBALL

As the major focus of this PhD project is about elite level basketball, in the following text we will shortly discuss current publications of elite players. As it is presented in Figure 3, there are 16 publications from which seven papers investigated game data (Caparros et al., 2017, McInnes et el., 1995, Moreira et al., 2012, Puente et al., 2016, Scanlan et al., 2011, Schelling et al. and 2015), six training demands (Aoki et al., 2016, Freitas et al., 2012, Hoffman et al., 1999, Ostojic et el., 2006, Schelling & Torres, 2016, Weiss et al., 2017) and three game and training loads together (Leite et al., 2012, Manzi et al., 2010, Torres-Ronda et al., 2016).

Regarding game analysis, McInnes et al. (1995) provided thorough time-motion analysis of elite basketball game where additional monitoring of heart rate showed mean values of 169 ±9 beats per minute (89±2% HRpeak) and blood lactate concentration of 6.8 ±2.8 mmol. Moreira et al. (2012) investigated official and simulated games where official games showed greater internal load via both sRPE and cortisol levels. Puente et al. (2016) found similar internal load as McInnes et al. (1995) regarding mean HR values, 89.8 ±4.4% of HRpeak. Additionally, 15Hz GPS accelerometers showed differences between playing positions where centers performed a lower number of accelerations and decelerations than guards and forwards. Torres-Ronda et al. (2016) compared friendly games (FGs) to various training drills where it was found that FGs elicit the greatest internal load via HR. However, average HR value in the game was 158±10 beats per minute (80% HRpeak) what is almost 10% less than in findings of McInnes et al (1995) and Puente et al. (2016). Additionally, time-motion analysis showed that 1vs1 training drill are to be the most demanding of all with 53±8 movements per minute, including the results from FGs (33±7 movements per minute). Finally, Scanlan et al. (2011) investigated differences between elite and sub-elite competition demands where time-motion analysis showed that elite players performed significantly more total movement changes and experienced greater activity workloads. Interesting finding was that sub-elite players performed significantly more sprinting activities.

Leite et al. (2012) and Manzi et al. (2010) have focused on weekly load distributions during competitive phase. In the study of Leite et al. (2012), unusual internal load method was used, the SPI scale (self-perceived intensity scale). However, this study provides useful information regarding training monotony and strain, as well as the medicine ball throw evaluation as a marker of physical tiredness. Manzi et al. (2010) used RPE and HR telemetry methods to profile weekly training loads where it was concluded that sRPE method is a valid and practical method to assess individual training loads. Moreover, aforementioned study provides very useful information regarding daily and weekly training loads (i.e. sRPE) in elite basketball competitive phase. Aoki et al. (2016) presented for the first time accelerometry-derived external training loads, together with sRPE and HR internal load values. The study showed that RPE, peak acceleration and mechanical load (i.e. accelerations and decelerations) increased from pre- to in-season period, probably due to intensification of trainings to mimic real competition demands. On the other hand, sRPE decreased from pre- to in-season, clearly due to reduced training time. Additionally, matching values of sRPE and HR once again confirmed that these markers are of similar construct. Finally, this study presents valuable descriptive information about both external and internal load parameters from pre- and in-season phase. Study of Schelling and Torres (2016) focused on various training drills with use of tri-axial accelerometers. The main finding was, as it was presented in previous chapter, that full-court 3vs3 and 5vs5 drills elicited the highest external workload.

Three papers (Caparros et al., 2017, Freitas et al., 2012, Weiss et al., 2017) have focused solely on injury risk, stress level and infections. Capparos et al. (2017) showed that players with less than 16 accelerations and accumulated distance of 2 miles per game have higher risk for injury in the games. Freitas et al. (2012) observed that decrease in internal training load during competitive phase increased severity of upper-respiratory tract infections when weekly training load was decreased. Weiss et al. (2017) concluded that players with 1-1.49 acute;chronic (A:C) ratio have less injury risk compared to players with A:C ratio lower than 1 or greater than 1.5.

Finally, three papers (Hoffman et al., 1999, Schelling et al., 2014, Schelling et al., 2015) investigated blood biomarkers as a feedback on training and competition demands. Hoffman et al. (1999) investigated 28-day training camp and changes in various blood parameters where it was concluded that training camp in overall might not cause significant disturbances in hormonal or biochemical stress markers. Two studies of Schelling et al. (2014 and 2015) showed that hormonal and biochemical markers such as testosterone (TT), cortisol (C) and creatine kinase (CK) are very useful markers for tracking players' stress/recovery states. It is important to note that aforementioned parameters are race-, playing position-, playing time- and season phase-dependent what implies that individualization in results interpretation is of utmost priority.

2.4. CONCLUSION

All of the above-mentioned findings play an important role in scientific research of elite, semi-proffesional and youth men's basketball. However, scientists and practitioners should be aware of several facts such as follows: 1) there is only one paper (Manzi et al., 2010) that clearly demonstrates distribution of daily training loads within a microcycle, but it is internal-load based, 2) only several papers presented accumulated weekly loads, but mainly sRPE-based, 3) there is no research that investigates relationship between external load parameters (i.e. accelerometer-based variables) and internal load (e.g. sRPE or HR), 4) there is only one paper that presented external load variables from basketball game and focuses on playing position differences (Puente et al., 2016), 5) there is only one paper (Schelling & Torres, 2016) that investigates playing position differences based on external variables in training drills, 6) when accelerometer-derived data were presented, only one or two variables were presented (e.g. acceleration load per minute, mechanical load, peak acceleration), there is no complete information regarding all movements that can be observed (e.g. accelerations, decelerations, changes of direction, jumps), 7) there is no research that presents daily distribution of external load within a competitive microcycle. These facts could serve as guidelines for future research in elite basketball.

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CHAPTER 3

RESEARCH GOALS

The objective of this project was to investigate team practices and match-play in elite basketball team, where main focus was on external and internal training/game loads. Additionally, author's desire was to contribute to scientific field of elite basketball, especially due to the fact that only paucity of research has focused on use of modern micro-technology to measure external load and its connection with internal responses.

This general objective will be addressed in four specific objectives, explained in the following points:

- Describing the correlation among external training load variables, and external and internal training load variables.

  There is no evidence of correlation between these external demands and their internal responses applied in elite basketball setting. The results of these connections among external and internal variables could support coaches in the selection of key variables in successful and effective load monitoring in basketball, avoiding redundant information when assessing the training load using different variables.

- Comparing the load of the training sessions leading up to the first match of the week, considering both external training load and internal training load parameters. Furthermore, the perception related to recovery status on the match day (via TQR questionnaire) was assessed. The assessment was used as the indicator in the selection of appropriate training load that secures enough recovery for players' well-being', while avoiding undesired overload and overtraining.

The findings of this study could help coaches setting appropriate level and intensity of accelerometry-derived training load in the days leading up to the match, as such data is currently unavailable in the literature.

- Investigation of the structure of interrelationships among the external and internal training session loads and determine how they vary among different positions.

  The potential application of results is focused on the identification of physical or external demand for each playing position, and it internal response, in order to establish a position-dependent profile.

- Comparing micro-sensor technology data in two types of 5vs5 training games with data recorded in match-play.

  The results of this study could help coaches in the selection of training drills and periodization of practices in elite basketball regarding thier similarity and/or difference in terms of physical demands.

CHAPTER 4

LOAD MONITORING SYSTEM IN TOP-LEVEL BASKETBALL TEAM: RELATIONSHIP BETWEEN EXTERNAL AND INTERNAL TRAINING LOAD

Abstract

The study aimed to describe and compare the external training load, monitored using microtechnology, with the internal training load, expressed as the session rating of perceived exertion (sRPE), in elite male basketball training sessions. Thirteen professional basketball players participated in this study (age=25.7±3.3 years; body height=199.2±10.7 cm; body mass=96.6±9.4 kg). All players belonged to the same team, competing in two leagues, ACB and the Euroleague, in the 2016/2017 season. The variables assessed within the external motion analysis included: Player Load (PL), acceleration and deceleration (ACC/DEC), jumps (JUMP), and changes of direction (CoD). The internal demands were registered using the sRPE method. Pearson product-moment correlations were used to determine relationships between the variables. A significant correlation was observed between the external load variables and sRPE (range r=0.71–0.93). Additionally, the sRPE variable showed a high correlation with the total PL, ACC, DEC, and CoD. The contrary was observed with respect to the relationship between sRPE and JUMP variables: the correlation was higher for the high band and lower for the total number of jumps. With respect to the external load variables, a stronger correlation was found between PL and the total number of ACC,

DEC and COD than the same variables within the high range. The only contrary finding was the correlation between PL and JUMP variables, which showed a stronger correlation for hJUMP. Tri-axial accelerometry technology and the sRPE method serve as valuable tools for monitoring the training load in basketball. Even though the two methods exhibit a strong correlation, some variation exists, likely due to frequent static movements (i.e. isometric muscle contractions) that accelerometers are not able to detect. Finally, it is suggested that both methods are to be used complementary, when possible, in order to design and control the training process as effectively as possible.

Keywords: team sport, training monitoring, accelerometry, sRPE, professional players

4.1. INTRODUCTION

Over the past few decades, basketball has been one of the leading team sports in the world, especially in the USA and Europe. Currently, the NBA teams in the United States compete in a single league, while the Euroleague teams simultaneously compete in the Euroleague and in local national or regional championships. Therefore, Euroleague teams play at least two, sometimes even three games per week. During the regular season, between October and April/May, Spanish teams that participate in the Euroleague play between 62 and 65 games in total, including the games in the Spanish King's Cup (i.e. Copa del Rey). Such a game schedule demands strenuous physical conditioning during the preparatory phase so that every player is able to withstand training and game activities during the competitive season. Therefore, detailed in-season strategies for controlling, maintaining and improving performance need to be established.

Apart from physical and mental recovery methods, adequate management of the training load (TL) is one of the most important tools for reducing injury risk (Soligard, Schwellnus, & Alonso, 2016). Successful training monitoring in team sports results in better performance (Akenhad & Nassis, 2015; Drew & Finch, 2016; Gabbett, 2004, 2016) and fewer injuries, especially non-contact and soft tissue injuries (Akenhad & Nassis, 2015; Drew & Finch, 2016; Gabbett, 2004, 2016; Halson, 2014). Furthermore, Coutts, Wallace and Slatery (2004) suggest that accurate monitoring of the training load gives the coach a better understanding of individual tolerance to training, as this is affected by many factors, such as player's fitness level, previous experience, age, nutrition and recovery practices, thus providing a solid basis for optimal training periodization. Lambert and Borresen (2010) explained the importance of training load monitoring by using the relationship between the training 'dose' and 'response'. In order to provide the best response (i.e., optimal improvement in performance), coaches need to find different methods to control and plan ideal psycho-physiological stress (i.e., training stimuli or the 'dose') for each athlete. In connection to this, external and internal training loads use different pathways and therefore need to be measured complementary. The external training load (eTL) represents the activities performed by athletes, that is, the dose performed (Impellizzeri, Rampinini, & Marcora, 2005), while the internal training load (iTL) represents the psycho-physiological response by the athlete that primarily takes the form of biochemical stress (Venrenterghem, Nedergaard, Robinson, & Drust, 2017). In team sports, the training load is mainly derived from team practices, whereas external load parameters are collectively defined. Consequently, internal responses to the external load could vary.

In a growing body of research, internal training load parameters have been measured using methods such as oxygen consumption (Castagna, Impellizzeri, Chaouachi, Abdelkrim, & Manzi, 2011), blood lactate measurement (Abdelkrim, et al., 2010; Castagna, et al., 2011; Marcelino, et al., 2016), heart rate monitoring (Aoki et al., 2016; Conte, Favero, Niederhausen, Capranica, & Tessitore, 2015, 2016; Klusemann, Pyne, Hopkins, & Drinkwater, 2013; Puente, Abian-Vicen, Areces, Lopez, & Del Coso, 2016; Torres-Ronda, et al., 2016) and, the very simple method of rating of perceived exertion (RPE) (Arruda et al., 2014; Leite et al., 2012; Manzi et al., 2010; Nunes et al., 2014; Scanlan, Wen, Tucker, Borges, & Dalbo, 2014). Foster et al. (2001) stated that the use of the session-RPE (sRPE) method might help coaches and athletes achieve their goals while minimizing undesired training outcomes and overtraining. Finally, as it was suggested by Lau et al. (2009), sRPE data collection and analysis can provide additional valuable information, such as training monotony (i.e., the measure of day-to-day training variability) and training strain (i.e., the measure of weekly TL and monotony).

External training load monitoring does not refer to a single system, since it can be based on tracking various load parameters, such as jumps, collisions, covered distance or lifted weights (Coutts, et al. 2004; Impellizzeri, et al., 2005; Wallace, Slattery, & Coutts, 2014). In basketball, the majority of external load research has been based on video analyses (Abdelkrim, et al., 2010; Delextrat, et al., 2015; Klusemann, et al., 2013), while only several investigators used GPS with accelerometry technology in friendly matches (Montgomery, Pyne, & Minahan, 2010; Puente, et al., 2016) and training sessions (Aoki, et al., 2016; Montgomery, et al., 2010; Scanlan, et al., 2014). The microtechnology used in devices, such as accelerometers, magnetometers and gyroscopes, can provide information related to changes in velocity (accelerations, decelerations and changes of directions) and other inertial-based events such as jumps, impacts, stride variables, etc. (Buchheit & Simpson, 2016). Previous investigations that analysed eTL involved youth or semi-professional basketball players (Montgomery et al., 2010; Scalan et al., 2014), or professionals in lower level leagues (National Brazilian League, Aoki, et al., 2016). Furthermore, the mentioned studies used only the PL variable to assess physical or external demands (i.e., eTL).

High numbers of physical variables used in micro-technology potentially make the analysis and application in practice difficult. Additionally, some of these variables are expected to present a high linear correlation (Casamichana, Castellano, Calleja-Gonzalez, San Roman, & Castagna, 2013), since they originate from similar or related dimension (e.g., acceleration-based variables). In order to provide a less complex scenario, practitioners should avoid redundancy and select only crucial variables in eTL monitoring.

Furthermore, to maintain an optimal connection between external and internal training load and to avoid players' maladaptations (i.e., over- or under-training), coaches need to be constantly aware of their relationship (Venrenterghem, et al., 2017). In connection to this, two studies examining team sports, conducted on Spanish (Casamichana, et al., 2013) and Australian footballers (Gallo, Cormack, Gannett, Williams, & Lorenzen, 2015), showed a very strong correlation ($r=0.74$ and $r=0.86$, respectively) between external (PL) and internal (sRPE) pathways. However, in basketball, only one paper investigated the relationship between the sRPE and the accelerometer-derived load. Scanlan et al. (2014) investigated the training activity of eight semi-professional players with 44 observations and found a moderate correlation ($r=0.49$) between PL and sRPE. Maybe the sample consisting of semi-professional players used in the study can explain this result. Although Scalan et al. (2014) provided novel findings regarding the comparison between internal and external TL in basketball, the relationships among different external TLs (such as PL in isolated planes, jumps, or changes of direction) are yet to be examined.

The focus of the present study is on establishing the correlation among external TL variables, and external and internal TL parameters in players of a top-level Spanish basketball team. As there is no evidence of the correlation between these demands in elite basketball, the results of this study could help coaches to single out key variables for successful and effective load monitoring in professional basketball.

4.2. METHODS

4.2.1. Participants

A total of 13 professional basketball players participated in this study (age: 25.7 ± 3.3 years; body height: 199.2 ± 10.7 cm; body mass: 96.6 ± 9.4 kg). All players belonged to the same team, competing in two basketball leagues, ACB (LigaEndesa, 1st Spanish Division) and the Euroleague, in the 2016/2017 season. The subjects were informed about the purpose, risks and benefits of the study and the types of tests that they would be submitted to, and they gave their informed consent in accordance with the Declaration of Helsinki.

4.2.3. Type of training session

As it is presented in Figure 1., training and game activities place a considerable load on basketball players. In order to approach load monitoring in basketball comprehensively and achieve a maximum effect, it is essential to consider the total load – a sum of all training and game activities. Game playing time can vastly vary during micro- and meso-cycles, having a strong impact on the total load, both in the acute and the chronic time-frame. Furthermore, training activities are divided into four categories: basketball training, individual basketball training, strength training and recovery training.

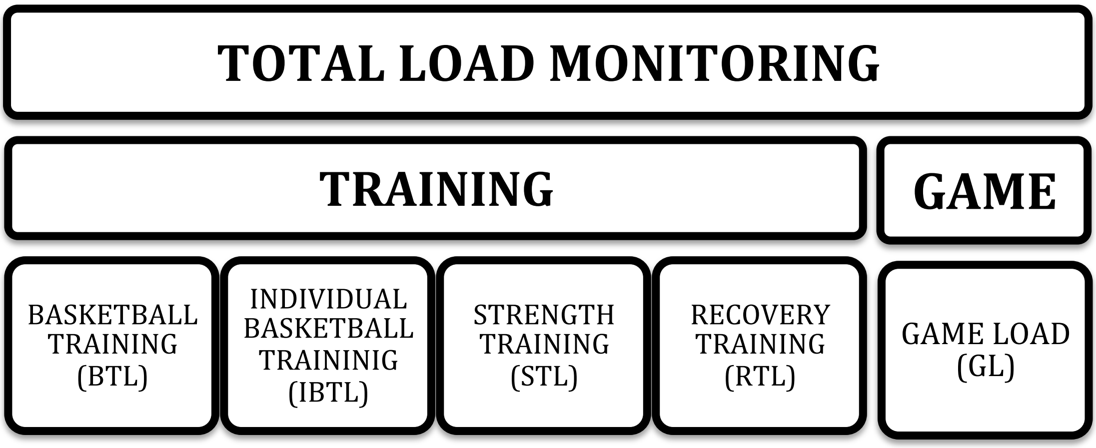

Figure 1. Total load monitoring system in basketball.

The basketball training is team training where all players participate in different technical and tactical tasks on the court, with a common goal of improving team's offensive and defensive performance as well as specific endurance. Individual basketball training (IBT) is focused on the player's technical proficiency on the court: moving without the ball, ball handling, dribbling, passing, shooting, etc. Strength training (ST) is based on the individual need for strength and power in-season development and maintenance. Recovery training (RT) is a low-intensity training that is focused on muscle, fascial and neural recovery, typically one day after the game. The game load (GL) is the load that the player accumulates in an official competition.

Internal load monitoring

The internal training load was monitored using the sRPE method, which researchers have shown to be a valid, reliable, inexpensive and very simple method for monitoring the training load in various exercise activities (Foster, et al., 2001; Singh, Foster, Tod, & McGuigan, 2007; Wallace et al., 2014; Williams, Trewartha, Cross, Kemp, & Stokes, 2016), as well as in team sport settings (Coutts, et al., 2004; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Lambert & Borresen, 2010). The RPE data were collected 15-30 minutes following each training or game, which was suggested to be the best time-frame by Singh et al. (2007). In order to obtain sRPE values, the RPE grade (1-10) was multiplied by the duration of a training session. The sRPE method was applied after all training sessions.

External load monitoring

The external load was monitored using accelerometer, gyroscope and magnetometer sensors included in S5 devices (Catapult Innovations, Melbourne, Australia). This sensor allows inertial movement analysis (IMA). The registered data included: player load, accelerations, decelerations, jumps and changes of direction.

Player Load (PL) was measured by a tri-axial 100 Hz accelerometer based on the player's three-planar movement, using the well-known formula (Casamichana & Castellano, 2015; Castellano, Casamichana & Dellal, 2013). The reliability of this variable had been previously evaluated (Akenhead, Hayes, Thompson, & French, 2013; Varley, Fairweather, & Aughey, 2012). In addition to PL, the player load of the three dimensions was analysed separately: (1) PLf is the PL accumulated in the anterior/posterior plane; (2) PLs is the PL accumulated in the lateral plane; and (3) PLu is the PL accumulated in the vertical plane only. The PL dwell time was 1 second.

The acceleration/deceleration (acc/dec) variables involved total and high-intensity inertial movements: (1) tACC refers to total inertial movements registered in a forward acceleration vector; (2) hACC are total inertial movements registered in a forward acceleration vector within the high band (>3.5 $m \cdot s^{-2}$); (3) tDEC are total inertial movements registered in a forward deceleration vector; and (4) hDEC are total inertial movements registered in a forward deceleration vector within the high band (<-3.5 $m \cdot s^{-2}$).

Regarding jumps, total jumps (tJUMP) and jumps done at the high band (hJUMP, over 0.4 m) were registered. Finally, two variables involved a change of direction (CoD): (1) tCoD (total inertial movements registered in a rightward lateral vector), and (2) hCoD (total inertial movements registered in a rightward lateral vector within the high band). All these variables (acc/dec, jumps and CoD) were assessed with respect to their frequency.

4.2.4. Procedures

The study was conducted during the 2016/2017 season (December - April). In that period, the players participated in 5 to 10 different types of training sessions and played between two and three games per week. All of the players were monitored in each BTL session using S5 devices (Catapult Innovations, Melbourne, Australia). Individual RPE measured at each session was multiplied by the duration of a session. The warm-up and rests between tasks were included in the total session duration.

The resulting data sets consist of 300 observations, with the numbers of training sessions per player ranging between 4 and 29. The external load data were downloaded and processed with the Openfield v1.14.0 software (Build #21923, Catapult, Canberra). After that, the data were exported to a central database in Microsoft Excel, containing measured variables (external and internal) for each player in each session. Finally, all statistical analyses were performed using SPSS v22.0 (SPSS Inc., Chicago, Illinois, USA).

4.2.5. Data analysis

The data are presented as mean values and standard deviations (±SD). The normality and homogeneity of variances were tested using the Kolmogorov-Smirnov and Levene's tests, respectively. The relationships between various internal and external variables were assessed using the Pearson's correlation coefficient with 95% percentile bootstrap Confidence Intervals (95%CI). The magnitude of correlation coefficients, according to Hopkins (2002), was considered trivial ($r<.1$), small ($.1<r<.3$), moderate ($.3<r<.5$), large ($.5<r<.7$), very large ($.7<r<.9$), almost perfect ($r>.9$) or perfect ($r=1$). The statistical significance was set at $p<.01$.

4.3. RESULTS

The mean and standard deviation values for each variable used for basketball training monitoring in this study are presented in Table 1. It can be seen that player load in the vertical plane (PLu) accumulated more arbitrary units than in the other two planes. Also, deceleration demands (total tDEC and high intensity hDEC) were higher than the acceleration.

Table 1. Mean and standard deviation (±SD) of the values for each physical variable and sRPE.

Variables (units)	**Mean**	**SD**
PL (AU)	314.9	±90.0
PLf (AU)	132.0	±37.3
PLs (AU)	127.4	±37.4
PLu (AU)	206.1	±59.9
tACC (n)	49.1	±24.2
hACC (n)	6.5	±4.6
tDEC (n)	89.1	±32.2
hDEC (n)	10.2	±6.8
tCoD (n)	324.1	±116.0
hCoD (n)	21.4	±12.5
tJUMP (n)	49.8	±20.0
hJUMP (n)	13.1	±6.8
RPE (AU)	6.6	±1.5
Duration (h:min:sec)	1:07:42	±0:15:24
sRPE (AU)	390.2	±135.6

Note: PL is player load, PLf is PL in the anterior/posterior plane, PLs is PL in the lateral plane, and PLu is PL in the vertical plane; tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 $m \cdot s^{-2}$), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 $m \cdot s^{-2}$), tJUMP is total jumps, hJUMP is jumps done at the high band (above 0.4 m), tCOD is total rightward/leftward lateral movements, and hCOD is total movements registered in a rightward/leftward lateral vector within the high band (<-3.5 $m \cdot s^{-2}$).

Table 2 shows Pearson correlation values between the external load variables. All the combinations showed a statistically significant relationship ($p<.01$). Interestingly, PL showed a higher correlation with tCoD and tDEC than with tACC and tJUMP. Moreover, PL showed a higher correlation with all total variables (tACC, tDEC, tCoC) as compared to high band variables (hACC, hDEC and hCoD), with the exception of the JUMP variable.

Table 2. Correlations (±95% confidence intervals) for external and internal training load variables.

	PLf	**PLs**	**PLu**	**tACC**	**hACC**	**tDEC**	**hDEC**	**tCoD**	**hCoD**	**tJUMP**	**hJUMP**
PL	0.98 (0.97-0.99)	0.99 (0.98-0.99)	0.99 (0.98-0.99)	0.65 (0.58-0.70)	0.53 (0.44-0.61)	0.83 (0.79-0.86)	0.65 (0.58-0.70)	0.84 (0.80-0.87)	0.67 (0.60-0.73)	0.49 (0.40-0.57)	0.55 (0.47-0.63)
PLf		0.97 (0.96-0.98)	0.96 (0.95-0.97)	0.67 (0.61-0.73)	0.56 (0.47-0.64)	0.81 (0.77-0.85)	0.60 (0.52-0.67)	0.81 (0.77-0.85)	0.64 (0.57-0.69)	0.50 (0.42-0.58)	0.55 (0.48-0.62)
PLs			0.97 (0.96-0.98)	0.69 (0.64-0.74)	0.58 (0.50-0.65)	0.83 (0.80-0.86)	0.66 (0.59-0.72)	0.86 (0.83-0.89)	0.69 (0.64-0.75)	0.50 (0.43-0.58)	0.56 (0.49-0.64)
PLu				0.60 (0.53-0.63)	0.49 (0.46-0.56)	0.81 (0.77-0.85)	0.65 (0.59-0.71)	0.83 (0.79-0.86)	0.65 (0.59-0.71)	0.46 (0.37-0.54)	0.54 (0.45-0.61)
tACC					0.72 (0.66-0.78)	0.69 (0.62-0.74)	0.29 (0.20-0.37)	0.66 (0.59-0.72)	0.52 (0.47-0.57)	0.49 (0.39-0.58)	0.43 (0.32-0.53)
hACE						0.47 (0.37-0.56)	0.28 (0.17-0.38)	0.62 (0.54-0.68)	0.49 (0.40-0.58)	0.43 (0.33-0.52)	0.29 (0.18-0.40)
tDEC							0.69 (0.63-0.75)	0.78 (0.72-0.83)	0.65 (0.57-0.70)	0.56 (0.48-0.62)	0.60 (0.52-0.67)
hDEC								0.63 (0.55-0.71)	0.65 (0.56-0.73)	0.28 (0.20-0.37)	0.38 (0.29-0.48)
tCoD									0.74 (0.69-0.79)	0.50 (0.41-0.59)	0.47 (0.38-0.56)
hCod										0.41 (0.31-0.51)	0.34 (0.24-0.44)
tJUMP											0.56 (0.48-0.64)

Note: PL is player load, PLf is PL in the anterior/posterior plane, PLs is PL in the lateral plane, and PLu is PL in the vertical plane; tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 $m \cdot s^{-2}$), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 $m \cdot s^{-2}$), tJUMP is total jumps, hJUMP is jumps done at the high band (above 0.4 m), tCOD is total rightward/leftward lateral movements, and hCOD is total movements registered in a rightward/leftward lateral vector within the high band (<-3.5 $m \cdot s^{-2}$). In all cases Pearson values were $p<0.01$ (bilateral).

Finally, Figure 2 shows Pearson correlations between sRPE (internal load) and the external load variables used. Although all of the presented relationships were statistically significant (p<.01), the strengths of correlations varied between variables. Very strong correlations were found between sRPE and all PL variables (PL, PLf, PLs and PLu), with values of r>.8. Finally, higher correlations were found between sRPE and tDEC and tCoD than tACC and tJUMP. Likewise, the total number of ACC, DEC and CoD displayed a higher correlation than high-band activities for the same variables.

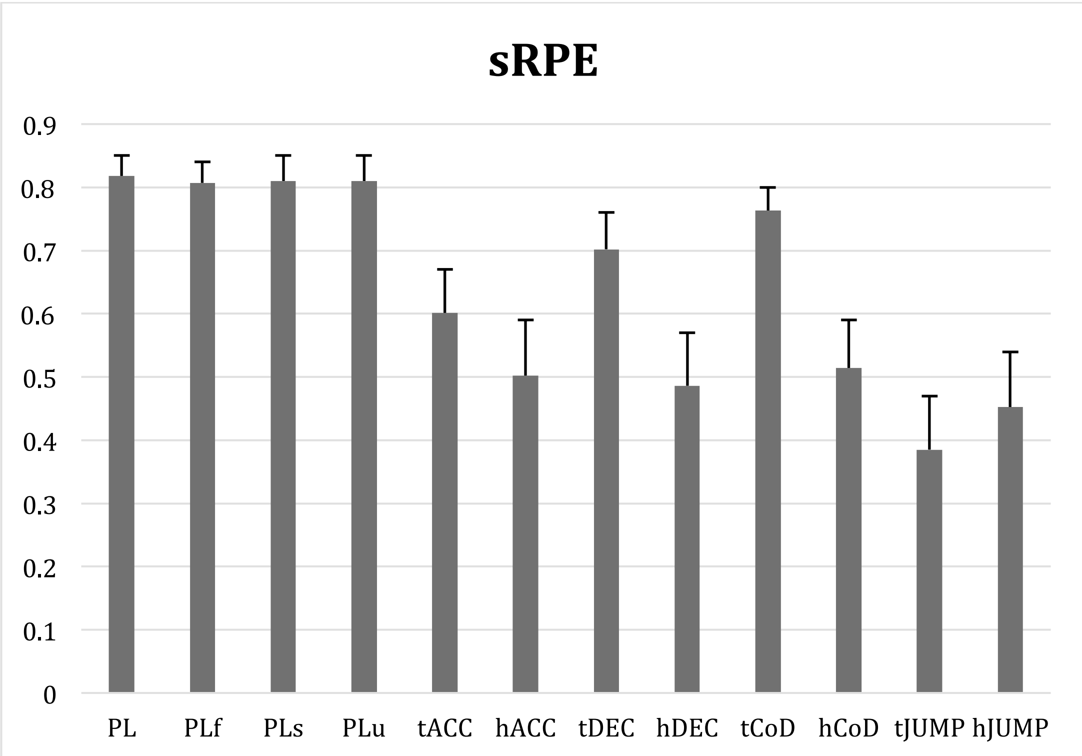

Figure 2. Pearson correlation (±95% confidence intervals) values between sRPE and the external load variables.

Note: PL is player load, PLf is PL in the anterior/posterior plane, PLs is PL in the lateral plane, and PLu is PL in the vertical plane; tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 $m \cdot s^{-2}$), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 $m \cdot s^{-2}$), tJUMP is total jumps, hJUMP is jumps done at the high band (above 0.4 m), tCOD is total rightward/leftward lateral movements and hCOD is total movements registered in a rightward/leftward lateral vector within the high band (<-3.5 $m \cdot s^{-2}$). In all cases, Pearson values were *p<0.01* (bilateral).

4.4. DISCUSSION AND CONSLUSSION

This is the first study that examined the relationship between indicators of external and internal load in elite male basketball. The main finding of this study was a very high and significant association between sRPE and external load variables – which present the motor activity of players during basketball training sessions – particularly when the total load was considered. Furthermore, strong correlations among external load variables suggest that coaches could be more selective in choosing variables for training monitoring in basketball so as to avoid redundancy.

The results of the current study support previous research findings in running-based team sports (Casamichana, et al., 2013; Gallo, et al., 2015; Scott, Lockie, Knight, Clark, & Janse de Jonge, 2013). To date, only one study (Scanlan, et al., 2014) investigated the relationship between accelerometer-derived load and sRPE in basketball, but with eight semi-professional male players. Unlike the current study ($r>.8$), the Scanlan's study showed a moderate correlation between PL and sRPE ($r=.49$). It was therefore suggested that professional basketball coaching and conditioning should not assume a linear dose and response relationship between the accelerometer and the internal training load models during training and that a combination of internal and external approaches was to be used in monitoring the training load in players. The difference in the results could be explained by the number of training observations in the two studies (44 in the Scanlan's study, compared to 300 in the current study) and the quality level of players (semi-professional vs. elite players). Moreover, the differences could be explained by the training design: the current study investigated in-seasonal training sessions, while the Scanlan's study focused on the general and specific preparatory phase during pre-season.

With respect to external variables, PL showed very strong correlations with tCoD and tDEC, but only a strong correlation with tACC and a moderate one with tJUMP. These findings could be explained by physical demands of basketball game, which involves a more frequent stress caused by decelerations and changes of direction than by accelerations and jumps, as it was presented in Table 1. Therefore, the total number of deceleration and changes of direction could be a valuable variable in describing the training load. However, it is important to realize that the number of high-intensity DEC and CoD accounted only for a small percentage of the total number of DEC and CoD: 8.7% and 15.1%, respectively.

Furthermore, a comparison of decelerations and accelerations shows that, in basketball training, there are almost twice as many decelerations than accelerations, both in the total and the high-intensity spectrums. Conversely, in football, where the size of the pitch is much greater, the players experience a different relationship between the total ACC and DEC. Akenhead, Harley and Tweddle (2016) found that the total distance covered in accelerations in male football training was 1,826 m, as compared to 1,598 m covered in decelerations, while Mara, Thompson, Pumpa, and Morgan (2017) studied female matches and found a total of 423 accelerations and 430 deceleration. These results could be explained by the small size of the basketball court and, like in small-sided football games (Castellano & Casamichana, 2013), the players need to constantly decelerate and change direction, especially when anticipating and reacting to the actions of the opposing team during live games. Finally, it is also important to state that JUMP variable was poorly correlated with other external variables. This finding could be explained by the selection of different shooting drills, involving a high number of low- and high-intensity jumps. However, the number of spot-up shots made by each player notably varies from training to training, as it is not specified for each type of basketball training, or for the selection of small-sided games that represent a major part of the in-seasonal basketball practices.

Regarding the correlations between the internal load and external load variables, interesting results were found: sRPE showed a very strong correlation with tDEC and tCoD, a strong correlation with tACC, and only a moderate one with tJUMPS. A very similar pattern was observed between PL and the mentioned external variables, since they belonged to the same representative natural group (after the application of the cluster analysis), as suggested by Fernandez, Medina, Gomez, Arias, and Gavalda (2016). Like in other team sports (Casamichana, et al., 2013; Gallo, et al., 2015), this further confirms a strong correlation between PL and sRPE in elite basketball, expressed as mechanical and biochemical stress (Vanrenterghem, et al., 2017), respectively. Regardless of this high correlation between the two groups of variables, it seems that recording of both could provide a better understanding of players' adaptation or increased states of fatigue.

Even though the sample used in the current study could be considered a potential limitation factor, it should be noted that this number represents a full-team roaster in basketball and it is therefore common that studies on professional teams are conducted on smaller samples. Moreover, future investigations should include the measures of internal load (such as the heart rate) that were not available in the current study. Considering that the current rules of the game forbid the use of devices and sensors, it would be very interesting to know if this relationship between internal and external loads remains at a similar level, since other non-mechanical stressors could potentially affect the general relationship between PL and sRPE. A complementary use of both the internal and external parameters will greatly contribute to the process of training load monitoring. Additionally, it is important to acknowledge the statement made by Schelling and Torres (2016) on the limitations of measuring the external load using accelerometers, since these devices are not able to collect information on isometric muscle contractions, which occur, for instance, during screens and low-post situations, where static movements have a very low acceleration, but potentially very high energy expenditure.

To sum up, it is important to state that the internal and external training loads are derived from inherently different constructs and a complementary use of the two types of loads is therefore advised. However, the strong correlation between them found by this study supports the argument in favour of using the sRPE as a global indicator of load in intermittent collision sports, such as basketball. Moreover, certain variables, such as the total number of changes of direction and decelerations, show strong correlations with PL and sRPE and could therefore be potentially used in prescribing individual and team training loads.

4.5. PRACTICAL APPLICATION

When considering the training load only, using both external and internal load monitoring methods provides the most valuable data for training analysis and training design. However, there are still many teams in professional basketball that do not use accelerometry technology in training nor in official matches, as it is currently not allowed. Therefore, based on the findings in this study, it is evident that the sRPE method alone could be sufficient to provide a general insight into load monitoring in professional basketball teams. However, even though both sRPE and accelerometry methods provide reliable training load values, it is important to know that the latter provides additional inertial-motion data with respect to individual movement patterns. For that reason, an individualized approach to external load monitoring in basketball is a complementary tool that could help coaches and teams minimize the number of injuries while achieving the best performance.

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CHAPTER 5

SHORT-TERM TAPERING PRIOR TO THE MATCH: EXTERNAL AND INTERNAL LOAD QUANTIFICATION IN TOP-LEVEL BASKETBALL

Abstract

The purpose of this study was to compare accelerometry-derived external load and internal load calculated as a session rate of perceived exertion (sRPE) in elite male basketball over 3-days prior to the match and assessing players' recovery status on the match-day. Thirteen professional basketball players participated in this study (age: 25.7±3.3 years; height: 199.2±10.7 cm; weight: 96.6±9.4 kg). All players belonged to a team competing in LigaEndesa (Spanish 1st Division) and Euroleague in the 2016/2017 season. Variables used in external motion analysis were: PlayerLoad (PL), accelerations and decelerations (ACC and DEC), jumps (JUMP) and changes of direction (CoD), in total (t) and high intensity (h) thresholds, while internal demands were registered using sRPE method. All variables were expressed in absolute (accumulated in the session) and relative values (per min of practice). For the evaluation of readiness, Total Quality of Recovery (TQR) questionnaire was used, measured in Arbitary Units (AU). The results showed differences in load and intensity (*p<0.01*) for almost all external (PL, hACC, tACC, hDEC, tDEC, hCoD and tCoD; in both absolute and relative values) and internal (sRPE) variables as training sessions were closer to the match day or MD (MD-3>MD-2>MD-1). Only hJUMP, tJUMP and RPE variables showed no difference between MD-3 and MD-2, while both days

significantly differed from MD-1. The average TQR score for all of the match days was 7.9±1.31 AU. This study showed differences in the amount of external and internal load between three days of training, where a team can be efficiently prepared for competitions by progressively decreasing the load over the 3-days prior to the match.

Keywords: training monitoring, micro-technology, accelerometry, team sports

5.1. INTRODUCTION

Training periodization and tapering are well-known principles commonly used in professional team-sports training during the season. According to literature[1,2], 'long-term' tapering in team-sports is implemented two to three weeks before important events, such as cups and play-offs, with the intention of peaking individual and team's physical and tactical performance. A recent study focusing on basketball revealed a relationship between internal training load, recovery-stress status, immune-endocrine responses, and physical performance in elite female basketball players[3] over a 12-week period, including two overloading and tapering phases. This study covered the period preceding an international championship (characterized by a short duration), providing an insight into long-term training stimulus and adaptations in elite sports. Regarding training activities, taper was applied by decrease of training volume for the resistance training, especially with parameters such as repetitions per set, goal intensity and number of sessions per week. Moreover, in the first seven weeks endurance training consisted of moderate to high intensity interval runs while in the weeks 8 to 12 endurance training was substituted with less metabolic speed-agility training. Finally, authors concluded that the application of session rate of perceived exertion (sRPE) method, as well as the recovery-stress questionnaire (REST-Q), can serve as an important tool to monitor training loads and players' recovery, thus maximizing dose-responses of the training stimulus.

However, for a team competing in seasonal championships, the coaching staff is presented with the challenge of making an optimal training schedule every single week. In this context, weekly periodization, i.e. tapering, could also refer to the practice of reducing training load in the days leading up to the weekly competition. To date, there is little scientific information available to guide coaches in prescribing efficient short-term tapering strategies for team sports players during the competitive week aimed at peaking performance on the match day.

Only one study[4] has looked at internal training load (iTL) using sRPE and heart rate (HR) monitoring methods, and it showed that, in the weeks with two games (i.e. Euroleague and Serie A1), the sRPE obtained on Tuesdays and Wednesdays were 748±71 and 275±54 AU, respectively. The short-term tapering assumed that Monday was the day-off and Thursday the match-day in Euroleague. However, the aforementioned study did not present any external load data and indicators of physical condition with respect to the accumulated training load. To date, no studies examining the relationship between prescribed external training loads in micro-cycle periods have been conducted.

Numerous methods can be used to monitor the physical condition of athletes. There are objective methods, such as heart rate monitoring and saliva measures[5], blood testing[6] or jumping performance[7,8], as well as subjective methods, such as various questionnaires[8,9,10], which could be easily implemented in everyday training. One of the questionnaires, known as Total Quality Recovery Scale (TQR), has demonstrated sufficient reliability in team sports[11].

At the moment, information on accelerometer–based data in top-level basketball is limited, especially with respect to weekly periodization and distribution of load. Therefore, the aim of this study is to compare the load of the training sessions leading up to the first match of the week, considering both external (eTL) and internal training load parameters. Furthermore, the perception related to recovery status on the match day (via TQR questionnaire) will be assessed. The assessment will be used as the indicator in the selection of appropriate training load that secures enough recovery for players' well-being, while avoiding undesired overload and overtraining. The findings of this study could help coaches set appropriate level and intensity of accelerometry-derived training load (TL) in the days leading up to the match, as such data is currently unavailable in the literature.

It was hypothesized that, with the application of a short-term 3-day taper, a progressive decrease in TL prior to the match day will positively affect players' recovery status, which would in turn lead to enhanced physical condition and performance in competition.

5.2. MATERIAL AND METHOD

5.2.1. Experimental Approach To The Problem

The research was carried out between December and February of the 2016/2017 season. The players were monitored in basketball training sessions using S5 devices from Catapult Innovations (Melbourne, Australia). Furthermore, sRPE was calculated based on the individual RPE obtained 15-30 minutes after the training session multiplied by the training duration. During that period, the players participated in three to eight training sessions and two or three games every week where the total number of recorded games was 10. The investigation data set consisted of 228 observations, where the numbers of training sessions per player ranged between 11 and 22. The eTL was transferred and managed using the Openfield v1.14.0 software (Build #21923, Catapult, Canberra). The data was subsequently exported to Microsoft Excel for the final selection and analysis of individual eTL and iTL variables.

5.2.2. Participants

A professional male basketball players (age: 25.7 ±3.3 years; height: 199.2 ±10.7 cm; weight: 96.6 ±9.4 kg) who play on the same team were participating in this investigation. The team competes in two basketball championships, ACB (Liga Endesa, Spanish 1st Division) and the Euroleague, in the 2016/2017 season. All of the players were verbally informed of the study requirements and they provided written consent before the study was conducted, all in accordance with the Declaration of Helsinki.

5.2.3. Type Of Training Session

The players typically played two games per week, with three team sessions usually conducted before the first game of the week (Euroleague) and only one or none before the second game (ACB League). Only the sessions before the first game of the week were considered in the analysis, due to individual adjustments in team sessions preceding the second game, which depended on the individual effort in the first game. Therefore, the data for the analysis was collected three days before the match day (MD-3), two days before the match day (MD-2) and one day before the match day (MD-1). The 3 consecutive days of practices were proposed by conditioning specialist in order to achieve optimal short-term tapering effect. Only players who complete all three training sessions were included in the analysis.

Table 1 provides the list and brief descriptions of basketball training exercises and drills used in the reference period. After the team preparation, players participated in one of the following: shooting exercises, no-contact drills or small-sided games (SSG).

Table 1. Usual training tasks.

TASK	DESCRIPTION	DAY OF USE
PREPARATION	Warm-up, myo-fascial release and stretching, balance and activation exercises with goal to functionally prepare each player for training demands. Usual time 10-15’.	MD-3, MD-2, MD-1
5x0 HC	No-contact play on half-court for learning and mastering offensive sets. Usual time of play is 15-20’’, work rest ratio 1:1.	MD-3, MD-1
5x0 FC	No-contact play using full court for learning and mastering offensive sets. Usual time of play is 20-40’’, work rest ratio 1:1.	MD-3, MD-2, MD-1
SSG 3x3 HC	Contact small-sided game on half-court for learning and mastering tactical rules. Usual time of play is 30-60’’, work rest ratio 1:1.	MD-2
SSG 4x4 HC	Contact small-sided game on half-court for learning and mastering tactical rules. Usual time of play is 30-60’’, work rest ratio 2:1.	MD-3, MD-2, MD-1
SSG 5x5 HC	Contact small-sided game on half-court for learning and mastering tactical rules. Usual time of play is 30-90’’, work rest ratio 1:2.	MD-3, MD-1
SSG 5x5 FC	Contact small-sided game using full court for learning and mastering tactical rules. Usual time of play is 30-120’’, work rest ratio 1:1.	MD-3, MD-2, MD-1
SHOOTING	Spot-up shooting drills in pairs, low to medium intensity, continuous 5-10’.	MD-3, MD-2, MD-1

Note: SSG is small-sided game, HC is half court, FC is full court, MD-3 is three days prior the match, MD-2 is two days prior the match and MD-1 is one day prior the match.

5.2.4. External Training Load Monitoring

The eTL was monitored using GPS S5 devices (Catapult Innovations, Melbourne, Australia), which include the accelerometer, gyroscope and magnetometer sensors that provide data for inertial movement analysis (IMA). The obtained data included the following variables: player load (PL), player load per minute (PL/min), accelerations (ACC), decelerations (DEC), jumps (JUMP) and changes of direction (CoD).

PL was obtained using the tri-axial accelerometer (100 Hz, Dwell time 1 second) based on the player's three-planar movement, applying the established formula[12,13] previously tested for reliability[14,15], where TE (i.e. typical error) for different ranges of acceleration varies from 0.18 – 0.13[15].

The ACC variable presents inertial movements registered in a forward acceleration vector, where tACC refers to all, and hACC only to high-intensity movements registered within the high band (>3.5 $m \cdot s^{-2}$). The DEC variable refers to inertial movements registered in a forward deceleration vector, where tDEC presents total and hDEC only high-intensity movements registered within the high band (>3.5 $m \cdot s^{-2}$). The jumps were also registered as total jumps (tJUMP) and high-intensity jumps (hJUMP, over 0.4 m), the same as changes of direction, tCoD (total inertial movements registered in a rightward lateral vector), and hCoD (total inertial movements registered in a rightward lateral vector within the high-intensity band). All aforementioned variables were assessed with respect to their frequency.

Considering the varied duration of the sessions, the relative values of the variables were used, obtained by dividing the accumulated values by the minutes of practice duration. The new relative variables for the analysis were: PL/min, hACC/min, hDEC/min, tACC/min, tDEC/min, hCoD/min, tCoD/min, tJUMP/min and hJUMP/min.

5.2.5. Internal Training Load Monitoring

The sRPE method, whose reliability and validity has been confirmed in previous research[16,17,18,19] as well as its simple and cost-effective use in practice with team sport athletes[20,21,22], was used to assess iTL. As suggested by research[17], the RPE values were collected within 15-30 minutes following the training session. The 1-10 RPE grading scale was used. In order to calculate sRPE after all sessions, RPE values were multiplied by training duration in minutes.

5.2.6. Monitoring Of Physical Condition

The TQR questionnaire was used to assess players' physical condition. On the match day, after the morning team shooting practice, players were asked to grade their current physical condition on a scale from 1 to 10 (where 1 means very, very poor and 10 very, very good), following this category classification: <6 = an alarming state; 6.1-7.5 = a good state; 7.6-9 = a very good state; and >9.1 = an excellent state.

5.2.7. Statistical Analysis

A data analysis was performed using the Statistical Package for Social Sciences (version 23 for Windows, SPSS™, Chicago, IL, USA). Standard statistical methods were used to calculate the mean (or median) and standard deviations (SD). The data was screened for normality of distribution and homogeneity of variances using Shapiro-Wilk and Levene's tests, respectively. Differences between dependent variables and TQR values in training sessions and on the match day were analyzed using one-way ANOVA, followed by Bonferroni's post hoc test (Kruskal Wallis test followed by Mann-Whitney U test, with Bonferroni correction of alpha, in this case, dividing alpha by three comparisons). The effect size (ES) was calculated using the method proposed by Batterham and Hopkins[23]. The effect values lower than 0.2, between 0.2 and 0.5, between 0.5 and 0.8, and higher than 0.8 were considered trivial, small, moderate, and large, respectively. The $p<0.05$ criterion was used for establishing statistical significance.

5.3. RESULTS

The duration (mean, standard deviation and confidence interval at 95%, in hours:minutes:seconds) of the sessions were 1:23:37±0:11:40 (1:19:56-1:27:18), 1:14:43±0:12:37 (1:12:07-1:17:20) and 0:58:25±0:07:57 (0:56:48-1:00:02) for MD-3, MD-2 and MD-1, respectively. A significant difference was found between all of the days.

Figure 1 shows values for PL (in AU) on each day of the week. The differences were statistically lower for training sessions closer to the match day (MD-3>MD-2>MD-1), where the values were as follows: 436.6±70.8, 358.4±51.1 and 253.2±58.7, respectively (ES: 1.27 for MD-3 vs. MD-2; 1.91 for MD-2 vs. MD-1; 2.82 for MD-3 vs. MD-1). Furthermore, the PL/min values for MD-3, MD-2 and MD-

1 were significantly different, 5.3±0.7, 4.9±0.8 and 4.3±0.7, respectively (ES: 0.53 for MD-3 vs. MD-2; 0.80 for MD-2 vs. MD-1; 1.43 for MD-3 vs. MD-1).

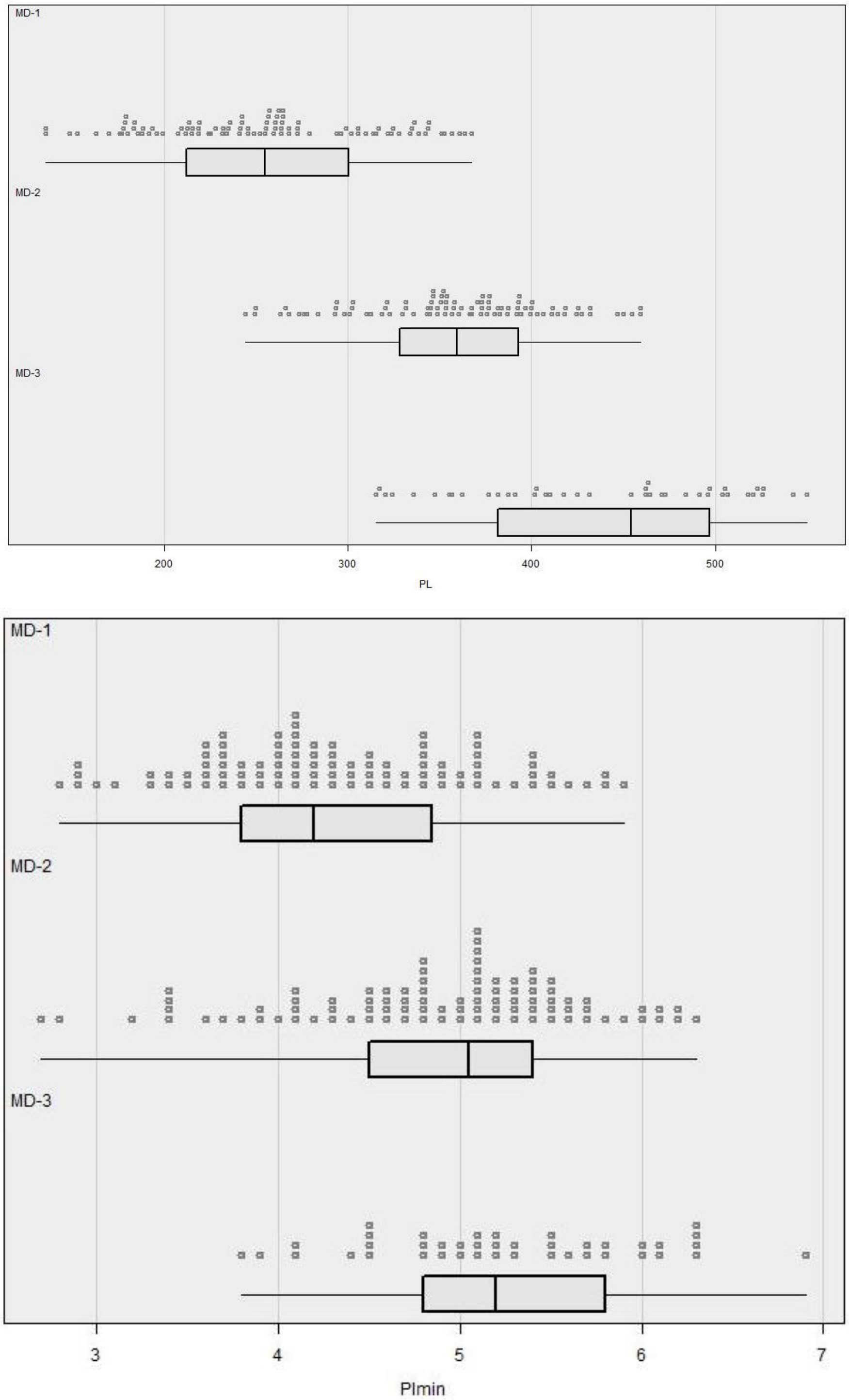

Figure 1. Median, ±standard deviation, confident interval at 95% for a) total PL (Player Load) in arbitrary units (AU) and b) PL/min (Player load per minute) in arbitrary units per minute (AU/min) regarding to the day of the week (MD-3 is match day minus 3, MD-2 is match day minus 2 and MD-1 is match day minus 1).

Table 2 shows absolute values of other external training load variables (mean, standard deviation and confidence interval at 95%) for each type of session in the week. In most variables, there was a statistically significant difference between the days MD-3 > MD-2 > MD-1. Only JUMP variable showed no difference between MD-3 and MD-2, while both days differed from MD-1.

Table 2. Mean, ±standard deviation, confident interval at 95% (in brackets) and effect size (ES) for absolute external training load variables.

VARIABLES	MD-3	MD-2	MD-1	ES
hACC (n)	10.8±5.5^{2,1} (9.0-12.5)	8.0±3.9^{1} (7.2-8.8)	4.1±3.0 (3.4-4.7)	A=0.59, B=1.12, C=1.51
tACC (n)	72.8±22.9^{2,1} (65.6-80.0)	62.2±21.0^{1} (57.8-66.5)	33.3±15.2 (30.2-36.4)	A=0.48, B=1.58, C=2.03
hDEC (n)	16.8±8.2^{2,1} (14.2-19.4)	12.0±6.1^{1} (10.7-13.2)	7.3±4.4 (6.4-8.2)	A=0.66, B=0.88, C=1.44
tDEC (n)	125.9±28.6^{2,1} (116.8-134.9)	101.2±23.4^{1} (96.4-106.1)	71.4±25.7 (66.1-76.6)	A=0.95, B=1.21, C=2.00
hCoD (n)	33.1±12.7^{2,1} (29.1-37.1)	26.6±12.0^{1} (24.1-29.1)	15.0±8.3 (13.3-16.7)	A=0.53, B=1.12, C=1.69
tCoD (n)	480.0±103.7^{2,1} (447.2-512.7)	374.8±67.1^{1} (360.9-388.7)	247.7±80.3 (231.3-264.0)	A=1.20, B=1.72, C=2.50
hJUMP (n)	17.5±7.3^{1} (15.2-19.8)	14.8±6.1^{1} (13.5-16.0)	10.2±5.3 (9.1-11.2)	B= 0.81, C=1.14
tJUMP (n)	58.2±17.6^{1} (52.7-63.8)	55.5±16.2^{1} (52.2-58.9)	42.7±21.3 (38.4-47.0)	B= 0.68, C=0.79

Note: 3 means > MD-3, 2 means > MD-2, 1 means > MD-1, A means MD-3vsMD-2, B means MD-2vsMD-1 and C means MD-3vsMD-1. tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 m·s-2), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 m·s-2), tCOD is total rightward lateral movements, hCOD is total movements registered in a rightward lateral vector within the high band, tJUMP is total jumps, and hJUMP is jumps done at the high band (above 0.4 m).

When variables were expressed in minutes of practice (Table 3), almost all of the variables showed the same pattern, with statistically significant differences between MD-3 > MD-2 > MD-1. Interestingly, tJUMP/min and hJUMP/min showed no difference between MD-3 and MD-2, while both days showed a difference when compared to MD-1.

Table 3. Mean, ±standard deviation, confident interval at 95% (in brackets) and effect size (ES) for relative (per minute) external training load variables.

VARIABLES	MD-3	MD-2	MD-1	ES
hACC/min	$0.14±0.07^{2,1}$ (0.12-0.17)	$0.11±0.05^{1}$ (0.10-0.12)	0.05±0.04 (0.05-0.06)	A=0.49, B=1.33, C=1.58
hDEC/min	$0.22±0.1^{2,1}$ (0.19-0.26)	$0.16±0.08^{1}$ (0.14-0.18)	0.10±0.06 (0.09-0.11)	A=0.67, B=0.85, C=1.46
tACC/min	$0.98±0.31^{2,1}$ (0.88-1.07)	$0.83±0.28^{1}$ (0.77-0.89)	0.45±0.20 (0.40-0.49)	A=0.51, B=1.56, C=2.03
tDEC/min	$1.69±0.38^{2,1}$ (1.57-1.81)	$1.36±0.31^{1}$ (1.29-1.42)	0.96±0.34 (0.89-1.03)	A=0.95, B=1.23, C=2.02
hCoD/min	$0.44±0.17^{2,1}$ (0.39-0.50)	$0.36±0.16^{1}$ (0.32-0.39)	0.20±0.11 (0.18-0.22)	A=0.48, B=1.17, C=1.68
tCoD/min	$6.43±1.39^{2,1}$ (5.99-6.87)	$5.02±0.90^{1}$ (4.84-5.21)	3.32±1.08 (3.10-3.54)	A=1.20, B=1.71, C=2.50
tJUMP/min	0.68±0.27 (0.64-0.71)	$0.78±0.24^{1,3}$ (0.71-0.85)	$0.74±0.22^{3}$ (0.70-0.79)	A= -0.39, C= -2.24
hJUMP/min	0.18±0.09 (0.17-0.19)	$0.23±0.10^{1,3}$ (0.20-0.26)	$0.20±0.08^{3}$ (0.18-0.21)	A= -0.53, C= -0.23

Note: 3 means > MD-3, 2 means > MD-2, 1 means > MD-1. A means MD-3vsMD-2, B means MD-2vsMD-1 and C means MD-3vsMD-1. tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 m·s-2), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 m·s-2), tCOD is total rightward lateral movements, hCOD is total movements registered in a rightward lateral vector within the high band, tJUMP is total jumps, and hJUMP is jumps done at the high band (above 0.4 m).

As for internal variables, the training load (sRPE) variable showed a statistically significant difference between days MD-3 > MD-2 > MD-1; 598.2±90.5 (569.6-626.7) AU, 441.4±73.4 (426.1-456.6) AU and 312.0±92.8 (293.1-330.9) AU, respectively (ES: 1.90 for MD-3 vs. MD-2, 1.55 for MD-2 vs. MD-1 and 3.12 for MD-3 vs. MD-1). The intensity variable RPE showed no differences between MD-3 and MD-2 with values 7.8±1.1 (7.4-8.1) AU and 7.3±0.9 (7.1-7.5) AU, respectively. However, the results for MD-1 were 6.0±1.4 (5.7-6.3) AU, what significantly differentiates from previous two days (1.10 for MD-2 vs. MD-1 and1.43 for MD-3 vs. MD-1).

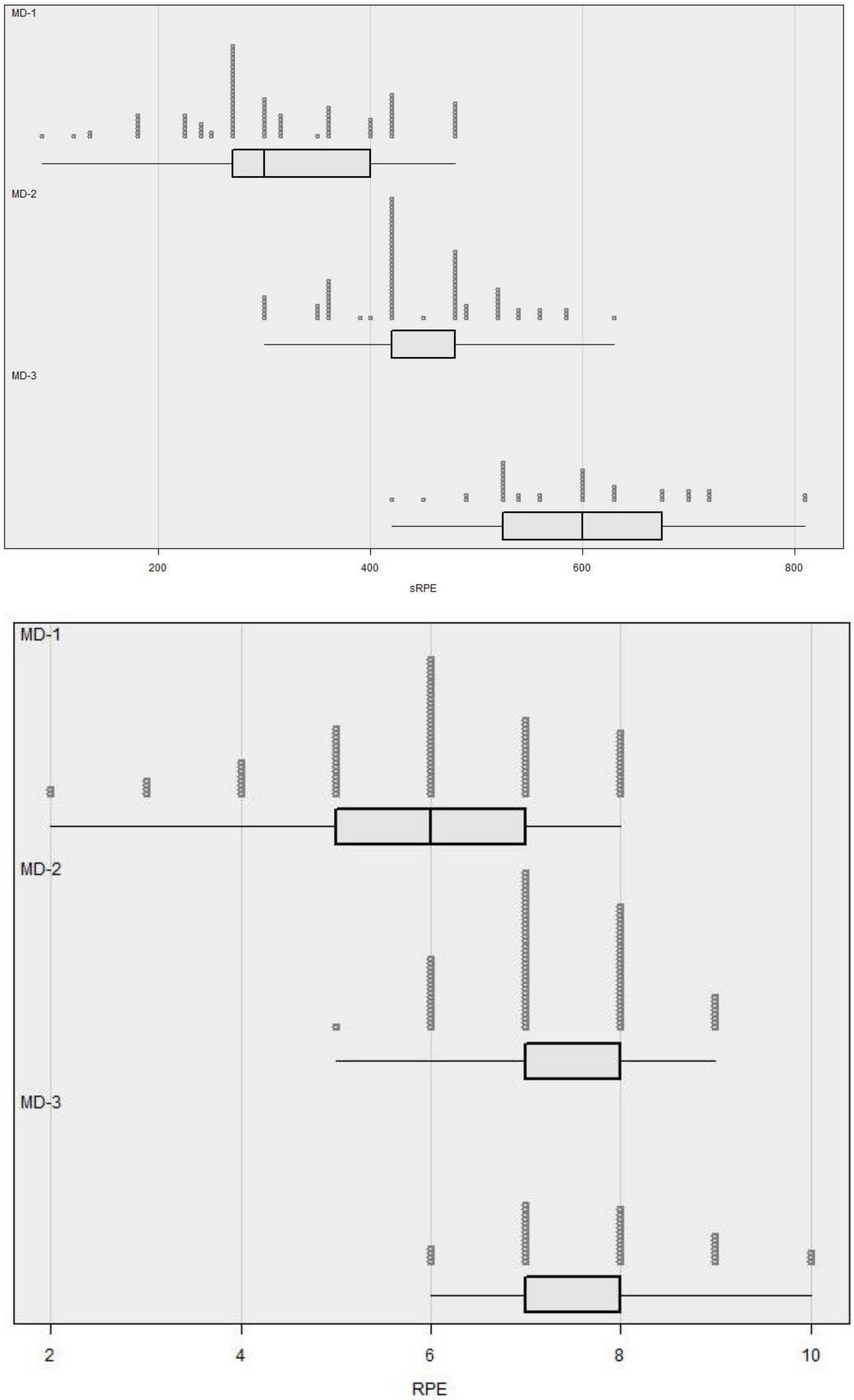

Figure 2. Median, ± standard deviation, confident interval at 95% for a) sRPE (session RPE) in arbitrary units (AU) and b) sRPE in arbitrary units per minute (AU/min) regarding to the day of the week (MD-3 in match day minus 3, MD-2 in match day minus 2 and MD-1 in match day minus 1).

Finally, Figure 3 presents the average scores in TQR questionnaire for all of the match days in the reference period. The average values from the first to the last game were as follows: 7.7 (6-10), 7.8 (6-10), 8.1 (6-10), 8.0 (6-10), 8.0 (7-10), 8.1 (6-10), 7.7 (6-10), 7.8 (6-10), 7.7 (6-10) and 8.0 (6-10). The average for all of the match days was 7.9 (±1.31), positioning the team in the category of a very good state. There were no significant differences in the recovery status (TQR questionnaire results) between all match days in the reference period.

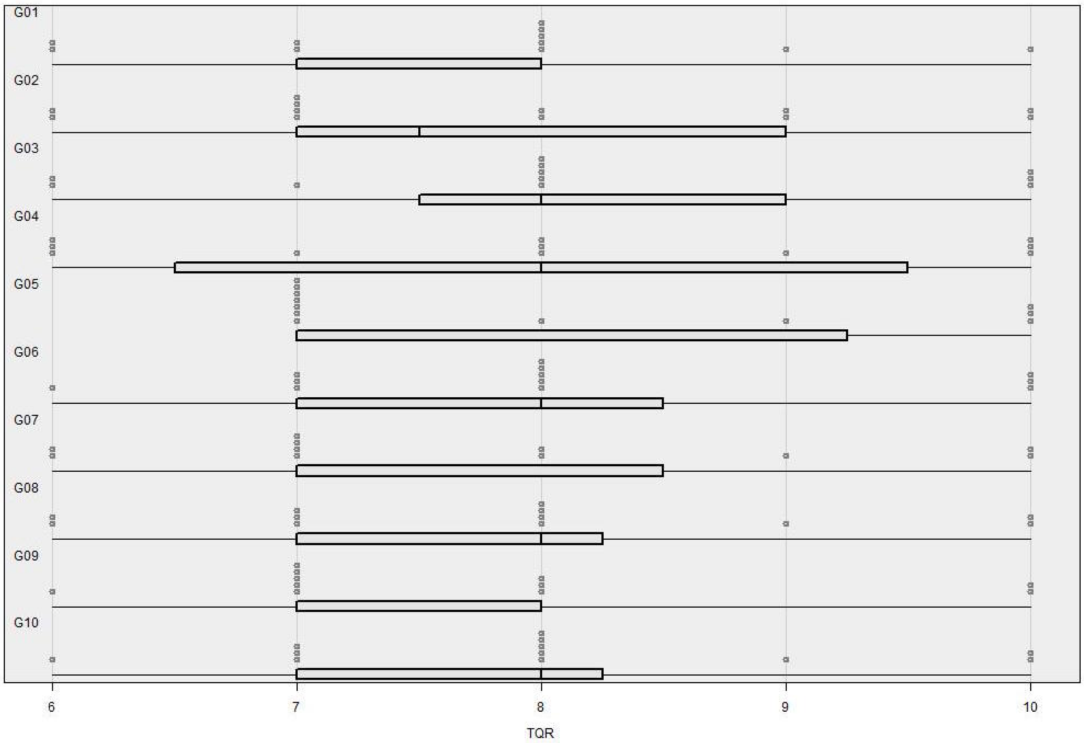

Figure 3. Median, ± standard deviation, confident interval at 95% for team's TQR scores prior the match (G presents a game, while the number classifies games from the first to the tenth).

5.4. DISCUSSION

The main aim of the present study was to describe differences between training sessions leading up to the first match of the week with respect to both eTL and iTL parameters. To the best of the authors' knowledge, this is the first study investigating short-term tapering in the elite basketball setting. The results showed differences in almost all variables (in both load and intensity) between the training sessions analyzed (MD-3>MD-2>MD-1). Furthermore, the TQR scores on the match day did not indicate any abnormality in players' optimal state of recovery. In particular, the results of the present study contributed to the improvement of specific periodization strategies with respect to different training durations, load and intensity.

Monitoring TL in basketball players is crucial in planning appropriate training programmes[24] and exposing players to adequate monotony and strain in order to reduce injury risk[25]. Additionally, in previous research on effects of specific periodization strategies to avoid overtraining syndrome or under-stimulation, it was concluded that training session duration and intensity manipulation is a very important component of tapering[2]. Experts[1] suggested that, out of the three main factors in tapering – training intensity, frequency and volume –, a decrease in the latter factor had the strongest effect on enhanced performance. In the present study, a decrease in the training duration (i.e, volume) in the days leading up to the match follows general tapering principles. However, tapering included only three-day cycles and can therefore be considered as a short-term taper. Furthermore, regardless of the cycle duration, as suggested by Foster[16], a link could be established between training load, strain and monotony, as main predictors of overtraining.

The majority of external load variables (i.e. hACC, tACC, hDEC, tDEC, hCoD and tCoD) revealed the same pattern in their inter-day relationships as the global variables, PL and sRPE. In connection with that finding, the authors suggest that these variables could be the most important eTL variables in prescribing load in basketball training sessions. Only two eTL variables of the same construct (i.e. hJUMP and tJUMP) showed different relationships between the days, with no difference found between MD-3 and MD-2, while both days differed from MD-1. This finding could be ascribed to different shooting drills, which significantly affected both hJUMP and tJUMP variables. In the future, it is important to differentiate between JUMP variables accumulated in SSG and other tasks, such as preparation for training or shooting. When the total number of ACC, DEC, CoD and JUMP variables is considered in basketball training, regardless of the day, it is important to recognize that the CoD variable had the highest values by far. For that reason, CoD also had the highest impact on load accumulation.

PL, a global eTL variable, shows significant differences between all of the days, starting from MD-3, which showed the highest value (436.6±70.8 AU), through MD-2 with a moderate value (358.4±51.1 AU), and finally, MD-1 with the lowest value (253.2±58.7 AU). These findings confirm previous research into short-term tapering in other team sports[7]. Unfortunately, eTL data on daily loads and short-term tapering in basketball does not exist.

With respect to iTL variables, the present study found that sRPE shared a very strong inter-day relationship as PL, unlike a previous study[26] on elite basketball players, which found only a moderate relationship (r=0.49). sRPE, a measure of internal training load, was the highest (598.2±90.5 AU) on MD-3, followed by 441.4±73.4 AU on MD-2 and was the lowest (312.0±92.8 AU) on MD-1. These findings support the previous study on elite basketball players[4]. However, Manzi's study covered only two days leading up to a Euroleague game, since MD-3 was a day without physical activities (i.e. day-off). Over these two days, the players accumulated on average 748±71 AU on MD-2 and 275±54 AU on MD-1, with players participating in both resistance (explosive weights) and technical training on MD-2, and in tactical team training on MD-2. A significant drop in load was applied in both cases, which supports the importance of the tapering concept of training volume decrease.

The PL/min variable, which can be considered a variable representing the intensity of work, shows a downward trend, with MD-3 showing the highest value of 5.3±0.7, MD-2 a moderate value of 4.9±0.8, and MD-1 the lowest value of 4.3±0.7. Even though Pyne et al. [1] suggested that training intensity should be maintained for an optimal taper, it is important to know that PL/min is an average value of the intensity of the training session, and the variable is affected by the overall duration of the session. With respect to the above said, the intention in practices was to maintain high intensity in competitive tasks, such as SSG, but this information was not provided in the current study. Therefore, as it can be seen in Table 2, almost all of the SSGs were used in all of the days leading up to the match. However, longer rest periods were used on MD-2 and, even more so, on MD-1 in order to decrease the metabolic stress, which could explain the significant drop in PL/min values.

Another intensity variable, the subjective RPE, did not show the exact same pattern as PL/min, and significant difference were not found between MD-3 and MD-2. However, both days differed from MD-1. This finding could be ascribed to the accumulated fatigue from MD-3, which is the most demanding day, having a direct impact on the next session on MD-2. However, a well-planned decrease in training volume and load did not have an impact on the residual fatigue on MD-1, but it did lead to a good readiness to play on the match day.

In order to evaluate the physical condition of players and their adaptation to training load prior to the match, a simple TQR questionnaire was used, as has been the practice in other team sports recently[27]. The team played 10 games in the reference period, with team scores ranging from 7.7 to 8.1, which positions them in the category of very good physical condition. There was no disturbance in the recovery status (as expressed by the TQR questionnaire) in any of the weeks prior to the matches (Figure 3). As suggested by Nunes et al.[3], overloading leads to poorer recovery and physical condition of players. However, we hereby propose that short-term tapering using the loads specified in this study could improve players' physical condition and enable them to be in good condition for the competition.

Even though it is important for all coaches to strive for better scores by applying different methods of both training and recovery, it is also important to understand that it is very difficult to constantly maintain an excellent physical condition. Playing modern basketball at the elite level requires the players to play 2-3 games per week, and sometimes take several flights a week, early in the morning or late at night, changing the sleeping environment on a weekly basis. These are only some of the factors that interrupt players' circadian rhythm. However, it is important to consider the findings by Rabbani & Buchheit[5], who state that fitter player may experience less wellness impairment when traveling than their less fit counterparts. Moreover, members of the coaching staff should establish a positive working environment, so that players are surrounded with positive energy and maintain healthy mentality in challenging moments on a daily basis.

Therefore, as the team in this investigation constantly averaged in the 'very good state' category, the authors concluded that the accumulated training load presented could be appropriate. Additionally, to keep the players in an optimal physical condition, it is important to maintain a sound acute:chronic workload ratio between micro-cycles, while considering both training and game loads. As suggested by previous research[28], it is better to maintain a high chronic load, because, in congested fixture, players are ready to support a high amount of load. In basketball, this idea has great importance for all players, especially those with more playing time.

This study accentuates the short-term tapering as a basic principle in weekly training load management. As the results of this study show, external and internal variables are complementary methods for monitoring training load. These methods are probably more effective than using only sRPE training load and training volume when the physical fitness level of players is to be assessed[29]. In order to perform at the optimal level in competitions, players need to accumulate a high amount of load, but with a particular distribution. It can be suggested that players experience a decrement (p.e.≈42%, ≈34% and ≈24% in MD-3, MD-2 and MD-1, respectively) in training load in the three days prior to the match, which leads to the enhancement of their physical condition, as a result of the so-called supercompensation phenomenon[2]. In elite basketball, as this dose-response investigation presents, a progressive decrease in training loads three days before the match could be an appropriate way of physical conditioning in a preparation of a team for competitive tasks.

One of the limitations in the current study was the lack of comparison group. However, that kind of experimental design is not available when the study is conducted in top-level performance teams. In the future, research in elite basketball should examine the effectiveness of different models of load distribution prior to the match day in correlation with both physical and key performance indicators in games.

5.5. CONCLUSION

Training load management is a crucial factor that leads to either enhanced or decreased physical condition in competitions. Basketball is an intermittent sport where accelerometry – derived data on individual accelerations, decelerations, jumps, changes of direction and PlayerLoad – provides a stable and clear platform for tracking and analyzing training load. Therefore, if training load is appropriately selected, coaches can find the most effective micro-tapering models prior to the match. According to the findings of this study, the accumulated PL of ≈1048 AU with ratio of ≈ 42 %, 34 % and 24 % in MD-3, MD-2 and MD-1 respectively, could be appropriate load distribution, as it leads to a very good physical condition on the match day. Moreover, the current study demonstrates that the use of different approaches to monitor training load provides a better micro-cycle (i.e. week) assessment and implementation of the short-term tapering prior to the games at the elite basketball level. Complementary monitoring of both external and internal loads provides a comprehensive insight about training demands and psycho-physiological responses in players. Successful training load monitoring across the pre- and in-season phases should be performed for two main reasons; to decrease injury risk and provide optimal level of stress and adaptation that leads to enhanced physical and competitive performance. Nevertheless, solely monitoring of training load is not enough to ensure a good management of the load. Complementary to load monitoring methods, coaches should assess players' state of recovery and readiness to play. In this paper, use of the TQR questionnaire was presented. However, complementary use of subjective and objective (e.g. creatin kinease values, heart rate, jumping performance) methods is advised. The practical implications may be further enhanced by understanding players' mental and physical states regarding the day of the week and its proximity to the match-day. Only in this way, coaching staff will manage to optimize the players' performance. Therefore, future research in basketball should provide more information on a) the accelerometry-derived game load, so that even better relationships can be established between training and competitive demands and b) the effects of sleep quality and mentality during travels on players' readiness and performance in competitions.

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CHAPTER 6

POSITIONAL DIFFERENCES IN ELITE BASKETBALL: SELECTING APPROPRIATE TRAINING-LOAD MEASURES

Abstract

Purpose: The purpose of this paper was to study the structure of interrelationships among external training load measures and how these vary among different positions in elite basketball. **Methods:** Eight external variables of jumping (JUMP), acceleration (ACC), deceleration (DEC) and change of direction (COD), and two internal load variables (RPE and sRPE) were collected from 13 professional players with 300 session records. Three playing positions were considered: guards (n=4), forwards (n=4) and centers (n=5). High and total external variables (hJUMP and tJUMP, hACC and tACC, hDEC and tDEC, hCOD and tCOD) were used for the principal component analysis. Extraction criteria were set at the eigenvalue of greater than one. *Varimax* rotation mode was used to extract multiple principal components. **Results:** The analysis showed that all positions had two or three principal components (explaining almost all of the variance), but the configuration of each factor was different: tACC, tDEC, tCOD and hJUMP for centers, hACC, tACC, tCOD and hJUMP for guards, and tACC, hDEC, tDEC, hCOD, and tCOD for forwards are specifically demanded in training sessions and, therefore, these variables must be prioritized in load monitoring. Furthermore, for all playing positions, RPE and sRPE have high correlation with the total amount of ACC, DEC and COD. This would suggest that, although players perform the same training tasks, the demands of each position can vary. **Conclusion:** A particular combination of external load measures is required to describe training load of each playing position, especially to better understand internal responses among players.

Keywords: playing position, team sport, time motion, RPE, training

6.1. INTRODUCTION

Athlete monitoring is the key to successful load management as well as to defining the quantity, quality and order of the content and its alterations with rest periods.[1] These prescriptive parameters must be considered by coaches when developing training plans. The management of the training load has received a lot of attention in recent years[2,3] due to its important role in improving performance and mitigating injuries.[4]

Accurate monitoring of the training load provides the coach with a better understanding of individual tolerance to training[5] and provides a solid basis for optimal training periodization. In order to understand the relationship between the training 'dose' and 'response', complementary use of external and internal load[6] is necessary to choose the best approach to optimally improve performance[7]. While external training load (eTL) represents the dose (activities) performed by players[1], internal training load (iTL) represents the psycho-physiological response (acute and chronic adaptations) by the athlete[8], and this process is individual[1] knowing the fact that the same external load can lead to different internal load in different players. Nevertheless, in team sports, training load is mainly derived from team practices, i.e. a combination of position-specific and non-position-specific tasks. Consequently, both external and internal loads can vary among players. In contrast to amateur level, sub-elite and elite basketball teams strive for the highest level of performance and for that reason data from high-level basketball should help coaches in everyday practice, especially knowing the fact that number of teams using modern micro-technologies has been growing in recent years.

At the elite level of play, an enormous amount of data about training sessions and games of a team is generated daily[4]. New technologies and analytical methods have led to new possibilities for monitoring load. In indoor sport, devices with micro-technologies (e.g. accelerometer, gyroscope and magnetometer) have produced a plethora of variables, enabling practitioners to quantify load in greater detail than ever before.[2] Since the implementation of this technology has begun only recently, there is not enough data to describe external training demands of basketball players[9]. Even though subjective load measures are not recommended to be used in isolation, they may be employed by coaches and the support staff with confidence to complement the objective measures or to substitute them in situations where such technology is not available.[3]

It is overwhelming to try to use all of the variables that are now available for each second of the activity. Implementing principal component analysis (PCA), which has been previously proposed[10] to measure training modes, could be a useful option to remove the redundancy in variables used to monitor load or to know if players are stimulated similarly, according to their playing position. The previous research[11,12] of elite-level players has confirmed differences between guards, forwards and centers in various parameters such as number and intensity of movements, blood lactate concentration and heart rate values during games. However, the aforementioned studies considered subjective movement observations that are time-consuming, compared to more practical micro-technology that offers very quick data turnaround. Currently, only one study[13] has investigated position-dependent differences in basketball drills using micro-technology where only one external load variable was presented (i.e. acceleration load). Therefore, additional information regarding position-specific data derived from micro-technologies is of utmost importance.

Therefore, the purpose of the current study was to investigate the structure of interrelationships among the external and internal training session loads and determine how they vary among different positions in elite basketball via use of modern micro-sensor technology. The potential application of results is twofold: they may be used to avoid redundant information when assessing the training load using different variables, as well as to identify what variables are position-dependent based on the inertial movement patterns and subjective load measures of each playing position in elite basketball training.

6.2. METHODS

6.2.1. Subjects

The professional male basketball players played on the same team (positions defined by the head coach; guards, age: 26.3 ±2.2 years; height: 186.0 ±4.3 cm; body mass: 88.0 ±8.6 kg; body fat: 10.6 ± 1.7%; forwards, age: 25.0 ± 4.1 years; height: 199.4 ± 4.1 cm; body mass: 93.7 ± 2.2 kg; body fat: 10.2 ± 1.3%; centers, age: 25.8 ± 3.8 years; height: 209.6 ± 2.7 cm; body mass: 105.8 ± 4.1 kg; body fat: 11.0 ± 1.1%; elite level experience 2-12 years). The team competed in two basketball championships, Liga Endesa (i.e. 1st Spanish Division) and the Euroleague, in the 2016/17 season. The weekly schedule consisted of two games (first on Thursday/Friday and second on Sunday), one rest day (Monday), and one team practice on each of the remaining days. All players were notified of the aim of the study, research procedures, requirements, and benefits and risks before giving informed consent, in accordance with the Declaration of Helsinki. Furthermore, the data was anonymized and institutional approval was given for this study.

6.2.2. Design

Thirteen elite-level basketball players were monitored during in-season competitive periods (16 weeks). Players were assigned to one of the three positional groups: (guards, n = 4; forwards, n = 4; and centers, n = 5). A total of 300 training observations were undertaken with a range of 4-26 training sessions per player. Training observations for each positional category were 84, 102 and 114 for guards, forwards and centers, respectively. Only the data derived from team training sessions (Tuesday to Wednesday/Thursday) prior to the first game of the week (i.e. Euroleague game on Thursday or Friday) were included in the analysis due to adjustments in team sessions prior to the second game (e.g. some players with more playing time in the first game would partially participate in the practices on Friday and Saturday due to accumulated fatigue). After the team warm-up and movement preparation, no-contact drills (4vs0 and 5vs0) and small-sided games (3vs3, 4vs4 and 5vs5) were used on a half and full-court size. The observation started after warm-up and movement preparation and lasted until the end of the practice, taking between 60 and 75 minutes. All players were observed simultaneously. Official matches (use is not permitted in both competitions), strength and recovery sessions, and individual basketball practices were not included in the investigation.

6.2.3. Procedures

The eTL was monitored using Catapult Innovations S5 devices (Melbourne, Australia), which include the accelerometer, gyroscope and magnetometer sensors, which provide data for inertial movement analysis (IMA). Most variables derived from the inertial sensors/accelerometers (only via micro-technology) were used.[2] All the variables were monitored using 100-Hz frequency. This kind of technology was previously confirmed as both valid and reliable.[14]

The iTL was monitored via RPE and the session-RPE (sRPE). Individual RPE was obtained using the 10-point Borg scale on which players rated their perceived physical effort 15-30 minutes after the training, in accordance with the procedures suggested by Foster et al.[15] in order to avoid the influence of the last part of the session on players' perception. Furthermore sRPE was calculated by multiplying RPE with the training duration expressed in minutes. sRPE has been reported to be a valid indicator of global internal load of training in intermittent team sports.[6] All the players were familiarized with the use of the scale during the preparatory period.

External and internal training load

The eTL data included the following variables: accelerations (ACC), decelerations (DEC), jumps (JUMP) and changes of direction (COD). The ACC variable refers to inertial movements registered in a forward acceleration vector, where tACC refers to all accelerations and hACC only to high-intensity accelerations ($>3.5\ m\cdot s^{-2}$). The DEC variable refers to inertial movements registered in a forward deceleration vector, where tDEC refers to total movements and hDEC only to high-intensity movements registered within the high threshold ($>3.5\ m\cdot s^{-2}$). The time interval during which acceleration is measured can significantly affect the data.[2] Based on the study results of Varley et al.[16] who concluded that is difficult to provide an appropriate *dwell time* or minimum effort duration (MED) with acceleration efforts, the dwell time in present study was selected to 0.4s. The jumps were also registered as total jumps (tJUMP) and high-intensity jumps (hJUMP, over 0.4 m), the same as changes of direction, tCOD (total inertial movements registered in a rightward/leftward lateral vector), and hCOD (total inertial movements registered in a rightward/leftward lateral vector within the high-intensity threshold). All aforementioned variables were assessed with respect to their frequency. The iTL was recorded using RPE and session-RPE (sRPE) in order to distinctly quantify intensity and load of training session.

6.2.4. Statistical analysis

Before carrying out Principal component analysis (PCA), the Pearson correlation matrix with eight training external load variables was conducted in order to perform a visual inspection of data factorability.[17] This method aims to extract the most important components and/or variables from data, without reducing the information. All data were centred and scaled (using within-individual data) before conducting the PCA. The Kaiser-Meyer-Olkin (KMO) values for three playing positions (center, guard and forward) were 0.85, 0.84 and 0.85, respectively, showing that the dataset is suitable for PCA.[18] Bartlett's sphericity test was significant for each training mode ($p<0.001$). The principal axis method was used to extract the components. Components with the eigenvalues of less than 1 were not retained for extraction.[18] The PCA was applied with a *VariMax* rotation to identify components that are not highly correlated. Consequently, each principal component provided distinct information. Subsequently, the rotation was performed with the goal of making the component loadings more easily interpretable. The stages involved in the calculation for PCA were the same as those used previously.[10] For each extracted PC, only the original variables that possessed a PC loading greater than 0.7 were retained for interpretation. Finally, the correlation between external and internal load variables was measured for each playing position. As proposed by Hopkins[19], the following qualitative correlation descriptors were used: trivial (0 – 0.09), small (0.1 – 0.29), moderate (0.3 – 0.49), large (0.5 – 0.69), very large (0.7 – 0.89), nearly perfect (0.9 – 0.99), and perfect (1). The Statistical Package for the Social Sciences (SPSS, Version 24.0 for Windows; SPSS Inc, Chicago, IL) was used to conduct the analysis.

6.3. RESULTS

A total of 300 observations of team training sessions were monitored for investigation and the data was distributed across three playing positions (Table 1).

Table 1. Means ± SD of internal and external training load measures according to playing position.

	Guards (n=84)		Forwards (n=102)		Centers (n=114)	
Variables	Mean	SD	Mean	SD	Mean	SD
tACC (n)	43.5	17.5	42.0	21.5	59.5	27.1
hACE (n)	6.4	4.4	5.8	4.3	7.2	4.8
tDEC (n)	84.7	30.1	93.2	35.4	88.5	30.3
hDEC (n)	11.9	5.7	12.7	8.3	6.8	4.0
tCOD (n)	324.8	110.2	336.8	121.4	312.1	114.8
hCOD (n)	23.5	12.5	24.7	14.5	16.8	8.6
tJUMP (n)	45.9	18.2	53.7	20.4	49.2	20.4
hJUMP (n)	13.3	6.1	12.5	6.1	13.6	7.8
RPE (AU)	6.7	1.7	6.5	1.5	6.6	1.3
sRPE (AU)	402.9	151.8	385.5	137.3	385.1	121.6

Note: tACC is total forward acceleration, hACC is high intensity acceleration (>3.5 $m \cdot s^{-2}$), tDEC is total deceleration, hDEC is high intensity deceleration (<-3.5 $m \cdot s^{-2}$), tJUMP is total jumps, hJUMP is high intensity jumps (above 0.4 m), tCOD is total rightward/leftward lateral movements, hCOD is high intensity movements registered in a rightward/leftward lateral vector. RPE is measurement of perceived exertion, and sRPE is session-RPE.

Table 2 shows PCA, including the eigenvalues for each principal component in each playing position and the total explained variance by each principal component for each playing position. In each playing position, two (for centers) or three (for forwards and guards) principal components were identified, but with different distribution of the internal and external load variables.

Table 2. Results of the PCA, showing the eigenvalue, percentage (%) of variance explained and the cumulative % of variance explained by each Principal Component (PC) for each playing position. Also showing the rotated training load component loadings for each PC extracted (values below 0.3 were removed).

		PC							
Playing position		1	2	3	4	5	6	7	8
Guards	Eigenvalue	4.58	2.28	1.14					
	% of V.	57.22	28.50	14.28					
	C. V. %	57.22	85.72	100.00					
	tACC	0.82	0.52						
	hACC	0.99							
	tDEC		0.97						
	hDEC	0.63	-0.37	0.68					
	tCOD	0.98							
	hCOD		0.33	0.94					
	tJUMP	0.59	-0.74	-0.33					
	hJUMP	1.00							
Forwards	Eigenvalue	5.10	1.89	1.02					
	% of V.	63.71	23.58	12.72					
	C. V. %	63.71	87.29	100.00					
	tACC	0.90	0.41						
	hACC	0.30	0.93						
	tDEC	0.96							
	hDEC	0.88	0.47						
	tCOD	0.91	-0.39						
	hCOD	0.97							
	tJUMP		0.99						
	hJUMP			0.99					
Centers	Eigenvalue	5.56	1.88	0.32	0.18	0.06	0.01		
	% of V.	69.52	23.45	3.95	2.22	0.71	0.15		
	C. V. %	69.52	92.96	96.91	99.14	99.85	100.00		
	tACC	0.99							
	hACC	0.61	0.75						
	tDEC	0.99							
	hDEC	-0.33	0.88						
	tCOD	0.99							
	hCOD	-0.89							
	tJUMP	0.37	0.87						
	hJUMP	0.95							

Note: tACC is total forward acceleration, hACC is high intensity acceleration (>3.5 $m \cdot s^{-2}$), tDEC is total deceleration, hDEC is high intensity deceleration (<-3.5 $m \cdot s^{-2}$), tJUMP is total jumps, hJUMP is high intensity jumps (above 0.4 m), tCOD is total rightward/leftward lateral movements, hCOD is high intensity movements registered in a rightward/leftward lateral vector.

Pearson correlations between internal and external training load variables for each playing position are presented in Table 3.

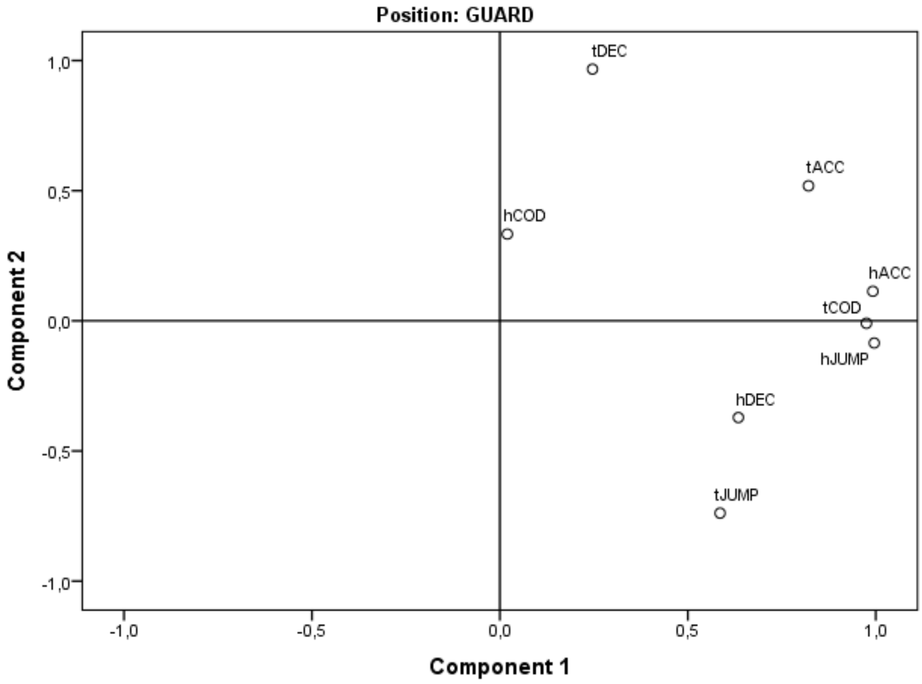
Table 3. Pearson correlations for internal and external training load measure for each playing position. All correlation had a significant value at >0.001 level.

	Guards		Forwards		Centers	
Variable	RPE	sRPE	RPE	sRPE	RPE	sRPE
tACC	.605	.686	.480	.614	.516	.710
hACC	.311	.462	.422	.480	.429	.582
tDEC	.723	.806	.497	.680	.452	.679
hDEC	.557	.665	.262	.463	.322	.542
tCOD	.679	.779	.585	.777	.592	.760
hCOD	.405	.482	.394	.574	.381	.555
tJUMP	.400	.453	.348	.440	.124	.320
hJUMP	.577	.655	.351	.482	.060	.311

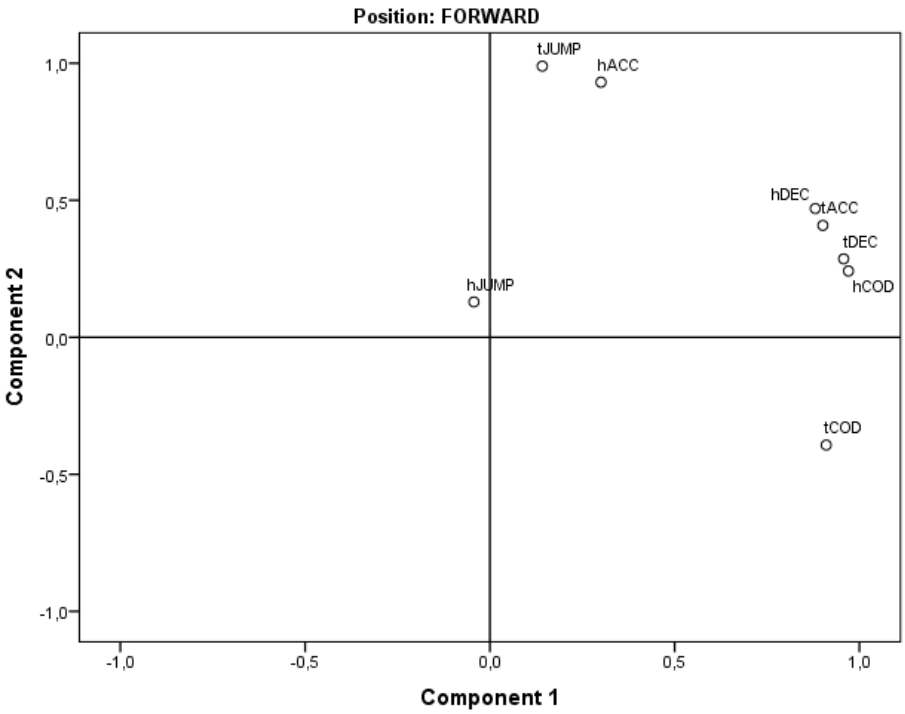
Note: tACC is total forward acceleration, hACC is high intensity acceleration (>3.5 $m \cdot s^{-2}$), tDEC is total deceleration, hDEC is high intensity deceleration (<-3.5 $m \cdot s^{-2}$), tJUMP is total jumps, hJUMP is high intensity jumps (above 0.4 m), tCOD is total rightward/leftward lateral movements, hCOD is high intensity movements registered in a rightward/leftward lateral vector. RPE is measurement of perceived exertion, and sRPE is session-RPE.

Figure 1 shows rotated component plots for each playing position. Only two main factors were plotted to visually represent playing position differences. For all playing positions, two to three principal components were retained for extraction, including their position within the rotated space.

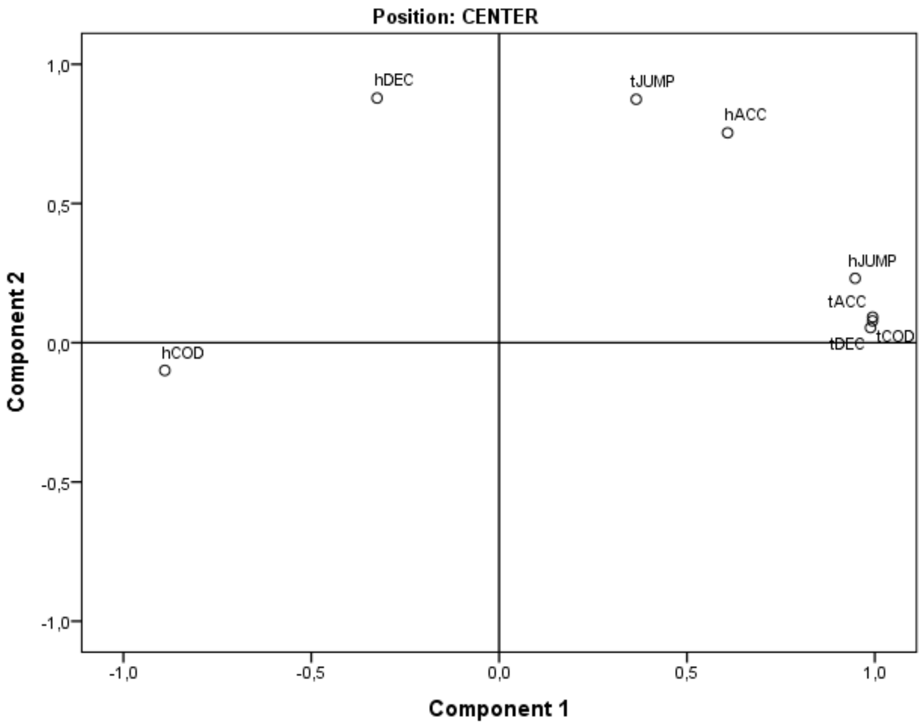
Figure 1. Rotated component plots of the playing positions: a) guards, b) forwards and, c) centers.



a)



b)



c)

Note: tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 m·s-^{2}), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 m·s-^{2}), tJUMP is total jumps, hJUMP is jumps done at the high band (above 0.4 m), tCOD is total rightward/leftward lateral movements, hCOD is total movements registered in a rightward/ leftward lateral vector within the high band.

6.4. DISCUSSION

The main finding of the present study was the identification of a structure with two or three principal components summarizing several external training load variables, which showed a different weight of variables depending on the playing position. Although the initial number of factors was the same as the number of variables used in the factor analysis – since factors where initial eigenvalues were more than 1 were used – only the first two factors for centers and three for forwards and guards were retained for playing positions. For the three playing positions studied, the cumulative percentage of variance accounted for by the second row (factor) and the first preceding factor showed values close to 90% of the total variance. Complementary, only two components obtained for centers could denote less variability in their movement patterns, maybe due to higher static exertion (e.g. doing screening/picking and positioning) activity when playing in this role[20]. For all playing positions, tACC and tCOD are relevant in their activity profiles. Considering the above said, we can conclude that these two or three factors (depending on playing position) adequately represent the original data.

When looking at the first principal component, which explains the greatest proportion of variance, the representation of the external load variables was position-dependent. For all playing positions, tACC and tCOD were common. Additionally, for forwards and centers, the tDEC activity is a representative in their profiles while for the guards this variable is in the second component. This is in line with the profile in activity demands in a multi-directional team sport, such as basketball, where the number of activity changes can range between 997 and 2733 per game[21]. For centers and guards, the hJUMP external load variable was also the most representative for the first factor in their profiles of activity, while additionally, tDEC was representative for both forwards and centers. The hJUMP variable for centers can be explained due to greater efforts when catching rebounds and for guards when shooting after intense penetration towards the basket.

Differences in the profile of playing positions are interesting. Compared to research of Puente et al.[22], who studied internal and external loads in friendly games with respect to playing positions, in the current study that investigated training sessions, players were demanded in a different way: hACC for guards, hDEC and hCOD for forwards. For that reason, the movement profile of each playing position is particular. Guards and forwards profiled more high activity actions than centers (e.g. hACC and hJUMP for guards and hDEC and hCOD for forward, centers only hJUMP). This could be explained due to minor movement frequency and intensity of centers in the game, as it was also proposed in previous research for total[11, 12] and high-intensity[11] actions. Additionally, centers are players who are positioned closer to the basket due to their height, what could further limit their movement area.

On the other hand, the content for the second component was different for each playing position. Variables tJUMP and hACC had impact for both forwards and centers, tDEC for guards and hDEC for centers. The aforementioned finding could be explained due to different physical demands of same training drill for each playing position. Additionally, it can be observed that tJUMP variable is not representative in physical profile of guards while for forwards and centers it is representative in the second component. This finding could indicate that jumps are not very frequent movement pattern in basketball training and game, like it was observed in previous research[11] (41-56 jumps per game), especially when compared to changes of direction, accelerations and decelerations.

Body height and body mass are known to be the main individual factors to define the court position of a basketball player. The anthropometric profile of participants in this study was similar to previous reports in Serbian[23], French[24] and Belgium[25] elite basketball players. Different anthropometric profiles of basketball players, which are highly relevant to the playing position, could probably be the main factor explaining effects that playing positions have on the relationships between external training demands measures during the same training sessions. The aforementioned is in the line with two principles of Schelling and Torres[13] who explain that smaller player has lower body mass, and therefore easier position to accelerate with less applied force. Moreover, playing zones for big players are more reduced compared to small players, meaning that small players ultimately cover more distance in each action on the court. Knowing that, based on the correlation values between external variables and internal response (sRPE) among centers for total (r = 0.71) and high accelerations (r = 0.58) it can be concluded that application of aforementioned variables will cause a greater internal response among centers compared to guards and forwards. In the same line, other variables such as total and high decelerations for guards and high changes of direction for forwards will cause greater internal response what could eventually lead to similar RPE and sRPE values among all playing positions.

Furthermore, the correlation between internal and external values provides interesting information. The sRPE shows greater correlation with external variables, compared to the RPE. Total values of variables such as ACC, DEC and COD (tACC, tDEC and tCOD, respectively) showed large or very large correlation with sRPE. Similary, Scanlan et al.[26] reported a moderate correlation between sRPE and accelerometer training load. However, in aforementioned research only one external load variable was reported. In our research, in all playing positions, one or more external load variables showed large or very large correlations with sRPE. In all playing positions studied, tCOD showed either a high correlation (for forwards) or a very high correlation (for centers and guards) with the sRPE. The strong correlation between eTL and iTL provides better understanding of stress-response relationship and therefore gives better insight into load management.

A lack of information on the type of drills used in the training sessions is one of the limitations of the present study. It is possible that the amount of time spent on both position-specific and non-position-specific tasks could affect the obtained results. The second limitation involves absence of differentiation between training modes. Following the recent "match day minus" format, used recently in other team sports, such as football[4], where each training session is categorized by its proximity to the match-day, a specific distribution of training load amount in the days preceding the match is typically employed[27], promoting a functional, short-term tapering for the competition ahead[1,28]. In those cases, other factors and correlations between variables can emerge. Consequently, further research is required to establish the dose-response relationship in different training modes for different combinations of external and internal load values, preferably for individuals, or, if this is not possible, for specific playing positions.

These results provide very interesting findings. Firstly, a combination of external load variables explains a higher proportion of the variance observed in professional basketball training, regardless of the playing position. Secondly, although players participate in the same drills during the team training sessions, the demands are not equal for all positions. Therefore, it could be interesting to take into account different types of external training load measures, as the use of only one external training load measure for all players may be both insufficient and incorrect. As it is presented throughout the paper, each playing position is represented with specific activities in external load variables spectrum and therefore their complementary use for different playing positions could be an appropriate way to select, analyze and control training loads. Additionally, adequate load management could prevent overuse injuries in professional basketball players.[29]

6.5. PRACTICAL APPLICATION

Findings in this study focus on training data and therefore can help coaches enhance the effectiveness of their training programs. It is obvious that particular movement patters should be highlighted in a specific type of team conditioning demanding that centers focus on accelerations and changes of direction, forwards on decelerations and changes of direction, and guards on decelerations. A combination of internal and external variables should be considered when deciding to measure training load. These methods are of different construct so their complementary use integrates data analysis and application in practice. As basketball is an intermittent team sport, inertial movements (acceleration, deceleration, change of direction and jump) have an important role in external training load monitoring in basketball. Despite the fact that players train together, differences in training load among playing positions exist, and coaches and conditioning specialists should be aware of them. Once coaches consider positional differences in basketball, optimal training loads can be selected together with management of other important aspects such as individual basketball development, preventive protocols and recovery.

6.7. CONCLUSION

The conclusion of the study was that a combination of several load measures is required to describe the load of the three playing positions in basketball training sessions. The authors agree with the suggestion by Williams et al.[30] that the training load monitoring process may be optimized by selecting and monitoring the most parsimonious set of variables, as this simplifies the analysis of training-load measures in team sport settings. Therefore, acceleration and change of direction for centers, deceleration and high jumps for guards and high and total amount of deceleration and change of direction for forwards are specifically demanded in professional basketball training. Future research should focus more on the application of accelerometry in elite basketball, especially in the analysis of small-sided games and positional differences.

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CHAPTER 7

A COMPARISON OF 5vs5 TRAINING GAMES AND MATCH-PLAY USING MICRO-SENSOR TECHNOLOGY IN ELITE BASKETBALL

Abstract

The aim of this study was to compare the data obtained using micro-sensor technology in two types of 5vs5 training games – the regular-stop game (RSG) and the no-stop game (NSG) – and in match-play (MP) in elite basketball. Sixteen top-level basketball players were monitored during pre- and in-season periods (10 weeks). The variables included: PlayerLoad (PL), accelerations (ACC), decelerations (DEC), changes of direction (CoD) and jumps (JUMP) – all in both total (t) and high intensity (h) relative values (i.e. per minute of play): PLmin, ACCmin, DECmin, CoDmin and JUMPmin, respectively. Almost all variables showed trivial difference between MP and RSG. The only variable that showed small difference was tACCmin (MP>RSG). In case of RSG vs. NSG, three variables showed trivial difference – tACCmin, hACCmin and hDECmin, three (i.e. hCODmin, tDECmin and PLmin) small differences and three (tCoDmin, tJUMPmin and hJUMPmin) moderate differences (NSG>RSG). In MP vs. NSG two variables (hCoDmin and tACCmin) showed trivial differences, variable hDECmin showed small difference while the other five variables (tCoDmin, tJUMPmin, hJUMPmin, tDECmin and PLmin) showed moderate difference (NSG>MP). Only one variable, hACCmin, showed moderate difference,

where MP>NSG. The main conclusion of the study was that by introducing some constraints into 5vs5 tasks, the coaching staff could elicit higher physical demands than those occurring in MP. By understanding the differences in demands of NSG, RSG and MP coaches in elite basketball can improve their system of training drills selection, especially when looking for optimal short-term tapering approach leading up to the game day.

Key words: team sport, training task, game, inertial movement analysis

7.1. INTRODUCTION

In recent years, elite basketball in Europe has moved towards the congested fixture, where the teams that participate in both Euroleague and domestic championships play two to three games per week in the regular part of the season. During play-offs, these teams could play as many as five games over a 10-day period. In total, elite Spanish teams could finish their seasons with up to 87 games played. The aforementioned phenomenon requires all members of the coaching staff, and especially performance specialists, to fully understand the training demands and physiological responses in employing various training drills. Therefore, the choice of drills could be crucial in setting up optimal training workload before competitions, which will eventually result in optimal short-term tapering and enhanced players' psycho-physical state. As presented in the latest review by Stojanovic et al. (21), there are numerous papers indicating significant differences in activity frequency and intensity between players of different playing level. Therefore, practitioners in elite basketball should be provided with reliable scientific data, while studies conducted on youth teams or semi-professional players need to be interpreted with caution.

In practice, training drills can be divided into two major categories with respect to the conditions of play: no-contact and contact drills. No-contact drills (referred to as *directed* drills by Schelling & Torres-Ronda (20)) enable coaches to work with players individually or in groups on developing technical qualities such as ball handling, passing, dribbling or shooting. Moreover, no-contact drills, like 2vs0 up to 5vs0, are used to practice team's tactical principles. On the other hand, contact drills (referred to as *special* and *competitive* tasks by Schelling & Torres-Ronda (20)), such as various small-sided games (SSG) and game simulations (GS), are used to master individual technical skills as well as to develop teams' tactical proficiency and specific basketball endurance (8). Regarding the number of players, it is important to know that SSG normally consider 1vs1 up to 4vs4 confrontation format, while 5vs4 and 5vs5 formats are used as GS (20). The use of SSG, also known as small-sided and conditioning games (SSCGs), has been adopted in practice as an alternative to traditional team conditioning (8,12,19,20). In this respect, it is important to note that the number of SSG investigations conducted on elite players in basketball is very limited, with only two such studies (19,23) known to the authors. Torres-Ronda et al. (23) have found that a higher physiological response (via heart rate monitoring) was elicited in match-play (MP), 5vs5 training game, and 3vs3 open-court training drills as compared to other drills, such as 5vs5 half-court, 2vs2, 4vs4, etc. Additionally, the relative frequency of movements per minute of play, as assessed using notational analysis (using Lince software), did not differ between MP and 5vs5 open-court and half-court drills (33±7, 32±4 and 31±4, respectively). It is important to know that despite the fact that Lince is a valuable source of information in the analysis of sports performance, the use of micro-technology (e.g. inertial movement sensors) could help us better understand physical demands and performance in trainings and games.

Constraints in the court size, number of players, work:rest ratio or rules of the play (8) are some of the factors that need to be investigated in depth if we are to better understand the demands of each SSG and GS. For example, full-court drills are both physically and physiologically more demanding than those conducted on the half-court (13,15). Moreover, fewer players on the regular court size will be exposed to a major physiological stress (7,9,10,12,13,18,23). With more players on the court, fewer technical actions per player will be conducted (19). Furthermore, the change of rules, such as no-dribble tasks, lead to an increase in physiological load and a higher number of passes (11). However, the majority of studies on SSG and GS in basketball were conducted with the use of heart rate monitors, notational analyses or blood lactate concentrations, while only few studies of trainings and games used the technology of micro-sensors (15,19).

The study of elite players by Schelling and Torres-Ronda (19) used tri-axial accelerometer in training settings and showed that playing full-court 3vs3 and 5vs5 scrimmage drills elicited higher acceleration load per minute (AL/min) as compared to full-court 2vs2 and 4vs4 drills and 5vs5 half-court drill. However, the study investigated only one type of metric (i.e. acceleration load per minute, AL/min). The study by Montgomery et al. (15) investigated differences between MP and 5vs5 half-court scrimmage games among junior players also by looking at a single variable (i.e. AL/min) and it was observed that MP put higher physical demands on the players than the 5vs5 scrimmage game on the half-court (279±58 as compared to 171±84a.u./min). Finally, it is important to state that no studies have presented objective micro-sensor technology data of elite MP to date, nor provided a comparison of any SSG and GS to MP. The use of modern technology, such as tri-axial accelerometry provides reliable data (2,24) for the prescription and management of the external load. As it is suggested by Weiss et al. (25), maintaining the workload ratio between 1-1.5 may be optimal to reduce injury risk in professional basketball players.

Based on the data collected during games, coaches are able to objectively quantify and compare all of the drills they use in practice in order to improve teams' performance, as data from match-play serves as a platform for understanding and prescribing physical demands for various training drills. Therefore, the goal of this study was to compare micro-sensor technology data in two types of 5vs5 training games (one game that replicates games conditions and other that intents to overload) with that in MP in elite basketball. The results of this study could help coaches in the selection of training drills and periodization of practices in elite-level basketball.

It was hypothesized that no-stop 5vs5 training game will elicit greater physical demands than regular-stop 5vs5 training game and match-play.

7.2. METHODS

7.2.1. Experimental approach to the problem

Sixteen top-level basketball players were monitored during the pre- and in-season periods (September-October). A total of 12 trainings (five no-stop and seven regular-stop games) and five games were analysed, with a total number of 385 records made. Out of all records, 208 were training records (9.5±5.6 per player) and 177 game records (10.7±5.5 per player). One record considered data collected by players' participation in game, lasting for at least 1 minute. The training games inertial movement data was obtained during team basketball sessions, while MP data was recorded during tournaments against ACB (Spanish 1st division) and international teams that compete in the Eurocup competition.

As a working hypothesis, it was assumed that the no-stop game (NSG) would put the greatest physical demands out of all investigated games. This was assumed due to the fact that regular no-activity periods (i.e. ball out-of-bounds reposition after ball is handed by referee, free throws shooting) were eliminated in NSG what potentially leads to intensification of the game. Additionally, it was assumed that regular-stop game (RSG) will be less demanding than MP due to players' greater mental and physical efforts during real-opponent conditions compared to those that occur in training.

7.2.2. Subjects

The subjects in this study were professional male basketball players who played on the same team (age: 26.2 ± 4.0 years; height: 199.9 ± 9.8 cm; weight: 97.2 ± 12.1 kg). The team participated simultaneously in two official competitions, ACB and the Euroleague, during the 2017/18 season. All players volunteered to participate in the investigation and were notified of the aim of the study, research procedures and requirements as well as the benefits and risks before giving their informed consent, in accordance with the Declaration of Helsinki. Furthermore, data was anonymized and institutional approval was given for this study.

7.2.3. Physical demands

The external training load was recorded using Catapult Innovations T6 devices (Melbourne, Australia) that include accelerometer, gyroscope and magnetometer technologies, which provide data for inertial movement analysis (IMA). Due to the differences in tasks and the MP duration, all variables were reported relative to time played: player load per minute (PLmin), accelerations per minute (ACCmin), decelerations per minute (DECmin), changes of direction per minute (CoDmin) and jumps per minute (JUMPmin).

The PLmin was recorded using the tri-axial accelerometer (100 Hz, Dwell time 1 second) based on the player's three-planar movement, applying the established formula (6). ACCmin and DECmin variables involved the total and high-intensity inertial movements: tACCmin refers to total inertial movements registered in a forward acceleration vector; hACCmin are total inertial movements registered in a forward acceleration vector within the high band ($>3.5\ m\cdot s^{-2}$); tDECmin are total inertial movements registered in a forward deceleration vector; and hDECmin are total inertial movements registered in a forward deceleration vector within the high band ($<-3.5\ m\cdot s^{-2}$). Moreover, total jumps per minute (tJUMPmin) and jumps done within the high band (hJUMPmin, over 0.4 m) were registered. Finally, two variables involved a change of direction (CoD): tCoDmin, which represents total inertial movements registered in a rightward/leftward lateral vector and hCoD, which represents total inertial movements registered in a rightward/leftward lateral vector within the high band ($<-3.5\ m\cdot s^{-2}$). The aforementioned variables (i.e. ACC, DEC, CoD) were previously investigated as part of accelerometer-derived data validity and reliability studies (1,4,5,14,24) where TE (i.e. typical error) for different ranges of acceleration varied from 0.18 – 0.20 $m\cdot s^{-1}$ (24) and from 0.05 – 0.12 $m\cdot s^{-1}$ (1). Furthermore, these types of variables were previously used in elite basketball investigations (22). Finally, for the purposes of this study, both validity and reliability of the JUMP variable were estimated through a regular jumping test protocol, well known to all participants from previous jumping performance measurements. While wearing simultaneously two micro-technology sensors, each of six players tested performed ten vertical jumps (measured with Optojump® photoelectric system, Microgate, Bolzano, Italy). The results of the ICC for validity were 0.45, 0.40 and 0.82, while the ICC for reliability were 1.0, 0.98 and 0.51 for <20, 20 – 40 and >40 ranges, respectively. The overall ICC for validity and reliability was 0.85 and 0.92, respectively.

7.2.4. Procedures

Two types of training games were studied: the no-stop game (NSG) and the regular-stop game (RSG). The games were performed under the official basketball rules in the regular 5vs5 format on the full court. However, some changes (see Table 1) were applied to the NSG: the activity was not stopped after fouls. In this task, players were instructed to make a quick sideline or baseline ball reposition. Additionally, there were no free throws in this game. The duration of NSG was 5 minutes. In case of RSG, free throws were allowed and they required the clock to be stopped. The same applied to ball-out-of-bounds. The goal of RSG was to replicate demands of a real basketball game. Therefore, the average time required to finish a 5-minute RSG was 7 min and 40 sec (±40 sec).

Table 1 Description of the rules in the no-stop game (NSG) and the regular-stop game (RSG).

NO-STOP GAME	REGULAR-STOP GAME
▪ Clock is not stopped ▪ No free-throw after a foul ▪ Quick ball-in-play reposition ▪ No time-outs	▪ Clock is stopped when the ball is out-of-bounds ▪ Clock is stopped for fouls ▪ Free-throws were given when the foul occurred during an attempt to shoot ▪ Regular ball-in-play reposition ▪ One time-out allowed per set*

Note: *If time-out was used during the game, it was excluded from the data analysis.

Depending on the training plan, the players played 2-3 sets with a typical 4-minute (±30 seconds) rest period. During rest periods, the players watched a video to analyse and discuss previous actions and were suggested to drink water *ad libitum*. NSG and RSG were a part of the team basketball practice that started out with a standardized warm-up and movement preparation followed by technical drills and no-contact tactical drills (e.g. shooting, 3vs0, 5vs0). The duration of trainings where data were collected was 80 min (±3.3 min).

Five real basketball games (i.e. MP) were recorded during two official pre-season tournaments and one international cup game. Each game started with a standardized 25-minute team warm-up and movement preparation. After that, four 10-minute quarters with a 15-minute rest interval at halftime and a 2-minute break between the first and the second and between the third and the fourth quarters were monitored. Overall game time was 103 minutes (±8 min and 15 sec). The average time that the players spent in the game was 17.2 min (±7.6 min) with average 2.5 (±1) records per game lasting for 9 min and 20 sec (±3 min and 20 sec). Only active players (i.e. players in the game) in each quarter were included in analysis, while time-outs were excluded from the analysis, the same as in SG.

Data collected from RSG, NSG and MP was downloaded and analysed via use of Openfield software, version 1.17.

7.2.5. Statistical analysis

Descriptive statistics data from trainings and games were presented using mean and standard deviation (± SD). Data analysis was performed using Statistical Package for Social Sciences (version 23 for Windows, SPSS™, Chicago, IL, USA). Additionally, magnitude-based inferences (MBI) were used to analyze the data, based on recommendations of Batterham and Hopkins (3). Differences between RSG, SG and MP were assessed via standardized mean differences (Cohen's *d*, and confidence limits at the 90%). The interpretation thresholds for standardized effect size (ES) were as follows: <0.2 (trivial), 0.2-0.6 (small), 0.6-1.2 (moderate), 1.2-2.0 (large) and >2.0 (very large). The MBI calculations were done with customized excel spreadsheet (downloaded and adapted from www.cem.org/effect-size-calculator).

7.3. RESULTS

Table 2 shows absolute values of all external load variables (mean, standard deviation and confidence interval at 95%) for RSG, NSG and MP.

Table 2 Mean, ±standard deviation, confidence interval at 95% (in brackets) for each external load variable in the regular-stop game (RSG), no-stop game (NSG) and match-play (MP).

Variables	**RSG** (n=174)	**NSG** (n=34)	**MP** (n=177)
PLmin	11.27±3.61	**13.15±1.65**	11.13±2.00
($n \cdot min^{-1}$)	(10.74-11.79)	(12.45-13.85)	(10.83-11.42)
hDECmin	0.24±0.22	**0.36±0.27**	0.25±0.19
($n \cdot min^{-1}$)	(0.21-0.28)	(0.25-0.48)	(0.22-0.28)
tDECmin	2.40±1.08	**2.95±0.88**	2.38±0.63
($n \cdot min^{-1}$)	(2.24-2.55)	(2.58-3.23)	(2.28-2.47)
hACCmin	0.33±0.26	0.25±0.20	**0.38±0.25**
($n \cdot min^{-1}$)	(0.29-0.37)	(0.17-0.34)	(0.34-0.42)
tACCmin	1.92±0.97	**2.20±0.76**	**2.19±0.84**
($n \cdot min^{-1}$)	(1.78-2.06)	(1.88-2.52)	(2.07-2.31)
hJUMPmin	0.23±0.25	**0.38±0.21**	0.25±0.21
($n \cdot min^{-1}$)	(0.20-0.27)	(0.30-0.47)	(0.21-0.28)
tJUMPmin	1.13±0.64	**1.76±0.76**	1.11±0.53
($n \cdot min^{-1}$)	(1.03-1.22)	(1.43-2.08)	(1.03-1.19)
hCoDmin	0.73±0.46	**0.95±0.58**	0.79±0.45
($n \cdot min^{-1}$)	(0.66-0.80)	(0.71-1.20)	(0.72-0.86)
tCoDmin	10.61±4.40	**13.25±3.69**	10.62±3.26
($n \cdot min^{-1}$)	(9.97-11.25)	(11.70-14.81)	(10.14-11.10)

Note: PLmin is player load per minute, tDECmin is total deceleration per minute, hDEC is total deceleration per minute within the high band ($<-3.5\ m \cdot s^{-2}$), tACCmin is total forward accelerations per minute, hACCmin is total forward acceleration per minute within the high band ($>3.5\ m \cdot s^{-2}$), tJUMPmin is total jumps per minute, hJUMPmin is jumps per minute done at the high band (above 0.4 m), tCoDmin is total rightward/ leftward lateral movements per minute, and hCoDmin is total movements registered in a rightward/leftward lateral vector per minute within the high band ($<-3.5\ m \cdot s^{-2}$). Bolded numbers represent magnitude-based inferences better than trivial.

Figure 1 represents effect sizes for three games compared mutually. On the top of the figure, match-play is compared to regular-stop games where it can be observed that two games do not differ in basically any of compared variables. The only variable that showed small difference was tACCmin (MP>RSG).

In the middle, regular-stop game is compared to no-stop game. In this case, three variables showed trivial difference – tACCmin, hACCmin and hDECmin. From the other six variables, three variables (i.e. hCODmin, tDECmin and PLmin) showed small differences (NSG>RSG) and three (tCoDmin, tJUMPmin and hJUMPmin) moderate differences (NSG>RSG).

At the bottom of the figure, match-play is compared to no-stop game. Two variables (hCoDmin and tACCmin) showed trivial differences. Variable hDECmin showed small difference while other five variables (tCoDmin, tJUMPmin, hJUMPmin, tDECmin and PLmin) showed moderate difference (NSG>MP). Only one variable, hACCmin, showed moderate difference, where MP>NSG.

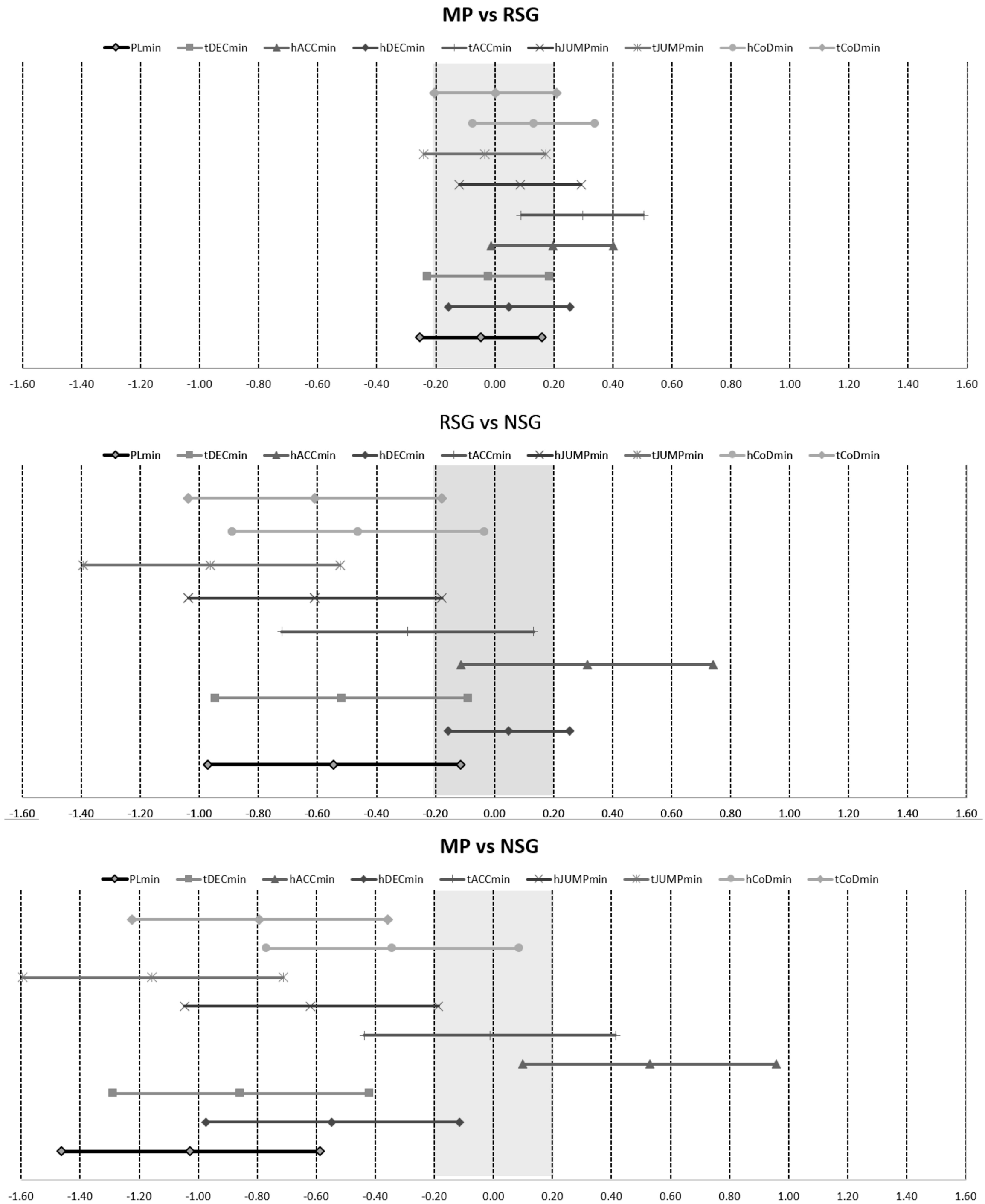

Figure 1. *Cohen's d* values and the 90% confidence interval according to two training games (NSG and RSG) and match-play (MP) for variables: PLmin is player load per minute, tDECmin is total deceleration per minute, hDEC is total deceleration per minute within the high band (<-3.5 m·s^{-2}), tACCmin is total forward accelerations per minute, hACCmin is total forward acceleration per minute within the high band (>3.5 m·s^{-2}), tJUMPmin is total jumps per minute, hJUMPmin is jumps per minute done at the high band (above 0.4 m), tCoDmin is total rightward/ leftward lateral movements per minute, and hCoDmin is total movements registered in a rightward/leftward lateral vector per minute within the high band (<-3.5 m·s^{-2}).

7.4. DISCUSSION

The objective of this study was to compare physical demands of two types of 5vs5 training games and match-play in elite basketball. This is the first study to investigate the aforementioned activities in elite basketball using micro-technology. The main conclusion of the study was that the constraints employed in 5vs5 tasks can elicit greater physical demands than MP. That knowledge can help coaches improve the training programme design and the overall periodization, as understanding which 5vs5 training drill is more physically demanding could effect players' physical condition on a game day.

The 5vs5 NSG elicits higher values of PLmin, tDECmin, tJUMPmin, hJUMPmin and tCODmin than 5vs5 RSG and MP. Additionally, hDECmin showed higher value in NSG compared to MP and hCODmin showed greater value in NSG than in RSG. The aforementioned findings can be simply explained by intentional intensification of NSG with minimal time to rest after personal fouls and ball out-of-bounds. The absence of free throws in NSG additionally increases the intensity. Due to these demands, the players tend to engage in more decelerations, jumps and changes of direction than in MP. Therefore, it can be concluded that the no-stop type of game can be used to elicit an increase in intensity (i.e. PLmin) and a greater number of movements, what eventually causes greater level of accumulated fatigue. As there was no previous research in this field, these findings could be put into practice by coaches who want to overload their teams with specific basketball movements in the 5vs5 full-court format of play.

The current study also showed trivial difference in external load parameters between MP and RSG in almost all variables. The difference was found only for tACCmin variable between MP and RSG (MP>SG). These results support the study by Torres-Ronda et al. (23) who found no differences in relative frequency of movement using time-motion analysis between MP and 5vs5 open-court game, with nearly the same rules as those applied to RSG in the present study. Based on these results, coaches can be sure that the physical load as measured by external load parameters (except for the tACC variable which shows a small effect size, ES=0.30) in 5vs5 RSG will match the demands of a match-play.

Finally, hACCmin variable showed moderate difference between MP and NSG (i.e. MP>NSG). It has to be recognized that in comparison of RSG and NSG, hACCmin tends to follow similar pattern where RSG>NSG. There are two possible rationales for these findings. The first one is the fatigue rationale (17): due to physiological causes of fatigue, it is normal to expect players who have less time to recover between intense actions on the court, like in NSG, to accumulate fatigue sooner and therefore lose the ability to perform high-intensity actions, like accelerations and changes of direction. The second one is the effort rationale, suggesting that, from psychological and motivational point of view, only a real game (in our case a match-play) involving a real opponent (i.e. not a teammate) can make players accelerate often in the high-intensity range due to their increased focus and seriousness. This is supported by previous research by Moreira et al. (16) who found differences in physical stress (using two internal load markers: saliva cortisol and RPE) between training and official games, which were obviously due to players' higher physical efforts when competing against a real opponent and in front of spectators. Moreover, the research by Torres-Ronda et al. (23) showed similar results in another internal load marker – the heart rate (HR): the peak HR in match-play was 97±3%, whereas the intensity level of 5vs5 open-court training games was almost 10% lower (88±7% peak HR).

In the end, there are several limitations of the current study that should be recognized. First, internal response variables were not included in the analysis. For this reason, while differences in demands between the games exist, the impact of those differences has not been investigated. Second, future research should investigate differences in external load parameters between official and friendly matches, since, the use of any kind of micro-technology is currently forbidden in official basketball competitions. Moreover, such research should look at the differences between all variables in different parts of the games, i.e. in each quarter of the game. Third, both NSG and RSG have always been a part of complex team sessions, while MP is conducted as a single task. Forth, differences in playing positions should be considered when investigating 5vs5 formats of play to successfully differentiate values for guards, forwards and centers. With the aforementioned improvements in the further research, coaches will have even more information on when and how to apply 5vs5 game simulations in practice.

In conclusion, findings in this investigation show that, with several training task constraints, it is possible to elicit greater or similar physical demands as those that occur during match-play. Based on the data from this research, all teams that are looking for the right 5vs5 training game format could benefit from the information that the no-stop game could elicit more intensity and more movement frequency than that elicited in a regular match-play. In the same line, the regular-stop game will provide very similar physical demands as a match-play.

7.5. PRACTICAL APPLICATION

Modern basketball training methodology demands accurate data for all training drills, especially those that consider competition conditions. Elite teams use various training drills to simulate game demands. Data from this study serve all coaches who at a certain point need competition conditions 'overload' to stimulate greater physical stress and specific type of fatigue (e.g. during pre-season camp). Finally, understanding the relationships between NSG, RSG and MP can help coaches improve their system of short-term tapering leading up to the game day. For example, in congested fixture during season, further to the game day (i.e. 3-4 days), coaches can use the no-stop game to elicit greater physiological response and fatigue, while closer to the game day (i.e. 1-2 days), a regular-stop game could be a more appropriate choice supporting optimal physical condition on the game day.

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CHAPTER 8
CONCLUSION

This doctoral study is focused on research in monitoring of the load of elite-level basketball. This is the first project in the field that presented various external load variables derived from use of micro-technology combined with internal response and readiness questionnaire. As several fields of load monitoring were investigated throughout the project, following practical conclusions can be pointed out:

- It is important to state that internal and external training loads are derived from inherently different constructs and a complementary use of the two types of loads is therefore advised. However, the large correlation between them found by this study supports the argument in favour of using the sRPE as a global indicator of load in intermittent collision sports, such as basketball. Moreover, certain variables, such as the total number of changes of direction and decelerations, show strong correlations with PL and sRPE and could therefore be potentially used in prescribing individual and team training loads.
- A combination of several load measures is required to describe the load of three playing positions in basketball training sessions. Training load monitoring process may be optimized by selecting and monitoring the most parsimonious set of variables, as this simplifies the analysis of training-load measures in team sport settings. Therefore, acceleration and change of direction for centers, deceleration and high jumps for guards, high and total amount of deceleration and change of direction for forwards are specifically demanded in professional basketball training.

- When using contact-type of training drills with direct opponent, with some constraints in 5vs5 tasks, the coaching staff could elicit higher physical demands than those occurring in match-play. All coaches who at a certain point need competition conditions ‘overload’ to stimulate greater physical and physiological stress (e.g. during the pre-season camp) can benefit from using no-stop type of game. In the same line, if regular game conditions are needed, it is appropriate to use regular-stop game. Additionally, understanding the differences in demands of no-stop game, regular-stop game and match-play can help coaches in elite basketball improve their system of short-term tapering and general periodization.
- Training load management is a crucial factor that leads to either enhanced or decreased physical condition in competitions. Basketball is an intermittent sport where accelerometry – derived data on individual accelerations, decelerations, jumps, changes of direction and Player Load™ – provides a stable and clear platform for tracking and analyzing training load. Therefore, if training load is appropriately selected, coaches can find the most effective micro-tapering models prior to the match. According to the findings in this project, the accumulated Player Load™ of ≈1048 AU with distribution of ≈ 42 %, 34 % and 24 % in MD-3, MD-2 and MD-1 respectively, could be appropriate load distribution, as it leads to a very good state of recovery (i.e. physical condition) on the match day.

Finally, it is important to say that several other fields of load monitoring in basketball are yet to be investigated, and authors’ suggestions will be presented in the following chapter. Moreover, we believe that studies of similar construct as presented in this project should be an interest of future investigations. With the growth of data in the field, practitioners with scientific background will be able to deliver the best methods of load monitoring in their daily work.

CHAPTER 9

LIMITATIONS, PRACTICAL APPLICATION AND FUTURE RESEARCH DIRECTIONS

In this chapter, we are going to present and discuss potential limitations that are recognized throughout the project. Moreover, all practical benefits based on findings in each study will be pointed out. In the end of the chapter, suggestions for future research will be listed.

9.1. LIMITATIONS

Investigations in elite-level sports, including basketball, are very often difficult due to time-consuming data collection and analyses. Normally, top-level teams compete two or three times per week what leaves very few time to practice. Each minute of practice for coach is valuable, as efficiency in training time gives more opportunity for rest and recovery of players. Also, very often high-level practitioners (i.e. physical conditioning coaches, performance specialists) are focused more on everyday practical tasks rather than scientific research and publications. Finally, some elite-level clubs have policy to protect their data from any kind of publishing.

In the present project there are some of the limitations that should be recognized. One of them was the sample size used throughout the project that consisted of 13 or 16 subjects. However, it should be noted that this number represents a full-team roaster in basketball and it is therefore common that studies on professional teams are conducted on smaller samples.

Additionally, another limitation could be a lack of comparison group when needed, such as in the case when effectiveness of short-term tapering model was investigated within a team. However, it is obvious that this kind of experimental design is very hard to establish in the environment where top-level teams are investigated. Top-level teams usually consist of 12-15 players where due to seriousness of training and competitive program it is barely impossible to separate a team in two groups. Looking for another top-level team that would serve as a comparison group is pretty hard, especially at this moment due to the fact that only our team uses this kind of micro-technology in Europe.

In the investigation of positional differences in basketball training, a lack of information on the type of drills used in the training sessions can be acknowledged as a limitation. It is possible that the amount of time spent on both position-specific and non-position-specific tasks could affect the obtained results. For example, if spot-up shooting drills are the same for all players at a certain point of practice, including these data in analysis can seriously impact relationship of number of jumps between playing positions required in a real game. Therefore, training data should be analyzed and presented with caution, especially once it has been related to demands of game.

Moreover, when match-play was investigated and compared to training games, internal response variables were not included in the analysis. With internal load data such as heart rate, physiological demands could have been related to physical demands. Having data from both internal and external demands, more comprehensive picture of both match-play and training games demands would be available. In the same line, another limitation was lack of positional differences comparison in the match-play, what would help to clarify more findings of the study about positional differences in basketball trainings.

Finally, it is important to acknowledge that one of the limitations of measuring external load using micro-technology is that due to the nature of accelerometer devices, it is not able to collect information of isometric muscle contractions, which occur, for instance, during the screens and low-post situations. The aforementioned static movements have very low acceleration, but potentially very high-energy expenditure.

9.2. PRACTICAL APPLICATIONS

Use of modern devices in everyday practice, such as micro-technology, gives coaches vast number of possibilities to monitor and analyse training loads. It provides plenty of information regarding training/game external load demands for each player on the team. In addition to micro-technology, use of internal load heart rate telemetry devices or simple rating of self-perceived exertion (RPE), objective and subjective assessment respectively, makes the whole load monitoring system more comprehensive. Having that in mind, practitioners have enough valuable data for optimal training load prescription. In the following text, the most useful applications from each study in project are pointed out.

When considering training load, using both external and internal load monitoring methods provides the most valuable data for training analysis and training design. Even though it is evident that the sRPE method alone could be sufficient to provide a general insight into load monitoring in professional basketball teams, both sRPE and micro-technology methods provide reliable training load values, while it is important to know that the latter provides additional inertial-motion data with respect to objective individual movement patterns (e.g. accelerations, decelerations, jumps, and changes of direction).

Despite the fact that players train together, research confirmed that differences in training load among playing positions exist. Therefore, coaches and conditioning specialists should be aware of them. It is obvious that particular movement patterns should be highlighted in a specific type of team conditioning demanding that centers focus on accelerations and changes of direction, forwards on decelerations and changes of direction, and guards on decelerations. Once coaches consider positional differences in basketball, optimal training loads can be selected together with management of other important aspects such as individual basketball development, preventive protocols and recovery.

In the research of match-play and training games, it was presented that the no-stop 5vs5 game format could elicit more intensity and more movement frequency than that elicited in regular stoppage conditions in training and match-play. Therefore, this data serves all coaches who at a certain point need competition conditions ‘overload’ to stimulate greater physical stress (e.g. during pre-season camp). Moreover, understanding the relationships between no-stop, regular-stop and match-play can help coaches improve their system of short-term tapering leading up to the match day.

For example, further to the game day (i.e. 3-4 days), coaches can use the no-stop game to elicit greater physiological response, while closer to the game day (i.e. 1-2 days), a regular-stop game could be a more appropriate choice supporting optimal physical condition on the game day.

Finally, as use of micro-technology provides an individual accelerometry-based metric called PlayerLoad™, that is valid and reliable variable for tracking (e.g. real-time tracking during training sessions) and analysis of training load, it can be used to find the most effective short-term tapering models prior to the match day. According to our research, the accumulated load of ≈1048 AU with ratio of ≈ 42 %, 34 % and 24 % in MD-3, MD-2 and MD-1 respectively, could be appropriate load distribution, as it leads to a very good physical condition of players on the match day.

9.3. FUTURE RESEARCH DIRECTIONS

The aim of this project was to present various topics regarding load monitoring investigations in elite basketball. Once the studies were done, various ideas for future research have originated to improve the field, which at this moment is quite poor compared to other team sports such as soccer and Australian football. The potential problem that arises when field is poor with data is that novelty research does not have appropriate data for comparison and discussion but very often seeks for data published in lower playing-level publications, investigation of different gender or even other team sports. This approach can always be questioned by research methodology principles. Therefore, here are some suggestions about future research in elite-level basketball:

- It is urgent to know the official game demands as data from official competition eventually serve as the best marker of demands in basketball.
- Future research should investigate differences in external load parameters between official and friendly elite-level games, so it can be clear if some non-mechanical stressors such as stress or self-motivation could potentially change values in physical demands metrics.
- Research should also investigate differences in external load parameters between elite-level, semi-professional and youth teams, so it can be clear if findings in non-elite level can be used for data comparison and discussion in elite-level publications.

- Moreover, such research should look at the differences between all variables regarding playing positions and in different parts of the games (i.e. in each quarter of the game).
- Additionally, it would be interesting to investigate potential differences within the elite-team by comparing two competitions (e.g. in our case, ACB vs. Euroleague).
- Research should also clearly present differences in external load parameters between man and female players, in both elite and sub-elite level.
- More research should focus on and present data about accelerometry in elite training, especially in the analysis of training games and positional differences. Consequently, further research is required to establish the dose-response relationship in different training modes for different combinations of external and internal load values, preferably for individuals, or, if this is not possible, for specific playing positions.
- Use of heart rate telemetry, that is still very common method of monitoring objective internal responses in elite basketball training, future research should provide more information regarding relationship between internal heart rate values and external micro-technology variables.
- Research should investigate relationship between external load variables (such as Player Load™) and internal load (HR, RPE and sRPE) throughout the pre-season and in-season. The aforementioned relationship could indicate individual increased levels of fatigue and alarm coaches about acute overload what further helps to avoid chronic state of overtraining. In the same line, more research should investigate relationship between acute:chronic workload and injury occurrence in elite basketball.
- Elite-level field of research lacks information regarding different models of load distribution prior to the match day. Additionally, amount of load and its distribution should be correlated to various markers of physical condition (such as levels of creatin kinease, cortisol or testosterone, resting heart rate or heart rate variability, jumping or throwing performance) and key performance indicators in games.
- Finally, during season of elite-level teams in Europe, long traveling to various destinations from Canaria islands to Russia and Israel occurs every several

days where night or early morning connected flights are normality. Therefore, the impact of traveling on sleep quality, players' physical condition, mentality and performance in competitions should be thoroughly investigated.

APPENDIX 1

LIST OF PUBLICATIONS SELECTED IN THE SYSTEMATIC REVIEW

REVIEW PAPERS (n=9)			
Year	**Author/s**	**Title**	**Journal**
2003	Taylor, J.	Basketball: Applying time motion data to conditioning	Strength and Conditioning Journal
2009	Ziv & Lidor	Physical Attributes, Physiological Characteristics, On-Court Performances and Nutritional Strategies of Female and Male Basketball Players	Sports Medicine
2013	Schelling & Torres-Ronda	Conditioning for Basketball: Quality and Quantity of Training	Strength and Conditioning Journal
2014	Lopez et al.	Time-Motion Analysis Procedure in Team Sports: Example for Youth Basketball	Strength and Conditioning Journal
2016	Clemente	Small-Sided and Conditioned Games in Basketball Training: A Review	Strength and Conditioning Journal
2017	Fox et al.	A review of player monitoring approaches in basketball: Current trends and future directions	Journal of Strength and Conditioning Research
2017	Torres Ronda & Schelling	Critical process for the implementation of technology in sport organizations	Strength and Conditioning Journal
2017	Berkelmans et al.	Heart rate monitoring in basketball: Applications and practical recommendations.	Journal of Strength and Conditioning Research
2018	Stojanovic et al.	The activity demands and physiological responses encountered during basketball match play; a systematic review	Sports Medicine

ORIGINAL RESEARCH (n=69)					
Year	**Author/s**	**Title**	**Journal**	**G**	**PL**
1995	McInnes et al.	The physiological load imposed on basketball players during competition	Journal of Sports Sciences	M	E
1999	Hoffman et al.	Hormonal and biochemical changes in elite basketball players during a 4-week training camp	Journal of Strength and Conditioning Research	M	E
2001	Coe & Pivarnik	Validation of CSA accelerometer in adolescent boys during basketball practice	Pediatric Exercise Science	M	Y
2003	Anderson et al.	Impact of Training patterns on incidence of illness and injury during a women collegiate basketball session	Journal of Strength and Conditioning Research	F	SP
2003	Rodriguez-Alonso et al.	Blood lactate and heart rate during national and international women's	The journal of sports medicine	F	E

		basketball	and physical fitness		
2005	Narazaki & Berg	Bioenergetics and Time-Motion Analysis of Competitive Basketball	Student work	M+F	Y
2006	Ostojic et al.	Profiling in basketball: Physical and physiological characteristics of elite players	Journal of Strength and Conditioning Research	M	E
2007	Ben Abdelkrim et al.	Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition.	British Journal of Sport Medicine	M	Y
2009	Sampaio et al.	Power, heart rate and perceived exertion to 3x3 and 4x4 basketball SSG	Revista de Psicologia del Deporte	M	Y
2009	Narazaki et al.	Physiological demands of competitive basketball	Scandinavian Journal of Medicine and Science in Sports	M+F	Y
2009	Matthew & Delextrat	Heart rate, blood lactate concentration, and time-motion analysis of female basketball players during competition	Journal of Sports Sciences	F	Y
2010	Montgomery et al.	The Physical and Physiological Demands of Basketball Training and Competition	International Journal of Sports Physiology and Performance	M	Y
2010	Manzi et al.	Profile of weekly training load in elite male professional basketball players	Journal of Strength and Conditioning Research	M	E
2010	Ben Abdelkrim et al.	Activity profile and physiological requirements of junior elite basketball players in relation to aerobic-anaerobic fitness	Journal of Strength and Conditioning Research	M	Y
2010	Ben Abdelkrim et al.	The effect of players' standard and tactical strategy on game demands in men's basketball	Journal of Strength and Conditioning Research	M	Y
2010	Moreira et al.	Monitoring Stress Tolerance and Occurrences of Upper Respiratory Illness in Basketball Players by Means of Psychometric Tools and Salivary Biomarkers	Stress and Health	M	Y
2011	Castagna et al.	Physiological responses to ball-drills in regional level male basketball players	Journal of Sports Sciences	M	SP
2011	Scanlan et al.	A comparison of the activity demands of elite and sub-elite Australian men's basketball competition	Journal of Sports Sciences	M	E

2011	Cortis et al.	Salivary Cortisol and Alpha-Amylase Reactivity to Basketball Games in Young and Senior Athletes	ACSM	M	Y
2012	Freitas et al.	Training load, stress tolerance and upper respiratory tract infection in basketball players	Brazilian Journal of Kinanthropometry & Human Performance	M	E
2012	Leite et al.	Objective and subjective variables for monitoring of different season cycles in basketball players	Revista Brasileira de medicina do esporte	M	E
2012	Moreira et al.	Monitoring internal load parameters during simulated and official basketball matches	Journal of Strength and Conditioning Research	M	E
2012	Delextrat, A.	Effect of a typical in-season week on strength jump and sprint performances in national-level female basketball players	The journal of Sports Medicine and Physical Fitness	F	E
2012	Moreira et al.	Session RPE and salivary immune-endocrine responses to simulated and official basketball matches in elite young male athletes	The journal of Sports Medicine and Physical Fitness	M	Y
2012	Klusemann et al.	Optimising technical skills and physical loading in small-sided games	Journal of Sports Sciences	M	Y
2012	McCormick et al.	Comparison of Physical Activity in Small-Sided Basketball Games Versus Full-Sided Games	International Journal of Sport Science and Coaching	M	Y
2013	Klusemann et al.	Activity Profiles and Demands of Seasonal and Tournament Basketball Competition	International Journal of Sports Physiology and Performance	M	Y
2013	Delextrat & Kraiem	Heart rate responses by playing position during ball drills in basketball	International Journal of Sports Physiology and Performance	M	Y
2013	Atl et al.	A comparison of heart rate response and frequencies of technical actions between half-court and full-court 3-a-side games in high school female basketball players	Journal of Strength and Conditioning Research	F	Y
2013	Leite et al.	Effects of fatigue and time-out on physiological, time-motion indicators and in patterns of spatial organization of the teams in basketball	Revista de Psicologie del Deporte	M	Y
2013	Hulka et al.	Time-motion analysis of basketball players: a reliability assessment of Video Manual Motion Tracker 1.0 software	Journal of Sports Sciences	M	Y

2013	Schultz de Arruda et al.	Monitoring stress level of Brazilian female basketball athletes during the preparation for the 2009 American cup	Revista Brasileira de Medicina do Esporte	F	E
2014	Scanlan et al.	Training Mode's Influence on the Relationships Between Training-Load Models During Basketball Conditioning	International Journal of Sports Physiology and Performance	M	SP
2014	Scanlan et al.	The relationships between internal and external training load models during basketball training	Journal of Strength and Conditioning Research	M	SP
2014	Nunes et al.	Monitoring training load, recovery-stress state, immune-endocrine responses, and physical performance in elite female basketball players during a periodized training program	Journal of Strength and Conditioning Research	F	E
2014	Pedro et al.	Temporal effect on the response of subjective perceived exertion	Revista Brasileira de Medicina do Esporte	M+ F	Y
2014	Arruda et al.	Influence of competition playing venue on the hormonal responses, state anxiety and perception of effort in elite basketball athletes	Physiology and Behaviour	M	Y
2014	Delextrat & Martinez	SSG training improves aerobic capacity and technical skills in basketball players	International journal of sports medicine	M	Y
2014	Schelling et al.	Creatine Kinase Responses 24-36 Hours After Elite Official Basketball Games. A 6-years Follow-up Study	ACSM	M	E
2015	Conte et al,	Effect of different number of players and training regimes on physiological and technical demands of ball-drills in basketball	Journal of Sports Sciences	M	Y
2015	Delextrat et al.	Match activity demands of elite Spanish female basketball players by playing position.	International Journal of Performance Analysis in Sport	F	E
2015	Vencúrik & Nykodým	The Intensity of Load Experienced by Female Basketball Players during Competitive Games	International Journal of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering	F	SP
2015	Conte et al.	Effect of different number of players and training regimes on physiological and technical demands of ball-drills in basketball	Journal of Sports Sciences	M	Y
2015	Conte et al.	Physiological and technical demands of no dribble game drill in young	Journal of Strength and	M	Y

		basketball players	Conditioning Research		
2015	Conte et al.	Time motion analysis of Italian elite women basketball games	Journal of Strength and Conditioning Research	F	E
2015	Schelling et al.	Using testosterone and cortisol as biomarker for training individualization in elite basketball: a 4-year follow-up study	Journal of Strength and Conditioning Research	M	E
2015	Scanlan et al.	Fluctuations in activity demands across game quarters in professional and semiprofessional male basketball	Journal of Strength and Conditioning Research	M	SP
2015	Scanlan et al.	Gender-Specific Activity Demands Experienced During Semiprofessional Basketball Game Play	International Journal of Sports Physiology and Performance	M+ F	SP
2016	Puente et al.	Physical and physiological demands of experienced male basketball players during a competitive game.	Journal of Strength and Conditioning Research	M	E
2016	Torres-Ronda et al.	Position-dependent cardiovascular response and time-motion analysis during training drills and friendly matches in elite male basketball players.	Journal of Strength and Conditioning Research	M	E
2016	Aoki et al.	Monitoring training loads in professional basketball players engaged in a periodized training programme.	Journal of Strength and Conditioning Research	M	E
2016	Schelling et al.	Accelerometer Load Profiles for Basketball-Specific Drills in Elite Players	Journal of Sports Science and Medicine	M	E
2016	Marcelino et al.	Does small-sided-games' court area influence metabolic, perceptual, and physical performance parameters of young elite basketball players?	Biology of Sport	M	Y
2016	Peterson & Quiggle	Tensiomyographical responses to accelerometer load in female collegiate basketball players	Journal of Sports Sciences	F	SP
2016	Dalbo et al.	Cumulative Training Dose Augments The Interrelationships Between Common Training Load Models During Basketball Activity	ACSM	M	SP
2017	Lupo et al.	Session RPE for quantifying the load of different youth basketball training sessions	Biology of Sport	M	Y
2017	Scanlan et al.	Cumulative training dose effects on interrelationships between common training load models during basketball activity	International Journal of Sports Physiology and Performance	M	Y

2017	Weiss et al.	The relationship between training load and injury in men pro basketball players	International Journal of Sports Physiology and Performance	M	E
2017	Weiss, K.	Quantification of load and lower limb injury in mens professional basketball	PhD thesis		
2017	Hulka et al.	Realiability and validity of a basketball-specific fatigue protocol simulating match load	Acta gymnica	M	Y
2017	Capparos et al.	The use of external workload to quantify injury risk during professional male basketball games	Journal of Sports Science and Medicine	M	E
2017	Herran et al.	A comparison between the physical profile of 3x3 and 5x5 tasks in formative basketball	Revista de internacional de medicina y ciencias de la actividad física y el deporte	F	Y
2017	Speckhard et al.	Comparison Of Physiological Demands Of Basketball Practice Sessions To A Pre-season Game	ACSM	M	Y
2017	Staunton et al	Construct Validity of Accelerometry-Derived Force to Quantify Basketball Movement Patterns	International journal of sports medicine	M	SP
2017	Conte et al.	Effect of Number of Players and Maturity on Ball-Drills Training Load in Youth Basketball	Sports	M	Y
2017	Clemente et al.	Effects of the Sports Level, Format of the Game and Task Condition on Heart Rate Responses, Technical and Tactical Performance of Youth Basketball Players	Journal of Human Kinetics	M	Y
2018	Fox & Scanlan	A Comparison of Training and Competition Demands in Semiprofessional Male Basketball Players.	Research Quarterly for Exercise and Sport	M	SP
2018	Ferioli et al.	The Preparation Period in Basketball: Training Load and Neuromuscular Adaptations.	International Journal of Sports Physiology and Performance	M	SP
2018	Ferioli et al.	Different training loads partially influence physiological responses to preparation period in basketball.	International Journal of Sports Physiology and Performance	M	SP

Note: G = gender, PL = playing level, F = female, M = male, Y = youth, SP = semi-professional, E = elite

APPENDIX 2

PUBLISHED WORK (JOURNAL EDITIONS)

1. Svilar, L., Castellano, J., Jukic, I. (2018). Load monitoring system in top-level basketball team: Relationship between external and internal training load. *Kinesiology*, *50*(1).

2. Svilar, L., Castellano, J., Jukic, I., Bok, D. (2018). Short-term tapering prior to the match: External and internal load quantification in top-level basketball. UNDER REVISION.

3. Svilar, L., Castellano, J., Jukic, I., Casamichana, D. (2018). Positional differences in elite basketball: selecting appropriate training - load measures. *International Journal of Sport Physiology and Performance*, doi.org/10.1123/ijspp.2017-0534.

4. Svilar, L., Castellano, J., Jukic, I. (2018). Comparison of 5vs5 small-sided and friendly games using micro-sensor technology in elite basketball. *Journal of Strength and Conditioning Research*, accepted for publishing on July 20th 2018.

LOAD MONITORING SYSTEM IN TOP-LEVEL BASKETBALL TEAM: RELATIONSHIP BETWEEN EXTERNAL AND INTERNAL TRAINING LOAD

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Abstract:

The study aimed to describe and compare the external training load, monitored using microtechnology, with the internal training load, expressed as the session rating of perceived exertion (sRPE), in elite male basketball training sessions. Thirteen professional basketball players participated in this study (age=25.7±3.3 years; body height=199.2±10.7 cm; body mass=96.6±9.4 kg). All players belonged to the same team, competing in two leagues, ACB and the Euroleague, in the 2016/2017 season. The variables assessed within the external motion analysis included: Player Load (PL), acceleration and deceleration (ACC/DEC), jumps (JUMP), and changes of direction (CoD). The internal demands were registered using the sRPE method. Pearson product-moment correlations were used to determine relationships between the variables. A significant correlation was observed between the external load variables and sRPE (range r=0.71–0.93). Additionally, the sRPE variable showed a high correlation with the total PL, ACC, DEC, and CoD. The contrary was observed with respect to the relationship between sRPE and JUMP variables: the correlation was higher for the high band and lower for the total number of jumps. With respect to the external load variables, a stronger correlation was found between PL and the total number of ACC, DEC and COD than the same variables within the high band. The only contrary finding was the correlation between PL and JUMP variables, which showed a stronger correlation for hJUMP. Tri-axial accelerometry technology and the sRPE method serve as valuable tools for monitoring the training load in basketball. Even though the two methods exhibit a strong correlation, some variation exists, likely due to frequent static movements (i.e., isometric muscle contractions) that accelerometers are not able to detect. Finally, it is suggested that both methods are to be used complementary, when possible, in order to design and control the training process as effectively as possible.

Key words: *team sport, training monitoring, accelerometry, sRPE, professional players*

Introduction

Over the past few decades, basketball has been one of the leading team sports in the world, especially in the USA and Europe. Currently, the NBA teams in the United States compete in a single league, while the Euroleague teams simultaneously compete in the Euroleague and in local national or regional championships. Therefore, Euroleague teams play at least two, sometimes even three games per week. During the regular season, between October and April/May, Spanish teams that participate in the Euroleague play between 62 and 65 games in total, including the games in the Spanish King's Cup (i.e., Copa del Rey). Such a game schedule demands strenuous physical conditioning during the preparatory phase so that every player is able to withstand training and game activities during the competitive season. Therefore, detailed in-season strategies for controlling, maintaining and improving performance need to be established.

Apart from physical and mental recovery methods, adequate management of the training load (TL) is one of the most important tools for reducing injury risk (Soligard, Schwellnus, & Alonso, 2016). Successful training monitoring in team sports results in better performance (Akenhad & Nassis, 2015; Drew & Finch, 2016; Gabbett, 2004, 2016) and fewer injuries, especially non-contact and soft tissue injuries (Akenhad & Nassis, 2015; Drew & Finch, 2016; Gabbett, 2004, 2016; Halson, 2014).

Furthermore, Coutts, Wallace and Slatery (2004) suggest that accurate monitoring of the training load gives the coach a better understanding of individual tolerance to training, as this is affected by many factors, such as player's fitness level, previous experience, age, nutrition and recovery practices, thus providing a solid basis for optimal training periodization. Lambert and Borresen (2010) explained the importance of training load monitoring by using the relationship between the training 'dose' and 'response'. In order to provide the best response (i.e., optimal improvement in performance), coaches need to find different methods to control and plan ideal psycho-physiological stress (i.e., training stimuli or the 'dose') for each athlete. In connection to this, external and internal training loads use different pathways and therefore need to be measured complementary. The external training load (eTL) represents the activities performed by athletes, that is, the dose performed (Impellizzeri, Rampinini, & Marcora, 2005), while the internal training load (iTL) represents the psycho-physiological response by the athlete that primarily takes the form of biochemical stress (Venrenterghem, Nedergaard, Robinson, & Drust, 2017). In team sports, the training load is mainly derived from team practices, whereas external load parameters are collectively defined. Consequently, internal responses to the external load could vary.

In a growing body of research, internal training load parameters have been measured using methods such as oxygen consumption (Castagna, Impellizzeri, Chaouachi, Abdelkrim, & Manzi, 2011), blood lactate measurement (Abdelkrim, et al., 2010; Castagna, et al., 2011; Marcelino, et al., 2016), heart rate monitoring (Aoki, et al., 2016; Conte, Favero, Niederhausen, Capranica, & Tessitore, 2015, 2016; Klusemann, Pyne, Hopkins, & Drinkwater, 2013; Puente, Abian-Vicen, Areces, Lopez, & Del Coso, 2016; Torres-Ronda, et al., 2015) and, the very simple method of rating of perceived exertion (RPE) (Arruda, et al., 2014; Leite, et al., 2012; Manzi, et al., 2010; Nunes, et al., 2014; Scanlan, Wen, Tucker, Borges, & Dalbo, 2014). Foster et al. (2001) stated that the use of the session-RPE (sRPE) method might help coaches and athletes achieve their goals while minimizing undesired training outcomes and overtraining. Finally, as it was suggested by Lau et al. (2009), sRPE data collection and analysis can provide additional valuable information, such as training monotony (i.e., the measure of day-to-day training variability) and training strain (i.e., the measure of weekly TL and monotony).

External training load monitoring does not refer to a single system, since it can be based on tracking various load parameters, such as jumps, collisions, covered distance or lifted weights (Coutts, et al. 2004; Impellizzeri, et al., 2005; Wallace, Slattery, & Coutts, 2014). In basketball, the majority of external load research has been based on video analyses (Abdelkrim, et al., 2010; Delextrat, et al., 2015; Klusemann, et al., 2013), while only several investigators used GPS with accelerometry technology in friendly matches (Montgomery, Pyne, & Minahan, 2010; Puente, et al., 2016) and training sessions (Aoki, et al., 2016; Montgomery, et al., 2010; Scanlan, et al., 2014). The microtechnology used in devices, such as accelerometers, magnetometers and gyroscopes, can provide information related to changes in velocity (accelerations, decelerations and changes of directions) and other inertial-based events such as jumps, impacts, stride variables, etc. (Buchheit & Simpson, 2016). Previous investigations that analysed eTL involved youth or semi-professional basketball players (Montgomery, et al., 2010; Scalan, et al., 2014), or professionals in lower level leagues (National Brazilian League; Aoki, et al., 2016). Furthermore, the mentioned studies used only the PL variable to assess physical or external demands (i.e., eTL).

High numbers of physical variables used in micro-technology potentially make the analysis and application in practice difficult. Additionally, some of these variables are expected to present a high linear correlation (Casamichana, Castellano, Calleja-Gonzalez, San Roman, & Castagna, 2013), since they originate from similar or related dimension (e.g., acceleration-based variables). In order to provide a less complex scenario, practitioners should avoid redundancy and select only crucial variables in eTL monitoring.

Furthermore, to maintain an optimal connection between external and internal training load and to avoid players' maladaptations (i.e., over- or under-training), coaches need to be constantly aware of their relationship (Venrenterghem, et al., 2017). In connection to this, two studies examining team sports, conducted on Spanish (Casamichana, et al., 2013) and Australian footballers (Gallo, Cormack, Gannett, Williams, & Lorenzen, 2015), showed a very strong correlation ($r=0.74$ and $r=0.86$, respectively) between external (PL) and internal (sRPE) pathways. However, in basketball, only one paper investigated the relationship between the sRPE and the accelerometer-derived load. Scanlan et al. (2014) investigated the training activity of eight semi-professional players with 44 observations and found a moderate correlation ($r=0.49$) between PL and sRPE. Maybe the sample consisting of semi-professional players used in the study can explain this result. Although Scalan et al. (2014) provided novel findings regarding the comparison between internal and external TL in basketball, the relationships among different external TLs (such as PL in isolated planes, jumps, or changes of direction) are yet to be examined.

The focus of the present study is on establishing the correlation among external TL variables, and external and internal TL parameters in players of a top-level Spanish basketball team. As there is no evidence of the correlation between these demands in elite basketball, the results of this study could help coaches to single out key variables for successful and effective load monitoring in professional basketball.

Methods

Participants

A total of 13 professional basketball players participated in this study (age: 25.7 ± 3.3 years; body height: 199.2 ± 10.7 cm; body mass: 96.6 ± 9.4 kg). All players belonged to the same team, competing in two basketball leagues, ACB (LigaEndesa, 1st Spanish Division) and the Euroleague, in the 2016/2017 season. The subjects were informed about the purpose, risks and benefits of the study and the types of tests that they would be submitted to, and they gave their informed consent in accordance with the Declaration of Helsinki.

Type of training session

As presented in Figure 1, training and game activities place a considerable load on basketball players. In order to approach load monitoring in basketball comprehensively and achieve a maximum effect, it is essential to consider the total load – a sum of all training and game activities. Game playing time can vastly vary during micro- and meso-cycles, having a strong impact on the total load, both in the acute and chronic timeframe. Furthermore, training activities are divided into four categories: basketball training, individual basketball training, strength training and recovery training.

The basketball training is team training where all players participate in different technical and tactical tasks on the court, with a common goal of improving team's offensive and defensive performance as well as specific endurance. Individual basketball training (IBT) is focused on the player's technical proficiency on the court: moving without the ball, ball handling, dribbling, passing, shooting, etc. Strength training (ST) is based on the individual need for strength and power in-season development and maintenance. Recovery training (RT) is a low-intensity training that is focused on muscle, fascial and neural recovery, typically one day after the game. The game load (GL) is the load that the player accumulates in an official competition.

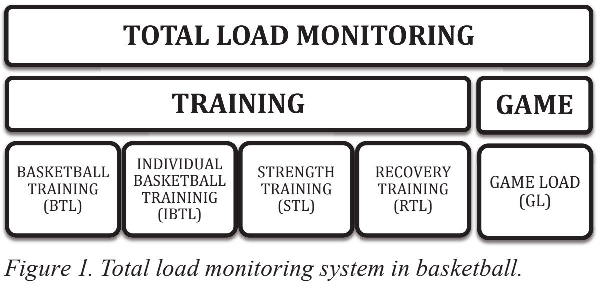


Figure 1. Total load monitoring system in basketball.

Internal load monitoring

The internal training load was monitored using the sRPE method, which researchers have shown to be a valid, reliable, inexpensive and very simple method for monitoring the training load in various exercise activities (Foster, et al., 2001; Singh, Foster, Tod, & McGuigan, 2007; Wallace et al., 2014; Williams, Trewartha, Cross, Kemp, & Stokes, 2016), as well as in team sport settings (Coutts, et al., 2004; Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Lambert & Borresen, 2010). The RPE data were collected 15-30 minutes following each training or game, which was suggested to be the best time-frame by Singh et al. (2007). In order to obtain sRPE values, the RPE grade (1-10) was multiplied by the duration of a training session. The sRPE method was applied after all training sessions.

External load monitoring

The external load was monitored using accelerometer, gyroscope and magnetometer sensors included in S5 devices (Catapult Innovations, Melbourne, Australia). This sensor allows inertial movement analysis (IMA). The registered data included: player load, accelerations, decelerations, jumps and changes of direction.

Player Load (PL) was measured by a tri-axial 100 Hz accelerometer based on the player's three-planar movement, using the well-known formula (Casamichana & Castellano, 2015; Castellano, Casamichana & Dellal, 2013). The reliability of this variable had been previously evaluated (Akenhead, Hayes, Thompson, & French, 2013; Varley, Fairweather, & Aughey, 2012). In addition to PL, the player load of the three dimensions was analysed separately: (1) PLf is the PL accumulated in the anterior/posterior plane; (2) PLs is the PL accumulated in the lateral plane; and (3) PLu is the PL accumulated in the vertical plane only. The PL dwell time was 1 second.

The acceleration/deceleration (acc/dec) variables involved total and high-intensity inertial movements: (1) tACC refers to total inertial movements registered in a forward acceleration vector; (2) hACC are total inertial movements registered in a forward acceleration vector within the high band (>3.5 $m \cdot s^{-2}$); (3) tDEC are total inertial movements registered in a forward deceleration vector; and (4) hDEC are total inertial movements registered in a forward deceleration vector within the high band (<-3.5 $m \cdot s^{-2}$).

Regarding jumps, total jumps (tJUMP) and jumps done at the high band (hJUMP, over 0.4 m) were registered. Finally, two variables involved a change of direction (CoD): (1) tCoD (total inertial movements registered in a rightward lateral vector), and (2) hCoD (total inertial movements registered in a rightward lateral vector within the high band). All these variables (acc/dec, jumps and CoD) were assessed with respect to their frequency.

Procedures

The study was conducted during the 2016/2017 season (December − April). In that period, the players participated in 5 to 10 different types of training sessions and played between two and three games per week. All of the players were monitored in each BTL session using S5 devices (Catapult Innovations, Melbourne, Australia). Individual RPE measured at each session was multiplied by the duration of a session. The warm-up and rests between tasks were included in the total session duration.

The resulting data sets consist of 300 observations, with the numbers of training sessions per player ranging between 4 and 29. The external load data were downloaded and processed with the Openfield v1.14.0 software (Build #21923, Catapult, Canberra). After that, the data were exported to a central database in Microsoft Excel, containing measured variables (external and internal) for each player in each session. Finally, all statistical analyses were performed using SPSS v22.0 (SPSS Inc., Chicago, Illinois, USA).

Data analysis

The data are presented as mean values and standard deviations (±SD). The normality and homogeneity of variances were tested using the Kolmogorov-Smirnov and Levene's tests, respectively. The relationships between various internal and external variables were assessed using the Pearson's correlation coefficient with 95% percentile bootstrap Confidence Intervals (95%CI). The magnitude of correlation coefficients, according to Hopkins (2002), was considered trivial ($r<.1$), small ($.1<r<.3$), moderate ($.3<r<.5$), large ($.5<r<.7$), very large ($.7<r<.9$), almost perfect ($r>.9$) or perfect ($r=1$). The statistical significance was set at $p<.01$.

Results

The mean and standard deviation values for each variable used for basketball training monitoring in this study are presented in Table 1. It can be seen that Player Load in the vertical plane (PLu) accumulated more arbitrary units than did the other two planes. Also, deceleration demands (total tDEC and high intensity hDEC) were higher than the acceleration.

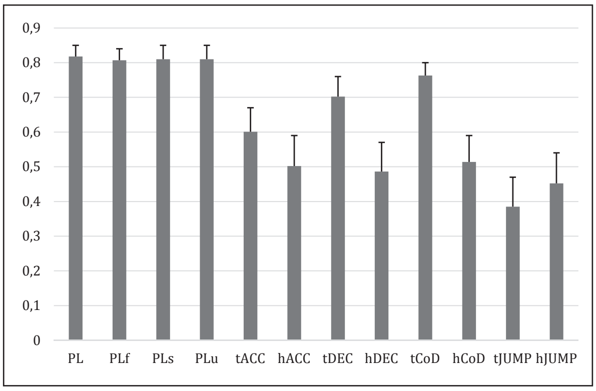
Table 2 shows Pearson correlation values between the external load variables. All the combinations showed a statistically significant relationship (p<.01). Interestingly, PL showed a higher

Table 1. Mean and standard deviation (±SD) of the values for each physical variable and sRPE

Variables (units)	Mean	SD
PL (AU)	314.9	±90.0
PLf (AU)	132.0	±37.3
PLs (AU)	127.4	±37.4
PLu (AU)	206.1	±59.9
tACC (n)	49.1	±24.2
hACC (n)	6.5	±4.6
tDEC (n)	89.1	±32.2
hDEC (n)	10.2	±6.8
tCoD (n)	324.1	±116.0
hCoD (n)	21.4	±12.5
tJUMP (n)	49.8	±20.0
hJUMP (n)	13.1	±6.8
RPE (AU)	6.6	±1.5
Duration (h:min:s)	1:07:42	±0:15:24
sRPE (AU)	390.2	±135.6

Note: PL is player load, PLf is PL in the anterior/posterior plane, PLs is PL in the lateral plane, and PLu is PL in the vertical plane; tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 m·s^{-2}), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 m·s^{-2}), tJUMP is total of jumps, hJUMP is jumps done at the high band (above 0.4 m), tCOD is total rightward lateral movements, and hCOD is total movements registered in a rightward lateral vector within the high band.

Scott, Lockie, Knight, Clark, & Janse de Jonge, 2013). To date, only one study (Scanlan, et al., 2014) investigated the relationship between accelerometer-derived load and sRPE in basketball, but with



Note: PL is player load, PLf is PL in the anterior/posterior plane, PLs is PL in the lateral plane, PLu is PL in the vertical plane; tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 m·s^{-2}), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 m·s^{-2}), tJUMP is total of jumps, hJUMP is jumps done at the high band (above 0.4 m), tCOD is total rightward lateral movements, hCOD is total movements registered in a rightward lateral vector within the high band. In all cases, Pearson values were p<.01 (bilateral).

Figure 2. Pearson correlation (±95% confidence intervals) values between sRPE and the external load variables.

Table 2. Correlations (±95% confidence intervals) for the external and internal training load variable

	PLf	PLs	PLu	tACC	hACC	tDEC	hDEC	tCoD	hCoD	tJUMP	hJUMP
PL	0.98 (0.97-0.99)	0.99 (0.98-0.99)	0.99 (0.98-0.99)	0.65 (0.58-0.70)	0.53 (0.44-0.61)	0.83 (0.79-0.86)	0.65 (0.58-0.70)	0.84 (0.80-0.87)	0.67 (0.60-0.73)	0.49 (0.40-0.57)	0.55 (0.47-0.63)
PLf		0.97 (0.96-0.98)	0.96 (0.95-0.97)	0.67 (0.61-0.73)	0.56 (0.47-0.64)	0.81 (0.77-0.85)	0.60 (0.52-0.67)	0.81 (0.77-0.85)	0.64 (0.57-0.69)	0.50 (0.42-0.58)	0.55 (0.48-0.62)
PLs			0.97 (0.96-0.98)	0.69 (0.64-0.74)	0.58 (0.50-0.65)	0.83 (0.80-0.86)	0.66 (0.59-0.72)	0.86 (0.83-0.89)	0.69 (0.64-0.75)	0.50 (0.43-0.58)	0.56 (0.49-0.64)
PLu				0.60 (0.53-0.63)	0.49 (0.46-0.56)	0.81 (0.77-0.85)	0.65 (0.59-0.71)	0.83 (0.79-0.86)	0.65 (0.59-0.71)	0.46 (0.37-0.54)	0.54 (0.45-0.61)
tACC					0.72 (0.66-0.78)	0.69 (0.62-0.74)	0.29 (0.20-0.37)	0.66 (0.59-0.72)	0.52 (0.47-0.57)	0.49 (0.39-0.58)	0.43 (0.32-0.53)
hACE						0.47 (0.37-0.56)	0.28 (0.17-0.38)	0.62 (0.54-0.68)	0.49 (0.40-0.58)	0.43 (0.33-0.52)	0.29 (0.18-0.40)
tDEC							0.69 (0.63-0.75)	0.78 (0.72-0.83)	0.65 (0.57-0.70)	0.56 (0.48-0.62)	0.60 (0.52-0.67)
hDEC								0.63 (0.55-0.71)	0.65 (0.56-0.73)	0.28 (0.20-0.37)	0.38 (0.29-0.48)
tCoD									0.74 (0.69-0.79)	0.50 (0.41-0.59)	0.47 (0.38-0.56)
hCod										0.41 (0.31-0.51)	0.34 (0.24-0.44)
tJUMP											0.56 (0.48-0.64)

Note: PL is player load, PLf is PL in the anterior/posterior plane, PLs is PL in the lateral plane, PLu is PL in the vertical plane; tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 $m \cdot s^{-2}$), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 $m \cdot s^{-2}$), tJUMP is total of jumps, hJUMP is jumps done at the high band (above 0.4 m), tCOD is total rightward lateral movements, hCOD is total movements registered in a rightward lateral vector within the high band. In all cases Pearson values were p<.01 (bilateral).

correlation with tCoD and tDEC than with tACC and tJUMP. Moreover, PL showed a higher correlation with all total variables (tACC, tDEC, tCoC) as compared to high band variables (hACC, hDEC and hCoD), with the exception of the JUMP variable.

Finally, Figure 2 shows Pearson correlations between sRPE (internal load) and the external load variables used. Although all of the presented relationships were statistically significant (p<.01), the strengths of correlations varied between variables. Very strong correlations were found between sRPE and all PL variables (PL, PLf, PLs and PLu), with values of r>.8. Finally, higher correlations were found between sRPE and tDEC and tCoD than tACC and tJUMP. Likewise, the total number of ACC, DEC and CoD displayed a higher correlation than high-band activities for the same variables.

Discussion and conclusions

This is the first study that examined the relationship between indicators of external and internal load in elite male basketball. The main finding of this study was a very high and significant association between sRPE and external load variables – which present the motor activity of players during basketball training sessions – particularly when the total load was considered. Furthermore, strong correlations among external load variables suggest that coaches could be more selective in choosing variables for training monitoring in basketball so as to avoid redundancy.

The results of the current study support previous research findings in running-based team sports (Casamichana, et al., 2013; Gallo, et al., 2015;

eight semi-professional male players. Unlike the current study (r>.8), the Scanlan's study showed a moderate correlation between PL and sRPE (r=.49). It was therefore suggested that professional basketball coaching and conditioning should not assume a linear dose and response relationship between the accelerometer and the internal training load models during training and that a combination of internal and external approaches was to be used in monitoring the training load in players. The difference in the results could be explained by the number of training observations in the two studies (44 in the Scanlan's study, compared to 300 in the current study) and the quality level of players (semi-professional vs. elite players). Moreover, the differences could be explained by the training design: the current study investigated in-seasonal training sessions, while the Scanlan's study focused on the general and specific preparatory phase during pre-season.

With respect to external variables, PL showed very strong correlations with tCoD and tDEC, but only a strong correlation with tACC and a moderate one with tJUMP. These findings could be explained by physical demands of basketball game, which involves a more frequent stress caused by decelerations and changes of direction than by accelerations and jumps, as it was presented in Table 1. Therefore, the total number of deceleration and changes of direction could be a valuable variable in describing the training load. However, it is important to realize that the number of high-intensity DEC and CoD accounted only for a small percentage of the total number of DEC and CoD: 8.7% and 15.1%, respectively.

Furthermore, a comparison of decelerations and accelerations shows that, in basketball training, there are almost twice as many decelerations than accelerations, both in the total and the high-intensity spectrums. Conversely, in football, where the size of the pitch is much greater, the players experience a different relationship between the total ACC and DEC. Akenhead, Harley, and Tweddle (2016) found that the total distance covered in accelerations in male football training was 1,826 m, as compared to 1,598 m covered in decelerations, while Mara, Thompson, Pumpa, and Morgan (2017) studied female matches and found a total of 423 accelerations and 430 decelerations. These results could be explained by the small size of the basketball court and, like in small-sided football games (Castellano & Casamichana, 2013), the players need to constantly decelerate and change direction, especially when anticipating and reacting to the actions of the opposing team during live games. Finally, it is also important to state that JUMP variable was poorly correlated with other external variables. This finding could be explained by the selection of different shooting drills, involving a high number of low- and high-intensity jumps. However, the number of spot-up shots made by each player notably varies from training to training, as it is not specified for each type of basketball training, or for the selection of small-sided games that represent a major part of the in-seasonal basketball practices.

Regarding the correlations between the internal load and external load variables, interesting results were found: sRPE showed a very strong correlation with tDEC and tCoD, a strong correlation with tACC, and only a moderate one with tJUMPS. A very similar pattern was observed between PL and the mentioned external variables, since they belonged to the same representative natural group (after the application of the cluster analysis), as suggested by Fernandez, Medina, Gomez, Arias, and Gavalda (2016). Like in other team sports (Casamichana, et al., 2013; Gallo, et al., 2015), this further confirms a strong correlation between PL and sRPE in elite basketball, expressed as mechanical and biochemical stress (Vanrenterghem, et al., 2017), respectively. Regardless of this high correlation between the two groups of variables, it seems that recording of both could provide a better understanding of players' adaptation or increased states of fatigue.

Even though the sample used in the current study could be considered a potential limitation factor, it should be noted that this number represents a full-team roaster in basketball and it is therefore common that studies on professional teams are conducted on smaller samples. Moreover, future investigations should include the measures of internal load (such as the heart rate) that were not available in the current study. Considering that the current rules of the game forbid the use of devices and sensors, it would be very interesting to know if this relationship between internal and external loads remains at a similar level, since other non-mechanical stressors could potentially affect the general relationship between PL and sRPE. A complementary use of both the internal and external parameters will greatly contribute to the process of training load monitoring. Additionally, it is important to acknowledge the statement made by Schelling and Torres (2016) on the limitations of measuring the external load using accelerometers, since these devices are not able to collect information on isometric muscle contractions, which occur, for instance, during screens and low-post situations, where static movements have a very low acceleration, but potentially very high energy expenditure.

To sum up, it is important to state that the internal and external training loads are derived from inherently different constructs and a complementary use of the two types of loads is therefore advised. However, the strong correlation between them found by this study supports the argument in favour of using the sRPE as a global indicator of load in intermittent collision sports, such as basketball. Moreover, certain variables, such as the total number of changes of direction and decelerations, show strong correlations with PL and sRPE and could therefore be potentially used in prescribing individual and team training loads.

Practical application

When considering the training load only, using both external and internal load monitoring methods provides the most valuable data for training analysis and training design. However, there are still many teams in professional basketball that do not use accelerometry technology in training nor in official matches, as it is currently not allowed. Therefore, based on the findings in this study, it is evident that the sRPE method alone could be sufficient to provide a general insight into load monitoring in professional basketball teams. However, even though both sRPE and accelerometry methods provide reliable training load values, it is important to know that the latter provides additional inertial-motion data with respect to individual movement patterns. For that reason, an individualized approach to external load monitoring in basketball is a complementary tool that could help coaches and teams minimize the number of injuries while achieving the best performance.

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ABSTRACT

The purpose of this study was to compare accelerometry-derived external load and internal load calculated as a session rate of perceived exertion (sRPE) in elite male basketball over 3-days prior to the match and assessing players' recovery status on the match-day. Thirteen professional basketball players participated in this study (age: 25.7±3.3 years; height: 199.2±10.7 cm; weight: 96.6±9.4 kg). All players belonged to a team competing in LigaEndesa (Spanish 1st Division) and Euroleague in the 2016/2017 season. Variables used in external motion analysis were: PlayerLoad (PL), accelerations and decelerations (ACC and DEC), jumps (JUMP) and changes of direction (CoD), in total (t) and high intensity (h) thresholds, while internal demands were registered using sRPE method. All variables were expressed in absolute (accumulated in the session) and relative values (per min of practice). For the evaluation of readiness, Total Quality of Recovery (TQR) questionnaire was used, measured in Arbitary Units (AU). The results showed differences in load and intensity (*p<0.01*) for almost all external (PL, hACC, tACC, hDEC, tDEC, hCoD and tCoD; in both absolute and relative values) and internal (sRPE) variables as training sessions were closer to the match day or MD (MD-3>MD-2>MD-1). Only hJUMP, tJUMP and RPE variables showed no difference between MD-3 and MD-2, while both days significantly differed from MD-1. The average TQR score for all of the match days was 7.9±1.31 AU. This study showed differences in the amount of external and internal load between three days of training, where a team can be efficiently prepared for competitions by progressively decreasing the load over the 3-days prior to the match.

Keywords: training monitoring, micro-technology, accelerometry, team sports

TÍTULO

Tapering a corto-plazo antes del partido: Cuantificación de carga externa e interna en baloncesto de élite

RESUMEN

El propósito de este estudio fue comparar la carga externa derivada de la acelerometría y la carga interna calculada a partir del esfuerzo percibido declarado en la sesión (sRPE) en el baloncesto masculino de élite durante los tres días previos al partido, evaluando el estado de recuperación en el día del partido. 13 jugadores de baloncesto profesionales participaron en este estudio (edad: 25.7±3.3 años, altura: 199.2±10.7 cm, peso: 96.6±9.4 kg). Todos los jugadores pertenecían al mismo equipo que compite en Liga Endesa (1ª División española) y Euroliga en la temporada 2016/2017. Las variables utilizadas para registrar la demanda externa fueron: PlayerLoad (PL), aceleraciones y desaceleraciones (ACC y DEC), saltos (JUMP) y cambios de dirección (CoD), tanto en el total (t) acumulado como en en rango de alta intensidad (h), mientras que las demanda interna fue registrada usando el método sRPE. Todas las variables se expresaron en valores absoluto (acumulado en la sesión) y relativos (por minuto de práctica). Para el resgistro del estado de recuperación, se utilizó el cuestionario *Total Quality Recovery* (TQR) medida en unidades arbitrarias (UA). Los resultados mostraron diferencias en la carga e intensidad ($p<0.01$) para casi todas las variables externas (PL, hACC, tACC, hDEC, tDEC, hCoD y tCoD, tanto en valores absolutos como relativos) e internas (sRPE), entre las sesiones de entrenamiento con respecto a su distancia al día de partido o MD (MD-3> MD-2> MD-1). Solo las variables hJUMP, tJUMP y RPE no mostraron diferencias entre MD-3 y MD-2, mientras que los dos días difirieron significativamente de MD-1. La puntuación promedio de TQR para todos los días de partido fue de 7.9 ±1.31 UA. Este estudio mostró diferencias en la carga total externa

e interna entre los tres días de entrenamiento, donde un equipo puede prepararse eficientemente para la competición disminuyendo progresivamente la carga durante los tres días previos al partido.

Palabras clave: monitorización del entrenamiento, micro-tecnología, acelerometría, deportes de equipo

Introduction

Training periodization and tapering are well-known principles commonly used in professional team-sports training during the season. According to literature[1,2], ‘long-term’ tapering in team-sports is implemented two to three weeks before important events, such as cups and play-offs, with the intention of peaking individual and team’s physical and tactical performance. A recent study focusing on basketball revealed a relationship between internal training load, recovery-stress status, immune-endocrine responses, and physical performance in elite female basketball players[3] over a 12-week period, including two overloading and tapering phases. This study covered the period preceding an international championship (characterized by a short duration), providing an insight into long-term training stimulus and adaptations in elite sports. Regarding training activities, taper was applied by decrease of training volume for the resistance training, especially with parameters such as repetitions per set, goal intensity and number of sessions per week. Moreover, in the first seven weeks endurance training consisted of moderate to high intensity interval runs while in the weeks 8 to 12 endurance training was substituted with less metabolic speed-agility training. Finally, authors concluded that the application of session rate of perceived exertion (sRPE) method, as well as the recovery-stress questionnaire (REST-Q), can serve as an important tool to monitor training loads and players’ recovery, thus maximizing dose-responses of the training stimulus.

However, for a team competing in seasonal championships, the coaching staff is presented with the challenge of making an optimal training schedule every single week. In this context, weekly periodization, i.e. tapering, could also refer to the practice of reducing training load in the days leading up to the weekly competition. To date, there is little scientific information available to guide coaches in prescribing efficient short-term tapering strategies for team sports players during the competitive week aimed at peaking performance on the match day.

Only one study[4] has looked at internal training load (iTL) using sRPE and heart rate (HR) monitoring methods, and it showed that, in the weeks with two games (i.e. Euroleague and Serie A1), the sRPE obtained on Tuesdays and Wednesdays were 748±71 and 275±54 AU, respectively. The short-term tapering assumed that Monday was the day-off and Thursday the match-day in Euroleague. However, the aforementioned study did not present any external load data and indicators of physical condition with respect to the accumulated training load. To date, no studies examining the relationship between prescribed external training loads in micro-cycle periods have been conducted.

Numerous methods can be used to monitor the physical condition of athletes. There are objective methods, such as heart rate monitoring and saliva measures[5], blood testing[6] or jumping performance[7,8], as well as subjective methods, such as various questionnaires[8,9,10], which could be easily implemented in everyday training. One of the questionnaires, known as Total Quality Recovery Scale (TQR), has demonstrated sufficient reliability in team sports[11].

At the moment, information on accelerometer–based data in top-level basketball is limited, especially with respect to weekly periodization and distribution of load. Therefore, the aim of this study is to compare the load of the training sessions leading up to the first match of the week, considering both external (eTL) and internal training load parameters. Furthermore, the perception related to recovery status on the match day (via TQR questionnaire) will be assessed. The assessment will be used as the indicator in the selection of appropriate training load that secures enough recovery for players' well-being, while avoiding undesired overload and overtraining. The findings of this study could help coaches set appropriate level and intensity of accelerometry-derived training load (TL) in the days leading up to the match, as such data is currently unavailable in the literature.

It was hypothesized that, with the application of a short-term 3-day taper, a progressive decrease in TL prior to the match day will positively affect players' recovery status, which would in turn lead to enhanced physical condition and performance in competition.

Material and method

Experimental Approach To The Problem

The research was carried out between December and February of the 2016/2017 season. The players were monitored in basketball training sessions using S5 devices from Catapult Innovations (Melbourne, Australia). Furthermore, sRPE was calculated based on the individual RPE obtained 15-30 minutes after the training session multiplied by the training duration. During that period, the players participated in three to eight training sessions and two or three games every week where the total number of recorded games was 10. The investigation data set consisted of 228 observations, where the numbers of training sessions per player ranged between 11 and 22. The eTL was transferred and managed using the Openfield v1.14.0 software (Build #21923, Catapult, Canberra). The data was subsequently exported to Microsoft Excel for the final selection and analysis of individual eTL and iTL variables.

Participants

A professional male basketball players (age: 25.7 ±3.3 years; height: 199.2 ±10.7 cm; weight: 96.6 ±9.4 kg) who play on the same team were participating in this investigation. The team competes in two basketball championships, ACB (Liga Endesa, Spanish 1st Division) and the Euroleague, in the 2016/2017 season. All of the players were verbally informed of the study requirements and they provided written consent before the study was conducted, all in accordance with the Declaration of Helsinki. The Ethics Committee (CEISH) gave its institutional approval before the procedures of this study took place.

Type Of Training Session

The players typically played two games per week, with three team sessions usually conducted before the first game of the week (Euroleague) and only one or none before the second game (ACB League). Only the sessions before the first game of the week were considered in the analysis, due to individual adjustments in team sessions preceding the second game, which depended on the individual effort in the first game. Therefore, the data for the analysis was collected three days before the match day (MD-3), two days before the match day (MD-2) and one day before the match day (MD-1). The 3 consecutive days of practices were proposed by conditioning specialist in order to achieve optimal short-term tapering effect. Only players who complete all three training sessions were included in the analysis.

Table 1 provides the list and brief descriptions of basketball training exercises and drills used in the reference period. After the team preparation, players participated in one of the following: shooting exercises, no-contact drills or small-sided games (SSG).

Table 1. here

External Training Load Monitoring

The eTL was monitored using GPS S5 devices (Catapult Innovations, Melbourne, Australia), which include the accelerometer, gyroscope and magnetometer sensors that provide data for inertial movement analysis (IMA). The obtained data included the following variables: player load (PL), player load per minute (PL/min), accelerations (ACC), decelerations (DEC), jumps (JUMP) and changes of direction (CoD).

PL was obtained using the tri-axial accelerometer (100 Hz, Dwell time 1 second) based on the player's three-planar movement, applying the established formula[12,13] previously tested for reliability[14,15], where TE (i.e. typical error) for different ranges of acceleration varies from 0.18 – 0.13[15].

The ACC variable presents inertial movements registered in a forward acceleration vector, where tACC refers to all, and hACC only to high-intensity movements registered within the high band (>3.5 $m \cdot s^{-2}$). The DEC variable refers to inertial movements registered in a forward deceleration vector, where tDEC presents total and hDEC only high-intensity movements registered within the high band (>3.5 $m \cdot s^{-2}$). The jumps were also registered as total jumps (tJUMP) and high-intensity jumps (hJUMP, over 0.4 m), the same as changes of direction, tCoD (total inertial movements registered in a rightward lateral vector), and hCoD (total inertial movements registered in a rightward lateral vector within the high-intensity band). All aforementioned variables were assessed with respect to their frequency.

Considering the varied duration of the sessions, the relative values of the variables were used, obtained by dividing the accumulated values by the minutes of practice duration. The new relative variables for the analysis were: PL/min, hACC/min, hDEC/min, tACC/min, tDEC/min, hCoD/min, tCoD/min, tJUMP/min and hJUMP/min.

Internal Training Load Monitoring

The sRPE method, whose reliability and validity has been confirmed in previous research[16,17,18,19] as well as its simple and cost-effective use in practice with team sport athletes[20,21,22], was used to assess iTL. As suggested by research[17], the RPE values were collected within 15-30 minutes following the training session. The 1-10 RPE grading scale was used. In order to calculate sRPE after all sessions, RPE values were multiplied by training duration in minutes.

Monitoring Of Physical Condition

The TQR questionnaire was used to assess players' physical condition. On the match day, after the morning team shooting practice, players were asked to grade their current physical condition on a scale from 1 to 10 (where 1 means very, very poor and 10 very, very good), following this category classification: <6 = an alarming state; 6.1-7.5 = a good state; 7.6-9 = a very good state; and >9.1 = an excellent state.

Statistical Analysis

A data analysis was performed using the Statistical Package for Social Sciences (version 23 for Windows, SPSS™, Chicago, IL, USA). Standard statistical methods were used to calculate the mean (or median) and standard deviations (SD). The data was screened for normality of distribution and homogeneity of variances using Shapiro-Wilk and Levene's tests, respectively. Differences between dependent variables and TQR values in training sessions and on the match day were analyzed using one-way ANOVA, followed by Bonferroni's post hoc test (Kruskal Wallis test followed by Mann-Whitney U test, with Bonferroni correction of alpha, in this case, dividing alpha by three comparisons). The effect size (ES) was calculated using the method proposed by Batterham and Hopkins[23]. The effect values lower than 0.2, between 0.2 and 0.5, between 0.5 and 0.8, and higher than 0.8 were considered trivial, small, moderate, and large, respectively. The $p<0.05$ criterion was used for establishing statistical significance.

Results

The duration (mean, standard deviation and confidence interval at 95%, in hours:minutes:seconds) of the sessions were 1:23:37±0:11:40 (1:19:56-1:27:18), 1:14:43±0:12:37 (1:12:07-1:17:20) and 0:58:25±0:07:57 (0:56:48-1:00:02) for MD-3, MD-2 and MD-1, respectively. A significant difference was found between all of the days.

Figure 1 shows values for PL (in AU) on each day of the week. The differences were statistically lower for training sessions closer to the match day (MD-3>MD-2>MD-1), where the values were as follows: 436.6±70.8, 358.4±51.1 and 253.2±58.7, respectively (ES: 1.27 for MD-3 vs. MD-2; 1.91 for MD-2 vs. MD-1; 2.82 for MD-3 vs. MD-1). Furthermore, the PL/min values for MD-3, MD-2 and MD-1 were significantly different, 5.3±0.7, 4.9±0.8 and 4.3±0.7, respectively (ES: 0.53 for MD-3 vs. MD-2; 0.80 for MD-2 vs. MD-1; 1.43 for MD-3 vs. MD-1).

Figure 1. here

Table 2 shows absolute values of other external training load variables (mean, standard deviation and confidence interval at 95%) for each type of session in the week. In most variables, there was a statistically significant difference between the days MD-3 > MD-2 > MD-1. Only JUMP variable showed no difference between MD-3 and MD-2, while both days differed from MD-1.

Table 2. here

When variables were expressed in minutes of practice (Table 3), almost all of the variables showed the same pattern, with statistically significant differences between MD-3 >

MD-2 > MD-1. Interestingly, tJUMP/min and hJUMP/min showed no difference between MD-3 and MD-2, while both days showed a difference when compared to MD-1.

Table 3. here

As for internal variables, the training load (sRPE) variable showed a statistically significant difference between days MD-3 > MD-2 > MD-1; 598.2±90.5 (569.6-626.7) AU, 441.4±73.4 (426.1-456.6) AU and 312.0±92.8 (293.1-330.9) AU, respectively (ES: 1.90 for MD-3 vs. MD-2, 1.55 for MD-2 vs. MD-1 and 3.12 for MD-3 vs. MD-1). The intensity variable RPE showed no differences between MD-3 and MD-2 with values 7.8±1.1 (7.4-8.1) AU and 7.3±0.9 (7.1-7.5) AU, respectively. However, the results for MD-1 were 6.0±1.4 (5.7-6.3) AU, what significantly differentiates from previous two days (1.10 for MD-2 vs. MD-1 and1.43 for MD-3 vs. MD-1).

Figure 2. here

Finally, Figure 3 presents the average scores in TQR questionnaire for all of the match days in the reference period. The average values from the first to the last game were as follows: 7.7 (6-10), 7.8 (6-10), 8.1 (6-10), 8.0 (6-10), 8.0 (7-10), 8.1 (6-10), 7.7 (6-10), 7.8 (6-10), 7.7 (6-10) and 8.0 (6-10). The average for all of the match days was 7.9 (±1.31), positioning the team in the category of a very good state. There were no significant differences in the recovery status (TQR questionnaire results) between all match days in the reference period.

Figure 3. here

Discussion

The main aim of the present study was to describe differences between training sessions leading up to the first match of the week with respect to both eTL and iTL parameters. To the best of the authors' knowledge, this is the first study investigating short-term tapering in the elite basketball setting. The results showed differences in almost all variables (in both load and intensity) between the training sessions analyzed (MD-3>MD-2>MD-1). Furthermore, the TQR scores on the match day did not indicate any abnormality in players' optimal state of recovery. In particular, the results of the present study contributed to the improvement of specific periodization strategies with respect to different training durations, load and intensity.

Monitoring TL in basketball players is crucial in planning appropriate training programmes[24] and exposing players to adequate monotony and strain in order to reduce injury risk[25]. Additionally, in previous research on effects of specific periodization strategies to avoid overtraining syndrome or under-stimulation, it was concluded that training session duration and intensity manipulation is a very important component of tapering[2]. Experts[1] suggested that, out of the three main factors in tapering – training intensity, frequency and volume –, a decrease in the latter factor had the strongest effect on enhanced performance. In the present study, a decrease in the training duration (i.e, volume) in the days leading up to the match follows general tapering principles. However, tapering included only three-day cycles and can therefore be considered as a short-term taper. Furthermore, regardless of the cycle duration, as suggested by Foster[16], a link could be established between training load, strain and monotony, as main predictors of overtraining.

The majority of external load variables (i.e. hACC, tACC, hDEC, tDEC, hCoD and tCoD) revealed the same pattern in their inter-day relationships as the global variables, PL and sRPE. In connection with that finding, the authors suggest that these variables could be the most important eTL variables in prescribing load in basketball training sessions. Only two eTL variables of the same construct (i.e. hJUMP and tJUMP) showed different relationships between the days, with no difference found between MD-3 and MD-2, while both days differed from MD-1. This finding could be ascribed to different shooting drills, which significantly affected both hJUMP and tJUMP variables. In the future, it is important to differentiate between JUMP variables accumulated in SSG and other tasks, such as preparation for training or shooting. When the total number of ACC, DEC, CoD and JUMP variables is considered in basketball training, regardless of the day, it is important to recognize that the CoD variable had the highest values by far. For that reason, CoD also had the highest impact on load accumulation.

PL, a global eTL variable, shows significant differences between all of the days, starting from MD-3, which showed the highest value (436.6±70.8 AU), through MD-2 with a moderate value (358.4±51.1 AU), and finally, MD-1 with the lowest value (253.2±58.7 AU). These findings confirm previous research into short-term tapering in other team sports[7]. Unfortunately, eTL data on daily loads and short-term tapering in basketball does not exist.

With respect to iTL variables, the present study found that sRPE shared a very strong inter-day relationship as PL, unlike a previous study[26] on elite basketball players, which found only a moderate relationship (r=0.49). sRPE, a measure of internal training load, was the highest (598.2±90.5 AU) on MD-3, followed by 441.4±73.4 AU on MD-2 and was the lowest (312.0±92.8 AU) on MD-1. These findings support the previous study on elite basketball players[4]. However, Manzi's study covered only two days leading up to a Euroleague game, since MD-3 was a day without physical activities (i.e. day-off). Over these two days, the players accumulated on average 748±71 AU on MD-2 and 275±54 AU on MD-1, with players participating in both resistance (explosive weights) and technical training on MD-2, and in tactical team training on MD-2. A significant drop in load was applied in both cases, which supports the importance of the tapering concept of training volume decrease.

The PL/min variable, which can be considered a variable representing the intensity of work, shows a downward trend, with MD-3 showing the highest value of 5.3±0.7, MD-2 a moderate value of 4.9±0.8, and MD-1 the lowest value of 4.3±0.7. Even though Pyne et al. [1] suggested that training intensity should be maintained for an optimal taper, it is important to know that PL/min is an average value of the intensity of the training session, and the variable is affected by the overall duration of the session. With respect to the above said, the intention in practices was to maintain high intensity in competitive tasks, such as SSG, but this information was not provided in the current study. Therefore, as it can be seen in Table 2, almost all of the SSGs were used in all of the days leading up to the match. However, longer rest periods were used on MD-2 and, even more so, on MD-1 in order to decrease the metabolic stress, which could explain the significant drop in PL/min values.

Another intensity variable, the subjective RPE, did not show the exact same pattern as PL/min, and significant difference were not found between MD-3 and MD-2. However, both days differed from MD-1. This finding could be ascribed to the accumulated fatigue from MD-3, which is the most demanding day, having a direct impact on the next session on MD-2. However, a well-planned decrease in training volume and load did not have an impact on the residual fatigue on MD-1, but it did lead to a good readiness to play on the match day.

In order to evaluate the physical condition of players and their adaptation to training load prior to the match, a simple TQR questionnaire was used, as has been the practice in other team sports recently[27]. The team played 10 games in the reference period, with team scores ranging from 7.7 to 8.1, which positions them in the category of very good physical condition. There was no disturbance in the recovery status (as expressed by the TQR questionnaire) in any of the weeks prior to the matches (Figure 3). As suggested by Nunes et al.[3], overloading leads to poorer recovery and physical condition of players. However, we hereby propose that short-term tapering using the loads specified in this study could improve players' physical condition and enable them to be in good condition for the competition.

Even though it is important for all coaches to strive for better scores by applying different methods of both training and recovery, it is also important to understand that it is very difficult to constantly maintain an excellent physical condition. Playing modern basketball at the elite level requires the players to play 2-3 games per week, and sometimes take several flights a week, early in the morning or late at night, changing the sleeping environment on a weekly basis. These are only some of the factors that interrupt players' circadian rhythm. However, it is important to consider the findings by Rabbani & Buchheit[5], who state that fitter player may experience less wellness impairment when traveling than their less fit counterparts. Moreover, members of the coaching staff should establish a positive working environment, so that players are surrounded with positive energy and maintain healthy mentality in challenging moments on a daily basis.

Therefore, as the team in this investigation constantly averaged in the 'very good state' category, the authors concluded that the accumulated training load presented could be appropriate. Additionally, to keep the players in an optimal physical condition, it is important to maintain a sound acute:chronic workload ratio between micro-cycles, while considering both training and game loads. As suggested by previous research[28], it is better to maintain a high chronic load, because, in congested fixture, players are ready to support a high amount of load. In basketball, this idea has great importance for all players, especially those with more playing time.

This study accentuates the short-term tapering as a basic principle in weekly training load management. As the results of this study show, external and internal variables are complementary methods for monitoring training load. These methods are probably more effective than using only sRPE training load and training volume when the physical fitness level of players is to be assessed[29]. In order to perform at the optimal level in competitions, players need to accumulate a high amount of load, but with a particular distribution. It can be suggested that players experience a decrement (p.e.≈42%, ≈34% and ≈24% in MD-3, MD-2 and MD-1, respectively) in training load in the three days prior to the match, which leads to the enhancement of their physical condition, as a result of the so-called supercompensation phenomenon[2]. In elite basketball, as this dose-response investigation presents, a progressive decrease in training loads three days before the match could be an appropriate way of physical conditioning in a preparation of a team for competitive tasks.

One of the limitations in the current study was the lack of comparison group. However, that kind of experimental design is not available when the study is conducted in top-level performance teams. In the future, research in elite basketball should examine the effectiveness of different models of load distribution prior to the match day in correlation with both physical and key performance indicators in games.

Conclusion

Training load management is a crucial factor that leads to either enhanced or decreased physical condition in competitions. Basketball is an intermittent sport where accelerometry – derived data on individual accelerations, decelerations, jumps, changes of direction and PlayerLoad – provides a stable and clear platform for tracking and analyzing training load. Therefore, if training load is appropriately selected, coaches can find the most effective micro-tapering models prior to the match. According to the findings of this study, the accumulated PL of ≈1048 AU with ratio of ≈ 42 %, 34 % and 24 % in MD-3, MD-2 and MD-1 respectively, could be appropriate load distribution, as it leads to a very good physical condition on the match day. Moreover, the current study demonstrates that the use of different approaches to monitor training load provides a better micro-cycle (i.e. week) assessment and implementation of the short-term tapering prior to the games at the elite basketball level. Complementary monitoring of both external and internal loads provides a comprehensive insight about training demands and psycho-physiological responses in players. Successful training load monitoring across the pre- and in-season phases should be performed for two main reasons; to decrease injury risk and provide optimal level of stress and adaptation that leads to enhanced physical and competitive performance. Nevertheless, solely monitoring of training load is not enough to ensure a good management of the load. Complementary to load monitoring methods, coaches should assess players' state of recovery and readiness to play. In this paper, use of the TQR questionnaire was presented. However, complementary use of subjective and objective (e.g. creatin kinease values, heart rate, jumping performance) methods is advised. The practical implications may be further enhanced by understanding players' mental and physical states regarding the day of the week and its proximity to the match-day. Only in this way, coaching staff will manage to optimize the players' performance. Therefore, future research in basketball should provide more information on a) the accelerometry-derived game load, so that even better relationships can be established between training and competitive demands and b) the effects of sleep quality and mentality during travels on players' readiness and performance in competitions.

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Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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TABLES

Table 1. Usual training tasks.

TASK	DESCRIPTION	DAY OF USE
PREPARATION	Warm-up, myo-fascial release and stretching, balance and activation exercises with goal to functionally prepare each player for training demands. Usual time 10-15’.	MD-3, MD-2, MD-1
5x0 HC	No-contact play on half-court for learning and mastering offensive sets. Usual time of play is 15-20’’, work rest ratio 1:1.	MD-3, MD-1
5x0 FC	No-contact play using full court for learning and mastering offensive sets. Usual time of play is 20-40’’, work rest ratio 1:1.	MD-3, MD-2, MD-1
SSG 3x3 HC	Contact small-sided game on half-court for learning and mastering tactical rules. Usual time of play is 30-60’’, work rest ratio 1:1.	MD-2
SSG 4x4 HC	Contact small-sided game on half-court for learning and mastering tactical rules. Usual time of play is 30-60’’, work rest ratio 2:1.	MD-3, MD-2, MD-1
SSG 5x5 HC	Contact small-sided game on half-court for learning and mastering tactical rules. Usual time of play is 30-90’’, work rest ratio 1:2.	MD-3, MD-1
SSG 5x5 FC	Contact small-sided game using full court for learning and mastering tactical rules. Usual time of play is 30-120’’, work rest ratio 1:1.	MD-3, MD-2, MD-1
SHOOTING	Spot-up shooting drills in pairs, low to medium intensity, continuous 5-10’.	MD-3, MD-2, MD-1

Note: SSG is small-sided game, HC is half court, FC is full court, MD-3 is three days prior the match, MD-2 is two days prior the match and MD-1 is one day prior the match.

Table 2. Mean, ±standard deviation, confident interval at 95% (in brackets) and effect size (ES) for absolute external training load variables.

VARIABLES	MD-3	MD-2	MD-1	ES
hACC (n)	10.8±5.5^{2,1} (9.0-12.5)	8.0±3.9^{1} (7.2-8.8)	4.1±3.0 (3.4-4.7)	A=0.59, B=1.12, C=1.51
tACC (n)	72.8±22.9^{2,1} (65.6-80.0)	62.2±21.0^{1} (57.8-66.5)	33.3±15.2 (30.2-36.4)	A=0.48, B=1.58, C=2.03
hDEC (n)	16.8±8.2^{2,1} (14.2-19.4)	12.0±6.1^{1} (10.7-13.2)	7.3±4.4 (6.4-8.2)	A=0.66, B=0.88, C=1.44
tDEC (n)	125.9±28.6^{2,1} (116.8-134.9)	101.2±23.4^{1} (96.4-106.1)	71.4±25.7 (66.1-76.6)	A=0.95, B=1.21, C=2.00
hCoD (n)	33.1±12.7^{2,1} (29.1-37.1)	26.6±12.0^{1} (24.1-29.1)	15.0±8.3 (13.3-16.7)	A=0.53, B=1.12, C=1.69
tCoD (n)	480.0±103.7^{2,1} (447.2-512.7)	374.8±67.1^{1} (360.9-388.7)	247.7±80.3 (231.3-264.0)	A=1.20, B=1.72, C=2.50
hJUMP (n)	17.5±7.3^{1} (15.2-19.8)	14.8±6.1^{1} (13.5-16.0)	10.2±5.3 (9.1-11.2)	B= 0.81, C=1.14
tJUMP (n)	58.2±17.6^{1} (52.7-63.8)	55.5±16.2^{1} (52.2-58.9)	42.7±21.3 (38.4-47.0)	B= 0.68, C=0.79

Note: 3 means > MD-3, 2 means > MD-2, 1 means > MD-1, A means MD-3vsMD-2, B means MD-2vsMD-1 and C means MD-3vsMD-1. tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 m·s-2), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 m·s-2), tCOD is total rightward lateral movements, hCOD is total movements registered in a rightward lateral vector within the high band, tJUMP is total jumps, and hJUMP is jumps done at the high band (above 0.4 m).

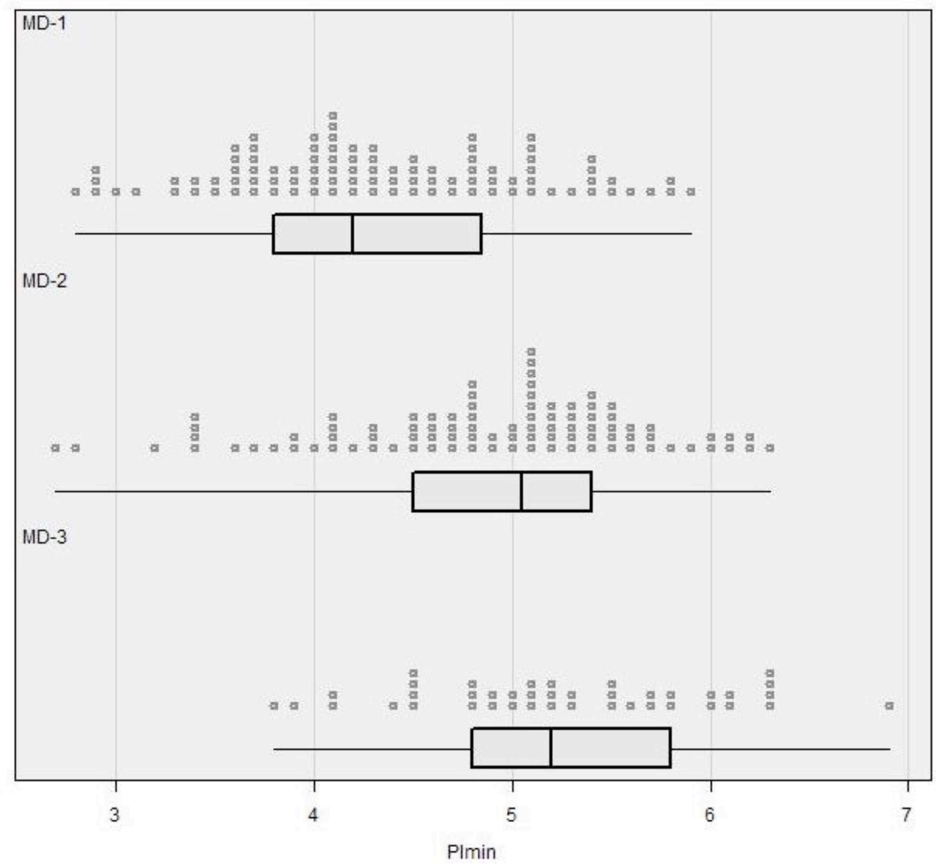
Table 3. Mean, ±standard deviation, confident interval at 95% (in brackets) and effect size (ES) for relative (per minute) external training load variables.

VARIABLES	MD-3	MD-2	MD-1	ES
hACC/min	0.14±0.07^{2,1} (0.12-0.17)	0.11±0.05^{1} (0.10-0.12)	0.05±0.04 (0.05-0.06)	A=0.49, B=1.33, C=1.58
hDEC/min	0.22±0.1^{2,1} (0.19-0.26)	0.16±0.08^{1} (0.14-0.18)	0.10±0.06 (0.09-0.11)	A=0.67, B=0.85, C=1.46
tACC/min	0.98±0.31^{2,1} (0.88-1.07)	0.83±0.28^{1} (0.77-0.89)	0.45±0.20 (0.40-0.49)	A=0.51, B=1.56, C=2.03
tDEC/min	1.69±0.38^{2,1} (1.57-1.81)	1.36±0.31^{1} (1.29-1.42)	0.96±0.34 (0.89-1.03)	A=0.95, B=1.23, C=2.02
hCoD/min	0.44±0.17^{2,1} (0.39-0.50)	0.36±0.16^{1} (0.32-0.39)	0.20±0.11 (0.18-0.22)	A=0.48, B=1.17, C=1.68
tCoD/min	6.43±1.39^{2,1} (5.99-6.87)	5.02±0.90^{1} (4.84-5.21)	3.32±1.08 (3.10-3.54)	A=1.20, B=1.71, C=2.50
tJUMP/min	0.68±0.27 (0.64-0.71)	0.78±0.24^{1,3} (0.71-0.85)	0.74±0.22^{3} (0.70-0.79)	A= -0.39, C= -2.24
hJUMP/min	0.18±0.09 (0.17-0.19)	0.23±0.10^{1,3} (0.20-0.26)	0.20±0.08^{3} (0.18-0.21)	A= -0.53, C= -0.23

Note: 3 means > MD-3, 2 means > MD-2, 1 means > MD-1. A means MD-3vsMD-2, B means MD-2vsMD-1 and C means MD-3vsMD-1. tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 m·s-2), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 m·s-2), tCOD is total rightward lateral movements, hCOD is total movements registered in a rightward lateral vector within the high band, tJUMP is total jumps, and hJUMP is jumps done at the high band (above 0.4 m).

TITLES OF FIGURES

Figure 1. Median, ±standard deviation, confident interval at 95% for a) total PL (Player Load) in arbitrary units (AU) and b) PL/min (Player load per minute) in arbitrary units per minute (AU/min) regarding to the day of the week (MD-3 is match day minus 3, MD-2 is match day minus 2 and MD-1 is match day minus 1).



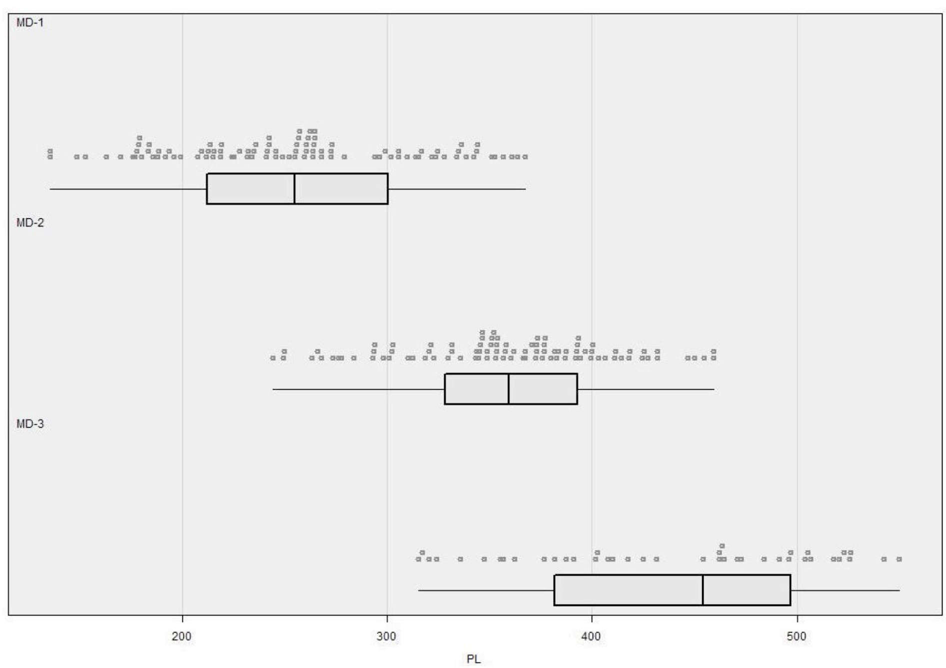
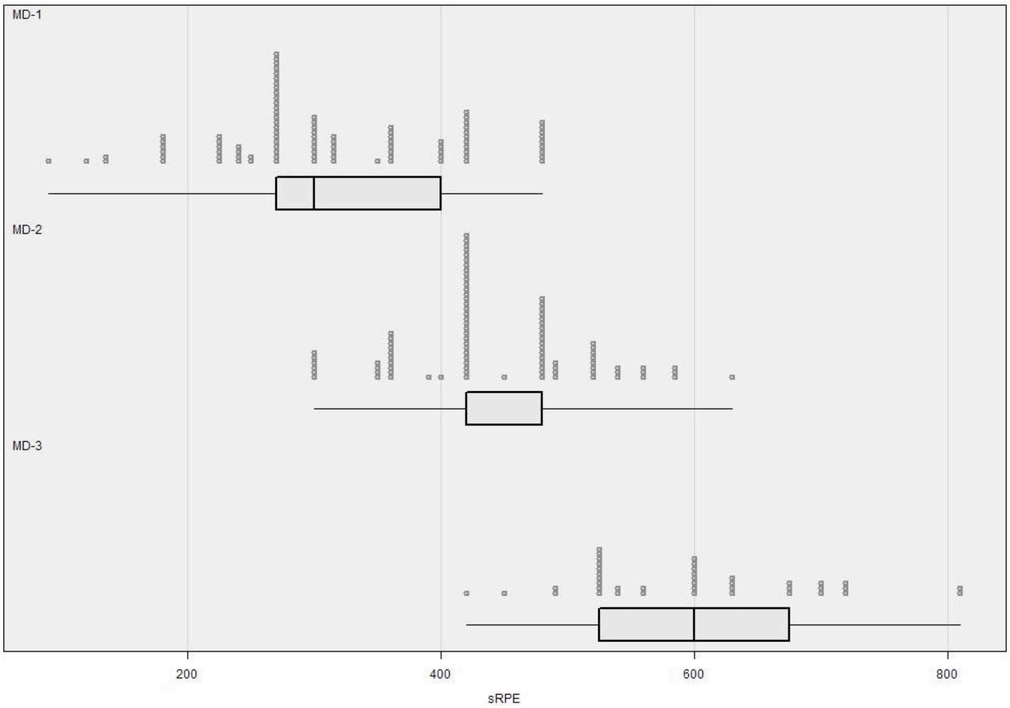


Figure 2. Median, ± standard deviation, confident interval at 95% for a) sRPE (session RPE) in arbitrary units (AU) and b) sRPE in arbitrary units per minute (AU/min) regarding to the day of the week (MD-3 in match day minus 3, MD-2 in match day minus 2 and MD-1 in match day minus 1).



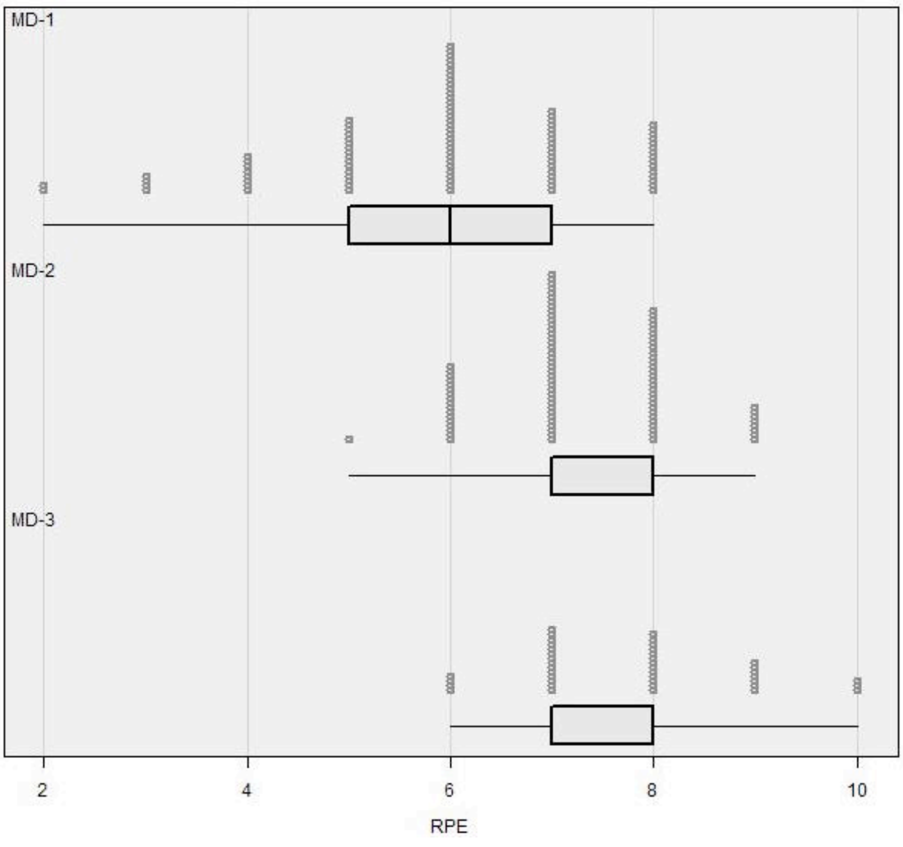
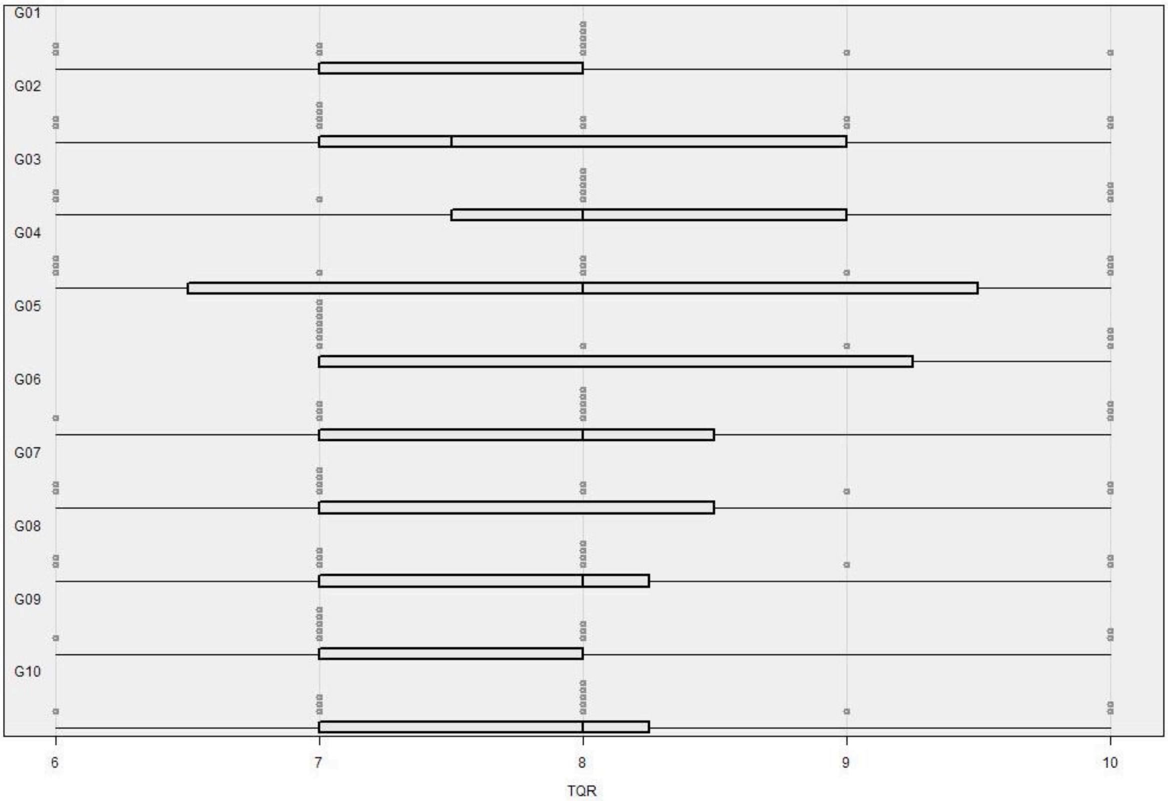


Figure 3. Median, ± standard deviation, confident interval at 95% for team's TQR scores prior the match (G presents a game, while the number classifies games from the first to the tenth).



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Article Title: Positional Differences in Elite Basketball: Selecting Appropriate Training - Load Measures

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"Positional Differences in Elite Basketball: Selecting Appropriate Training - Load Measures"
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Title: POSITIONAL DIFFERENCES IN ELITE BASKETBALL: SELECTING APPROPRIATE TRAINING - LOAD MEASURES

Submission type: Original investigation

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Abstract

Purpose: The purpose of this paper was to study the structure of interrelationships among external training load measures and how these vary among different positions in elite basketball. **Methods:** Eight external variables of jumping (JUMP), acceleration (ACC), deceleration (DEC) and change of direction (COD), and two internal load variables (RPE and sRPE) were collected from 13 professional players with 300 session records. Three playing positions were considered: guards (n=4), forwards (n=4) and centers (n=5). High and total external variables (hJUMP and tJUMP, hACC and tACC, hDEC and tDEC, hCOD and tCOD) were used for the principal component analysis. Extraction criteria were set at the eigenvalue of greater than one. *Varimax* rotation mode was used to extract multiple principal components. **Results:** The analysis showed that all positions had two or three principal components (explaining almost all of the variance), but the configuration of each factor was different: tACC, tDEC, tCOD and hJUMP for centers, hACC, tACC, tCOD and hJUMP for guards, and tACC, hDEC, tDEC, hCOD, and tCOD for forwards are specifically demanded in training sessions and, therefore, these variables must be prioritized in load monitoring. Furthermore, for all playing positions, RPE and sRPE have high correlation with the total amount of ACC, DEC and COD. This would suggest that, although players perform the same training tasks, the demands of each position can vary. **Conclusion:** A particular combination of external load measures is required to describe training load of each playing position, especially to better understand internal responses among players.

Keywords: playing position, team sport, time motion, RPE, training

Introduction

Athlete monitoring is the key to successful load management as well as to defining the quantity, quality and order of the content and its alterations with rest periods.[1] These prescriptive parameters must be considered by coaches when developing training plans. The management of the training load has received a lot of attention in recent years[2,3] due to its important role in improving performance and mitigating injuries.[4]

Accurate monitoring of the training load provides the coach with a better understanding of individual tolerance to training[5] and provides a solid basis for optimal training periodization. In order to understand the relationship between the training 'dose' and 'response', complementary use of external and internal load[6] is necessary to choose the best approach to optimally improve performance[7]. While external training load (eTL) represents the dose (activities) performed by players[1], internal training load (iTL) represents the psycho-physiological response (acute and chronic adaptations) by the athlete[8], and this process is individual[1] knowing the fact that the same external load can lead to different internal load in different players. Nevertheless, in team sports, training load is mainly derived from team practices, i.e. a combination of position-specific and non-position-specific tasks. Consequently, both external and internal loads can vary among players. In contrast to amateur level, sub-elite and elite basketball teams strive for the highest level of performance and for that reason data from high-level basketball should help coaches in everyday practice, especially knowing the fact that number of teams using modern micro-technologies has been growing in recent years.

At the elite level of play, an enormous amount of data about training sessions and games of a team is generated daily[4]. New technologies and analytical methods have led to new possibilities for monitoring load. In indoor sport, devices with micro-technologies (e.g.

accelerometer, gyroscope and magnetometer) have produced a plethora of variables, enabling practitioners to quantify load in greater detail than ever before.[2] Since the implementation of this technology has begun only recently, there is not enough data to describe external training demands of basketball players[9]. Even though subjective load measures are not recommended to be used in isolation, they may be employed by coaches and the support staff with confidence to complement the objective measures or to substitute them in situations where such technology is not available.[3]

It is overwhelming to try to use all of the variables that are now available for each second of the activity. Implementing principal component analysis (PCA), which has been previously proposed[10] to measure training modes, could be a useful option to remove the redundancy in variables used to monitor load or to know if players are stimulated similarly, according to their playing position. The previous research[11,12] of elite-level players has confirmed differences between guards, forwards and centers in various parameters such as number and intensity of movements, blood lactate concentration and heart rate values during games. However, the aforementioned studies considered subjective movement observations that are time-consuming, compared to more practical micro-technology that offers very quick data turnaround. Currently, only one study[13] has investigated position-dependent differences in basketball drills using micro-technology where only one external load variable was presented (i.e. acceleration load). Therefore, additional information regarding position-specific data derived from micro-technologies is of utmost importance.

Therefore, the purpose of the current study was to investigate the structure of interrelationships among the external and internal training session loads and determine how they vary among different positions in elite basketball via use of modern micro-sensor technology. The potential application of results is twofold: they may be used to avoid redundant information when assessing the training load using different variables, as well as to identify what variables are position-dependent based on the inertial movement patterns and subjective load measures of each playing position in elite basketball training.

Methods

Subjects

The professional male basketball players played on the same team (positions defined by the head coach; guards, age: 26.3 ±2.2 years; height: 186.0 ±4.3 cm; body mass: 88.0 ±8.6 kg; body fat: 10.6 ± 1.7%; forwards, age: 25.0 ± 4.1 years; height: 199.4 ± 4.1 cm; body mass: 93.7 ± 2.2 kg; body fat: 10.2 ± 1.3%; centers, age: 25.8 ± 3.8 years; height: 209.6 ± 2.7 cm; body mass: 105.8 ± 4.1 kg; body fat: 11.0 ± 1.1%; elite level experience 2-12 years). The team competed in two basketball championships, Liga Endesa (i.e. 1st Spanish Division) and the Euroleague, in the 2016/17 season. The weekly schedule consisted of two games (first on Thursday/Friday and second on Sunday), one rest day (Monday), and one team practice on each of the remaining days. All players were notified of the aim of the study, research procedures, requirements, and benefits and risks before giving informed consent, in accordance with the Declaration of Helsinki. Furthermore, the data was anonymized and institutional approval was given for this study.

Design

Thirteen elite-level basketball players were monitored during in-season competitive periods (16 weeks). Players were assigned to one of the three positional groups: (guards, n = 4; forwards, n = 4; and centers, n = 5). A total of 300 training observations were undertaken with a range of 4-26 training sessions per player. Training observations for each positional category were 84, 102 and 114 for guards, forwards and centers, respectively. Only the data derived from team training sessions (Tuesday to Wednesday/Thursday) prior to the first game of the week (i.e. Euroleague game on Thursday or Friday) were included in the analysis due to adjustments in team sessions prior to the second game (e.g. some players with more playing time in the first game would partially participate in the practices on Friday and Saturday due to accumulated fatigue). After the team warm-up and movement preparation, no-contact drills (4vs0 and 5vs0) and small-sided games (3vs3, 4vs4 and 5vs5) were used on a half and full-court size. The observation started after warm-up and movement preparation and lasted until the end of the practice, taking between 60 and 75 minutes. All players were observed simultaneously. Official matches (use is not permitted in both competitions), strength and recovery sessions, and individual basketball practices were not included in the investigation.

Procedures

The eTL was monitored using Catapult Innovations S5 devices (Melbourne, Australia), which include the accelerometer, gyroscope and magnetometer sensors, which provide data for inertial movement analysis (IMA). Most variables derived from the inertial sensors/accelerometers (only via micro-technology) were used.[2] All the variables were monitored using 100-Hz frequency. This kind of technology was previously confirmed as both valid and reliable.[14]

The iTL was monitored via RPE and the session-RPE (sRPE). Individual RPE was obtained using the 10-point Borg scale on which players rated their perceived physical effort 15-30 minutes after the training, in accordance with the procedures suggested by Foster et al.[15] in order to avoid the influence of the last part of the session on players’ perception. Furthermore sRPE was calculated by multiplying RPE with the training duration expressed in minutes. sRPE has been reported to be a valid indicator of global internal load of training in intermittent team sports.[6] All the players were familiarized with the use of the scale during the preparatory period.

External and internal training load

The eTL data included the following variables: accelerations (ACC), decelerations (DEC), jumps (JUMP) and changes of direction (COD). The ACC variable refers to inertial movements registered in a forward acceleration vector, where tACC refers to all accelerations and hACC only to high-intensity accelerations (>3.5 $m \cdot s^{-2}$). The DEC variable refers to inertial movements registered in a forward deceleration vector, where tDEC refers to total movements and hDEC only to high-intensity movements registered within the high threshold (>3.5 $m \cdot s^{-2}$). The time interval during which acceleration is measured can significantly affect the data.[2] Based on the study results of Varley et al.[16] who concluded that is difficult to provide an appropriate *dwell time* or minimum effort duration (MED) with acceleration efforts, the dwell time in present study was selected to 0.4s. The jumps were also registered as total jumps (tJUMP) and high-intensity jumps (hJUMP, over 0.4 m), the same as changes of direction, tCOD (total inertial movements registered in a rightward/leftward lateral vector), and hCOD (total inertial movements registered in a rightward/leftward lateral vector within the high-intensity threshold). All aforementioned variables were assessed with respect to their frequency. The iTL was recorded using RPE and session-RPE (sRPE) in order to distinctly quantify intensity and load of training session.

Statistical analysis

Before carrying out Principal component analysis (PCA), the Pearson correlation matrix with eight training external load variables was conducted in order to perform a visual inspection of data factorability.[17] This method aims to extract the most important components and/or variables from data, without reducing the information. All data were centred and scaled (using within-individual data) before conducting the PCA. The Kaiser-Meyer-Olkin (KMO) values for three playing positions (center, guard and forward) were 0.85, 0.84 and 0.85, respectively, showing that the dataset is suitable for PCA.[18] Bartlett's sphericity test was significant for each training mode ($p<0.001$). The principal axis method was used to extract the components. Components with the eigenvalues of less than 1 were not retained for extraction.[18] The PCA was applied with a *VariMax* rotation to identify components that are not highly correlated. Consequently, each principal component provided distinct information. Subsequently, the rotation was performed with the goal of making the component loadings more easily interpretable. The stages involved in the calculation for PCA were the same as those used previously.[10] For each extracted PC, only the original variables that possessed a PC loading greater than 0.7 were retained for interpretation. Finally, the correlation between external and internal load variables was measured for each playing position. As proposed by Hopkins[19], the following qualitative correlation descriptors were used: trivial (0 – 0.09), small (0.1 – 0.29), moderate (0.3 – 0.49), large (0.5 – 0.69), very large (0.7 – 0.89), nearly perfect (0.9 – 0.99), and perfect (1). The Statistical Package for the Social Sciences (SPSS, Version 24.0 for Windows; SPSS Inc, Chicago, IL) was used to conduct the analysis.

Results

A total of 300 observations of team training sessions were monitored for investigation and the data was distributed across three playing positions (Table 1).

Table 2 shows PCA, including the eigenvalues for each principal component in each playing position and the total explained variance by each principal component for each playing position. In each playing position, two (for centers) or three (for forwards and guards) principal components were identified, but with different distribution of the internal and external load variables.

Pearson correlations between internal and external training load variables for each playing position are presented in Table 3.

Figure 1 shows rotated component plots for each playing position. Only two main factors were plotted to visually represent playing position differences. For all playing positions, two to three principal components were retained for extraction, including their position within the rotated space.

Discussion

The main finding of the present study was the identification of a structure with two or three principal components summarizing several external training load variables, which showed a different weight of variables depending on the playing position. Although the initial number of factors was the same as the number of variables used in the factor analysis – since factors where initial eigenvalues were more than 1 were used – only the first two factors for centers and three for forwards and guards were retained for playing positions. For the three playing positions studied, the cumulative percentage of variance accounted for by the second row (factor) and the first preceding factor showed values close to 90% of the total variance. Complementary, only two components obtained for centers could denote less variability in their movement patterns, maybe due to higher static exertion (e.g. doing screening/picking and positioning) activity when playing in this role[20]. For all playing positions, tACC and tCOD are relevant in their activity profiles. Considering the above said, we can conclude that these two or three factors (depending on playing position) adequately represent the original data.

When looking at the first principal component, which explains the greatest proportion of variance, the representation of the external load variables was position-dependent. For all playing positions, tACC and tCOD were common. Additionally, for forwards and centers, the tDEC activity is a representative in their profiles while for the guards this variable is in the second component. This is in line with the profile in activity demands in a multi-directional team sport, such as basketball, where the number of activity changes can range between 997 and 2733 per game[21]. For centers and guards, the hJUMP external load variable was also the most representative for the first factor in their profiles of activity, while additionally, tDEC was representative for both forwards and centers. The hJUMP variable for centers can be explained due to greater efforts when catching rebounds and for guards when shooting after intense penetration towards the basket.

Differences in the profile of playing positions are interesting. Compared to research of Puente et al.[22], who studied internal and external loads in friendly games with respect to playing positions, in the current study that investigated training sessions, players were demanded in a different way: hACC for guards, hDEC and hCOD for forwards. For that reason, the movement profile of each playing position is particular. Guards and forwards profiled more high activity actions than centers (e.g. hACC and hJUMP for guards and hDEC and hCOD for forward, centers only hJUMP). This could be explained due to minor movement frequency and intensity of centers in the game, as it was also proposed in previous research for total[11, 12] and high-intensity[11] actions. Additionally, centers are players who are positioned closer to the basket due to their height, what could further limit their movement area.

On the other hand, the content for the second component was different for each playing position. Variables tJUMP and hACC had impact for both forwards and centers, tDEC for guards and hDEC for centers. The aforementioned finding could be explained due to different physical demands of same training drill for each playing position. Additionally, it can be observed that tJUMP variable is not representative in physical profile of guards while for forwards and centers it is representative in the second component. This finding could indicate that jumps are not very frequent movement pattern in basketball training and game, like it was observed in previous research[11] (41-56 jumps per game), especially when compared to changes of direction, accelerations and decelerations.

Body height and body mass are known to be the main individual factors to define the court position of a basketball player. The anthropometric profile of participants in this study was similar to previous reports in Serbian[23], French[24] and Belgium[25] elite basketball players. Different anthropometric profiles of basketball players, which are highly relevant to the playing position, could probably be the main factor explaining effects that playing positions have on the relationships between external training demands measures during the same training sessions. The aforementioned is in the line with two principles of Schelling and Torres[13] who explain that smaller player has lower body mass, and therefore easier position to accelerate with less applied force. Moreover, playing zones for big players are more reduced compared to small players, meaning that small players ultimately cover more distance in each action on the court. Knowing that, based on the correlation values between external variables and internal response (sRPE) among centers for total (r = 0.71) and high accelerations (r = 0.58) it can be concluded that application of aforementioned variables will cause a greater internal response among centers compared to guards and forwards. In the same line, other variables such as total and high decelerations for guards and high changes of direction for forwards will cause greater internal response what could eventually lead to similar RPE and sRPE values among all playing positions.

Furthermore, the correlation between internal and external values provides interesting information. The sRPE shows greater correlation with external variables, compared to the RPE. Total values of variables such as ACC, DEC and COD (tACC, tDEC and tCOD, respectively) showed large or very large correlation with sRPE. Similary, Scanlan et al.[26] reported a moderate correlation between sRPE and accelerometer training load. However, in aforementioned research only one external load variable was reported. In our research, in all playing positions, one or more external load variables showed large or very large correlations with sRPE. In all playing positions studied, tCOD showed either a high correlation (for forwards) or a very high correlation (for centers and guards) with the sRPE. The strong correlation between eTL and iTL provides better understanding of stress-response relationship and therefore gives better insight into load management.

A lack of information on the type of drills used in the training sessions is one of the limitations of the present study. It is possible that the amount of time spent on both position-specific and non-position-specific tasks could affect the obtained results. The second limitation involves absence of differentiation between training modes. Following the recent “match day minus” format, used recently in other team sports, such as football[4], where each training session is categorized by its proximity to the match-day, a specific distribution of training load amount in the days preceding the match is typically employed[27], promoting a functional, short-term tapering for the competition ahead[1,28]. In those cases, other factors and correlations between variables can emerge. Consequently, further research is required to establish the dose-response relationship in different training modes for different combinations of external and internal load values, preferably for individuals, or, if this is not possible, for specific playing positions.

These results provide very interesting findings. Firstly, a combination of external load variables explains a higher proportion of the variance observed in professional basketball training, regardless of the playing position. Secondly, although players participate in the same drills during the team training sessions, the demands are not equal for all positions. Therefore, it could be interesting to take into account different types of external training load measures, as the use of only one external training load measure for all players may be both insufficient and incorrect. As it is presented throughout the paper, each playing position is represented with specific activities in external load variables spectrum and therefore their complementary use for different playing positions could be an appropriate way to select, analyze and control training loads. Additionally, adequate load management could prevent overuse injuries in professional basketball players.[29]

Practical application

Findings in this study focus on training data and therefore can help coaches enhance the effectiveness of their training programs. It is obvious that particular movement patters should be highlighted in a specific type of team conditioning demanding that centers focus on accelerations and changes of direction, forwards on decelerations and changes of direction, and guards on decelerations. A combination of internal and external variables should be considered when deciding to measure training load. These methods are of different construct so their complementary use integrates data analysis and application in practice. As basketball is an intermittent team sport, inertial movements (acceleration, deceleration, change of direction and jump) have an important role in external training load monitoring in basketball. Despite the fact that players train together, differences in training load among playing positions exist, and coaches and conditioning specialists should be aware of them. Once coaches consider positional differences in basketball, optimal training loads can be selected together with management of other important aspects such as individual basketball development, preventive protocols and recovery.

Conclusion

The conclusion of the study was that a combination of several load measures is required to describe the load of the three playing positions in basketball training sessions. The authors agree with the suggestion by Williams et al.[30] that the training load monitoring process may be optimized by selecting and monitoring the most parsimonious set of variables, as this simplifies the analysis of training-load measures in team sport settings. Therefore, acceleration and change of direction for centers, deceleration and high jumps for guards and high and total amount of deceleration and change of direction for forwards are specifically demanded in professional basketball training. Future research should focus more on the application of accelerometry in elite basketball, especially in the analysis of small-sided games and positional differences.

Acknowledgments

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"Positional Differences in Elite Basketball: Selecting Appropriate Training - Load Measures"
by Svilar L, Castellano J, Jukic I, Casamichana D
International Journal of Sports Physiology and Performance

Figure 1a:

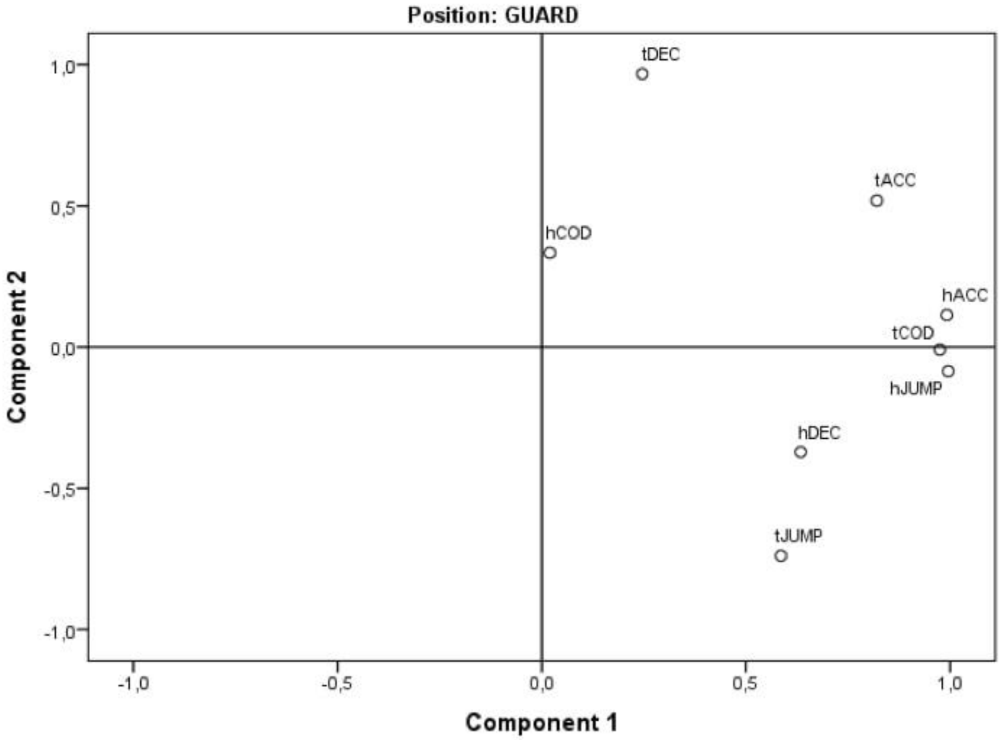

Figure 1b:

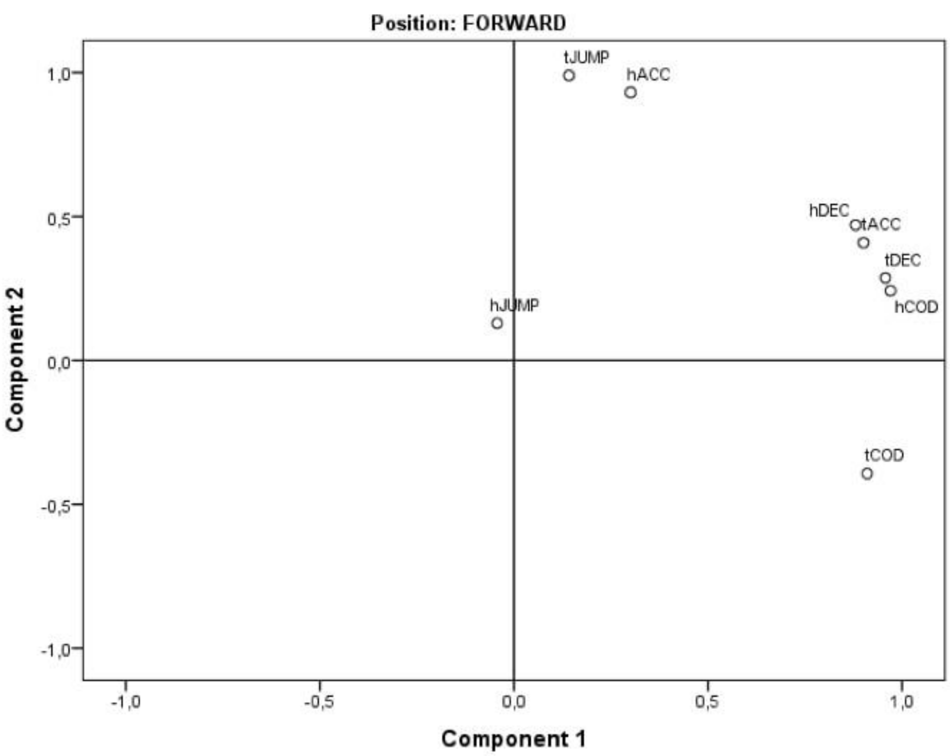

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Figure 1c:

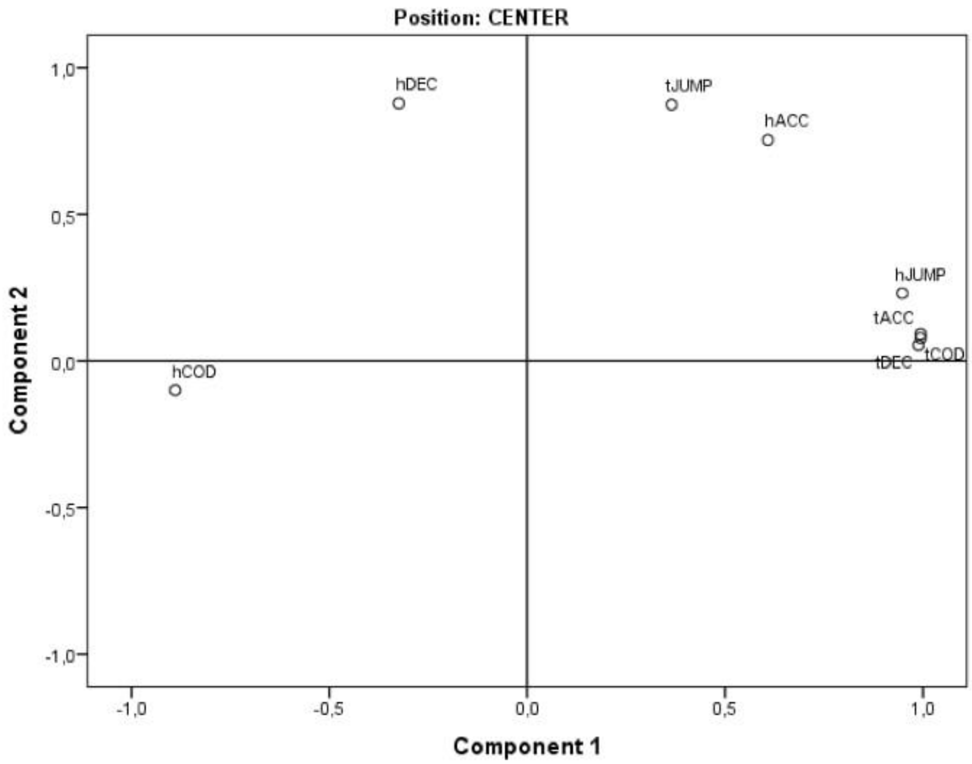

Figure 1: Rotated component plots of the playing positions: a) guards, b) forwards and, c) centers.

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Table 1. Means ± SD of internal and external training load measures according to playing position.

	Guards (n=84)		Forwards (n=102)		Centers (n=114)	
Variables	Mean	SD	Mean	SD	Mean	SD
tACC (n)	43.5	17.5	42.0	21.5	59.5	27.1
hACE (n)	6.4	4.4	5.8	4.3	7.2	4.8
tDEC (n)	84.7	30.1	93.2	35.4	88.5	30.3
hDEC (n)	11.9	5.7	12.7	8.3	6.8	4.0
tCOD (n)	324.8	110.2	336.8	121.4	312.1	114.8
hCOD (n)	23.5	12.5	24.7	14.5	16.8	8.6
tJUMP (n)	45.9	18.2	53.7	20.4	49.2	20.4
hJUMP (n)	13.3	6.1	12.5	6.1	13.6	7.8
RPE (AU)	6.7	1.7	6.5	1.5	6.6	1.3
sRPE (AU)	402.9	151.8	385.5	137.3	385.1	121.6

Note: tACC is total forward acceleration, hACC is high intensity acceleration (>3.5 m·s-^{2}), tDEC is total deceleration, hDEC is high intensity deceleration (<-3.5 m·s-^{2}), tJUMP is total jumps, hJUMP is high intensity jumps (above 0.4 m), tCOD is total rightward/leftward lateral movements, hCOD is high intensity movements registered in a rightward/leftward lateral vector. RPE is measurement of perceived exertion, and sRPE is session-RPE.

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Table 2. Results of the PCA, showing the eigenvalue, percentage (%) of variance explained and the cumulative % of variance explained by each Principal Component (PC) for each playing position. Also showing the rotated training load component loadings for each PC extracted (values below 0.3 were removed).

		PC							
Playing position		1	2	3	4	5	6	7	8
Guards	Eigenvalue	4.58	2.28	1.14					
	% of V.	57.22	28.50	14.28					
	C. V. %	57.22	85.72	100.00					
	tACC	0.82	0.52						
	hACC	0.99							
	tDEC		0.97						
	hDEC	0.63	-0.37	0.68					
	tCOD	0.98							
	hCOD		0.33	0.94					
	tJUMP	0.59	-0.74	-0.33					
	hJUMP	1.00							
Forwards	Eigenvalue	5.10	1.89	1.02					
	% of V.	63.71	23.58	12.72					
	C. V. %	63.71	87.29	100.00					
	tACC	0.90	0.41						
	hACC	0.30	0.93						
	tDEC	0.96							
	hDEC	0.88	0.47						
	tCOD	0.91	-0.39						
	hCOD	0.97							
	tJUMP		0.99						
	hJUMP			0.99					
Centers	Eigenvalue	5.56	1.88	0.32	0.18	0.06	0.01		
	% of V.	69.52	23.45	3.95	2.22	0.71	0.15		
	C. V. %	69.52	92.96	96.91	99.14	99.85	100.00		
	tACC	0.99							
	hACC	0.61	0.75						
	tDEC	0.99							
	hDEC	-0.33	0.88						
	tCOD	0.99							
	hCOD	-0.89							

	PC							
Playing position	1	2	3	4	5	6	7	8
tJUMP	0.37	0.87						
hJUMP	0.95							

Note: tACC is total forward acceleration, hACC is high intensity acceleration (>3.5 m·s-^{2}), tDEC is total deceleration, hDEC is high intensity deceleration (<-3.5 m·s-^{2}), tJUMP is total jumps, hJUMP is high intensity jumps (above 0.4 m), tCOD is total rightward/leftward lateral movements, hCOD is high intensity movements registered in a rightward/leftward lateral vector.

Table 3. Pearson correlations for internal and external training load measure for each playing position. All correlation had a significant value at >0.001 level.

	Guards		Forwards		Centers	
Variable	RPE	sRPE	RPE	sRPE	RPE	sRPE
tACC	.605	.686	.480	.614	.516	.710
hACC	.311	.462	.422	.480	.429	.582
tDEC	.723	.806	.497	.680	.452	.679
hDEC	.557	.665	.262	.463	.322	.542
tCOD	.679	.779	.585	.777	.592	.760
hCOD	.405	.482	.394	.574	.381	.555
tJUMP	.400	.453	.348	.440	.124	.320
hJUMP	.577	.655	.351	.482	.060	.311

Note: tACC is total forward acceleration, hACC is high intensity acceleration (>3.5 $m \cdot s^{-2}$), tDEC is total deceleration, hDEC is high intensity deceleration (<-3.5 $m \cdot s^{-2}$), tJUMP is total jumps, hJUMP is high intensity jumps (above 0.4 m), tCOD is total rightward/leftward lateral movements, hCOD is high intensity movements registered in a rightward/leftward lateral vector. RPE is measurement of perceived exertion, and sRPE is session-RPE.

Comparison of 5vs5 Training Games and Match-Play Using Microsensor Technology in Elite Basketball

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Abstract

Svilar, L, Castellano, J, and Jukic, I. Comparison of 5vs5 training games and match-play using microsensor technology in elite basketball. *J Strength Cond Res* XX(X): 000–000, 2018—The aim of this study was to compare the data obtained using microsensor technology in 2 types of 5vs5 training games—the regular-stop game (RSG) and the no-stop game (NSG)—and in match-play (MP) in elite basketball. Sixteen top-level basketball players were monitored during pre- and in-season periods (10 weeks). The variables included: player load, accelerations (ACC), decelerations (DEC), changes of direction (CoD), and jumps (JUMP)—all in both total (*t*) and high-intensity (*h*) relative values (i.e., per minute of play): PLmin, ACCmin, DECmin, CoDmin, and JUMPmin, respectively. Almost all variables showed trivial difference between MP and RSG. The only variable that showed small difference was tACCmin (MP > RSG). In case of RSG vs. NSG, 3 variables showed trivial difference—tACCmin, hACCmin, and hDECmin, 3 (i.e., hCODmin, tDECmin, and PLmin) small differences, and 3 (tCoDmin, tJUMPmin, and hJUMPmin) moderate differences (NSG > RSG). In MP vs. NSG, 2 variables (hCoDmin and tACCmin) showed trivial differences; variable hDECmin showed small difference, whereas the other 5 variables (tCoDmin, tJUMPmin, hJUMPmin, tDECmin, and PLmin) showed moderate difference (NSG > MP). Only one variable, hACCmin, showed moderate difference, when MP > NSG. The main conclusion of the study was that by introducing some constraints into 5vs5 tasks, the coaching staff could elicit higher physical demands than those occurring in MP. By understanding the differences in demands of NSG, RSG, and MP, coaches in elite basketball can improve their system of training drills selection, especially when looking for optimal short-term tapering approach, leading up to the game day.

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Introduction

In recent years, elite basketball in Europe has moved toward the congested fixture, where the teams that participate in both Euroleague and domestic championships play 2–3 games per week in the regular part of the season. During play-offs, these teams could play as many as 5 games over a 10-day period. In total, elite Spanish teams could finish their seasons with up to 87 games played. The aforementioned phenomenon requires all members of the coaching staff, and especially performance specialists, to fully understand the training demands and physiological responses in using various training drills. Therefore, the choice of drills could be crucial in setting up optimal training workload before competitions, which will eventually result in optimal short-term tapering and enhanced players' psychophysical state. As presented in the latest review by Stojanovic et al. (21), there are numerous articles indicating significant differences in activity frequency and intensity between players of different playing levels. Therefore, practitioners in elite basketball should be provided with reliable scientific data, while studies conducted on youth teams or semiprofessional players need to be interpreted with caution.

In practice, training drills can be divided into 2 major categories with respect to the conditions of play: no-contact and contact drills. No-contact drills (referred to as *directed* drills by Schelling and Torres-Ronda (20)) enable coaches to work with players individually or in groups on developing technical qualities such as ball handling, passing, dribbling, or shooting. Moreover, no-contact drills, such as 2vs0 up to 5vs0, are used to practice team's tactical principles. On the other hand, contact drills (referred to as *special* and *competitive* tasks by Schelling and Torres-Ronda (20)), such as various small-sided games (SSGs) and game simulations (GS), are used to master individual technical skills as well as to develop teams' tactical proficiency and specific basketball endurance (8). Regarding the number of players, it is important to know that SSGs normally consider 1vs1 up to 4vs4 confrontation format, whereas 5vs4 and 5vs5 formats are used as GS (20). The use of SSG, also known as small-sided and conditioning games, has been adopted in practice as an alternative to traditional team conditioning (8,12,19,20). In this respect, it is important to note that the number of SSG investigations conducted on elite players in basketball is very limited, with only 2 such studies (19,23) known to the authors. Torres-Ronda et al. (23) have found that a higher physiological response (through heart rate [HR] monitoring) was elicited in match-play (MP), 5vs5 training game, and 3vs3 open-court training drills as compared to other drills, such as 5vs5 half-court, 2vs2, 4vs4, etc. In addition, the relative frequency of movements per minute of play, as assessed using notational analysis (using Lince software), did not differ between MP and 5vs5 open-court and half-court drills (33 $\pm$ 7, 32 $\pm$ 4, and 31 $\pm$ 4, respectively). It is important to know that despite the fact that Lince is a valuable source of information in the analysis of sports performance, the use of microtechnology (e.g., inertial movement sensors) could help us better understand physical demands and performance in trainings and games.

Constraints in the court size, number of players, work:rest ratio, or rules of the play (8) are some of the factors that need to be investigated in depth if we are to better understand the demands of each SSG and GS. For example, full-court drills are both physically and physiologically more demanding than those conducted on the half-court (13,15). Moreover, fewer players on the regular court size will be exposed to a major physiological stress (7,9,10,12,13,18,23). With more players on the court, fewer technical actions per player will be conducted (19). Furthermore, the change of rules, such as no-dribble tasks, lead to an increase in physiological load and a higher number of passes (11). However, most studies on SSG and GS in basketball were conducted with the use of HR monitors, notational analyses, or blood lactate concentrations, whereas only few studies of trainings and games used the technology of microsensors (15,19).

The study of elite players by Schelling and Torres-Ronda (19) used triaxial accelerometer in training settings and showed that playing full-court 3vs3 and 5vs5 scrimmage drills elicited higher acceleration load per minute ($AL \cdot min^{-1}$) as compared to full-court 2vs2 and 4vs4 drills and 5vs5 half-court drill. However, the study investigated only one type of metric (i.e., acceleration load per minute, $AL \cdot min^{-1}$). The study by Montgomery et al. (15) investigated differences between MP and 5vs5 half-court scrimmage games among junior players also by looking at a single variable (i.e., $AL \cdot min^{-1}$), and it was observed that MP puts higher physical demands on the players than the 5vs5 scrimmage game on the half-court (279 $\pm$ 58 as compared to 171 $\pm$ 84 $a.u. \cdot min^{-1}$). Finally, it is important to state that no studies have presented objective microsensor technology data of elite MP to date, nor provided a comparison of any SSG and GS to MP. The use of modern technology, such as triaxial accelerometry, provides reliable data (2,24) for the prescription and management of the external load. As it is suggested by Weiss et al. (25), maintaining the workload ratio between 1 and 1.5 may be optimal to reduce injury risk in professional basketball players.

Based on the data collected during games, coaches are able to objectively quantify and compare all the drills they use in practice to improve teams' performance, as data from MP serve as a platform for understanding and prescribing physical demands for various training drills. Therefore, the goal of this study was to compare microsensor technology data in 2 types of 5vs5 training games (one game that replicates games' conditions and other that intents to overload) with that in MP in elite basketball. The results of this study could help coaches in the selection of training drills and periodization of practices in elite-level basketball.

It was hypothesized that no-stop 5vs5 training game will elicit greater physical demands than regular-stop 5vs5 training game and MP. AU5

Methods

Experimental Approach to the Problem

Sixteen top-level basketball players were monitored during the pre- and in-season periods (September–October). A total of 12 trainings (5 no-stop and 7 regular-stop games [RSGs])

Table 1. Description of the rules in the no-stop game (NSG) and the regular-stop game (RSG).

No-stop game	Regular-stop game
Clock is not stopped	Clock is stopped when the ball is out-of-bounds
No free throw after a foul	Clock is stopped for fouls
Quick ball-in-play reposition	Free throws were given when the foul occurred during an attempt to shoot
No time-outs	Regular ball-in-play reposition
	One time-out allowed per set*

*If time-out was used during the game, it was excluded from the data analysis.

and 5 games were analyzed, with a total number of 385 records made. Out of all records, 208 were training records (9.5 ± 5.6 per player) and 177 game records (10.7 ± 5.5 per player). One record considered data collected by players' participation in game, lasting for at least 1 minute. The training games' inertial movement data were obtained during team basketball sessions, whereas MP data were recorded during tournaments against ACB (Spanish first division) and international teams that compete in the Eurocup competition.

As a working hypothesis, it was assumed that the no-stop game (NSG) would put the greatest physical demands out of all investigated games. This was assumed due to the fact that regular no-activity periods (i.e., ball out-of-bounds reposition after ball is handed by referee and free throws shooting) were eliminated in NSG what potentially leads to intensification of the game. In addition, it was assumed that RSG will be less demanding than MP because of players' greater mental and physical efforts during real-opponent conditions compared with those that occur in training.

AU6
Subjects

AU8 AU7 The subjects in this study were professional male basketball players who played on the same team (age: 26.2 ± 4.0 years; height: 199.9 ± 9.8 cm; and body mass: 97.2 ± 12.1 kg). The team participated simultaneously in 2 official competitions, ACB and the Euroleague, during the 2017/2018 season. All players volunteered to participate in the investigation and were notified of the aim of the study, research procedures, and requirements as well as the benefits and risks before giving their informed consent, in accordance with the Declaration of Helsinki. Furthermore, data were anonymized and institutional approval was given for this study.

Physical Demands

The external training load was recorded using Catapult Innovations T6 devices (Melbourne, Australia) that include accelerometer, gyroscope, and magnetometer technologies, which provide data for inertial movement analysis. Because of the differences in tasks and the MP duration, all variables were reported relative to time played: player load (PL) per minute (PLmin), accelerations per minute (ACCmin), decelerations per minute (DECmin), changes of direction per minute (CoDmin), and jumps per minute (JUMPmin).

The PLmin was recorded using the triaxial accelerometer (100 Hz, dwell time 1 second) based on the player's 3-planar movement, applying the established formula (6). ACCmin and DECmin variables involved the total and high-intensity inertial movements: tACCmin refers to total inertial movements registered in a forward acceleration vector; hACCmin is total inertial movements registered in a forward acceleration vector within the high band ($>3.5\ \text{m}\cdot\text{s}^{-2}$); tDECmin is total inertial movements registered in a forward deceleration vector; and hDECmin is total inertial movements registered in a forward deceleration vector within the high band ($<-3.5\ \text{m}\cdot\text{s}^{-2}$). Moreover, total jumps per minute (tJUMPmin) and jumps performed within the high band (hJUMPmin, over 0.4 m) were registered. Finally, 2 variables involved a CoD: tCoDmin, which represents total inertial movements registered in a rightward/leftward lateral vector, and hCoD, which represents total inertial movements registered in a rightward/leftward lateral vector within the high band ($<-3.5\ \text{m}\cdot\text{s}^{-2}$). The aforementioned variables (i.e., ACC, DEC, and CoD) were previously investigated as part of accelerometer-derived data validity and reliability studies (1,4,5,14,24), where TE (i.e., typical error)

Table 2. Mean, ±*SD*, and CI at 95% (in brackets) for each external load variable in the regular-stop game (RSG), no-stop game (NSG), and match-play (MP).*

Variables	RSG ($n = 174$)	NSG ($n = 34$)	MP ($n = 177$)
PLmin ($n\cdot\text{min}^{-1}$)	11.27 ± 3.61 (10.74–11.79)	13.15 ± 1.65 (12.45–13.85)	11.13 ± 2.00 (10.83–11.42)
hDECmin ($n\cdot\text{min}^{-1}$)	0.24 ± 0.22 (0.21–0.28)	**0.36 ± 0.27** (0.25–0.48)	0.25 ± 0.19 (0.22–0.28)
tDECmin ($n\cdot\text{min}^{-1}$)	2.40 ± 1.08 (2.24–2.55)	**2.95 ± 0.88** (2.58–3.23)	2.38 ± 0.63 (2.28–2.47)
hACCmin ($n\cdot\text{min}^{-1}$)	0.33 ± 0.26 (0.29–0.37)	0.25 ± 0.20 (0.17–0.34)	**0.38 ± 0.25** (0.34–0.42)
tACCmin ($n\cdot\text{min}^{-1}$)	1.92 ± 0.97 (1.78–2.06)	**2.20 ± 0.76** (1.88–2.52)	**2.19 ± 0.84** (2.07–2.31)
hJUMPmin ($n\cdot\text{min}^{-1}$)	0.23 ± 0.25 (0.20–0.27)	**0.38 ± 0.21** (0.30–0.47)	0.25 ± 0.21 (0.21–0.28)
tJUMPmin ($n\cdot\text{min}^{-1}$)	1.13 ± 0.64 (1.03–1.22)	**1.76 ± 0.76** (1.43–2.08)	1.11 ± 0.53 (1.03–1.19)
hCoDmin ($n\cdot\text{min}^{-1}$)	0.73 ± 0.46 (0.66–0.80)	**0.95 ± 0.58** (0.71–1.20)	0.79 ± 0.45 (0.72–0.86)
tCoDmin ($n\cdot\text{min}^{-1}$)	10.61 ± 4.40 (9.97–11.25)	**13.25 ± 3.69** (11.70–14.81)	10.62 ± 3.26 (10.14–11.10)

*PLmin is player load per minute, tDECmin is total deceleration per minute, hDEC is total deceleration per minute within the high band ($<-3.5\ \text{m}\cdot\text{s}^{-2}$), tACCmin is total forward accelerations per minute, hACCmin is total forward acceleration per minute within the high band ($>3.5\ \text{m}\cdot\text{s}^{-2}$), tJUMPmin is total jumps per minute, hJUMPmin is jumps per minute performed at the high band (above 0.4 m), tCoDmin is total rightward/leftward lateral movements per minute, and hCoDmin is total movements registered in a rightward/leftward lateral vector per minute within the high band ($<-3.5\ \text{m}\cdot\text{s}^{-2}$). Bolded numbers represent magnitude-based inferences better than trivial.

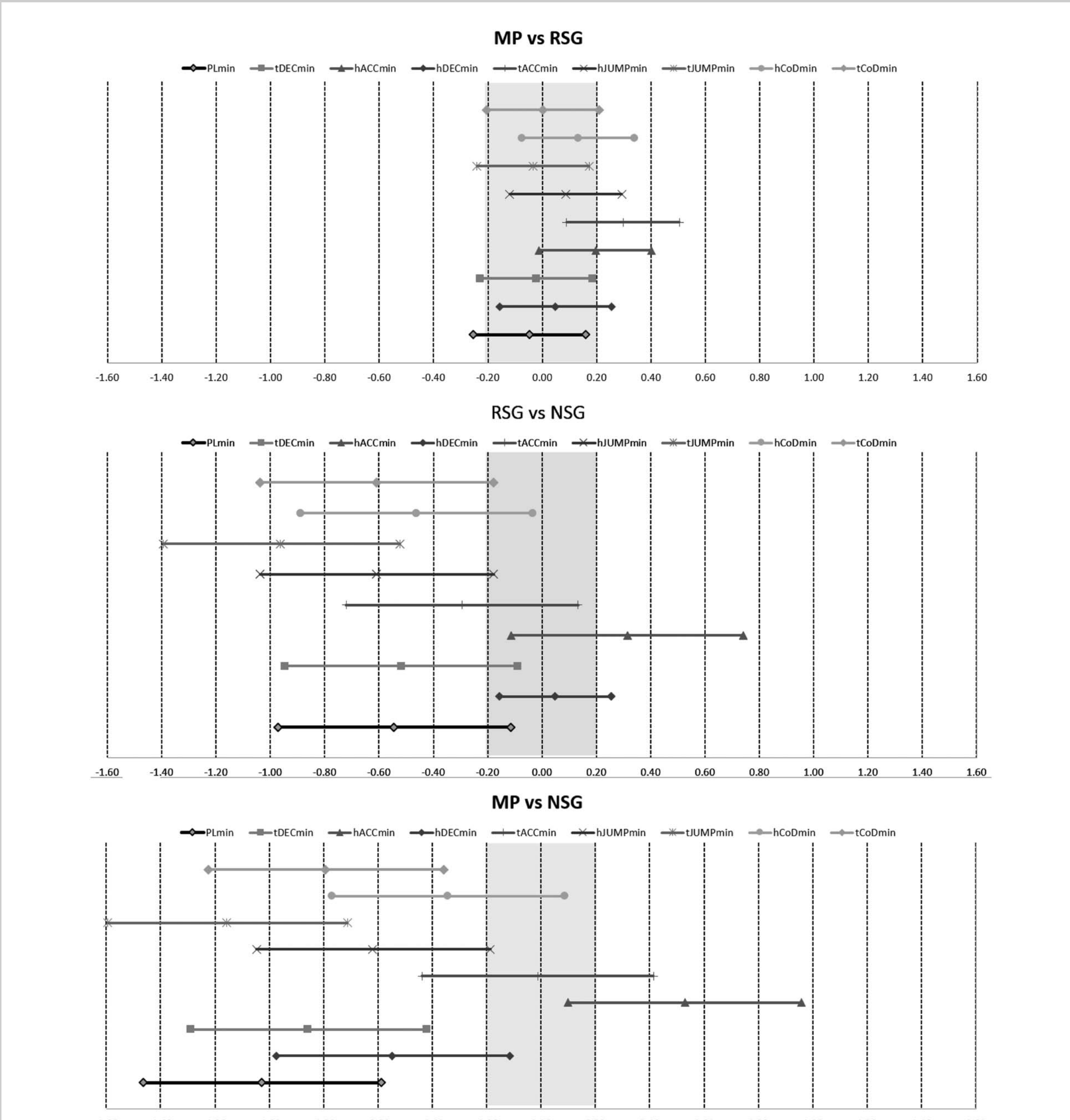

Figure 1. Cohen's *d* values and the 90% CI according to 2 training games (NSG and RSG) and match-play (MP) for variables: PLmin is PL per minute, tDECmin is total deceleration per minute, hDEC is total deceleration per minute within the high band ($<-3.5\ \mathrm{m \cdot s^{-2}}$), tACCmin is total forward accelerations per minute, hACCmin is total forward acceleration per minute within the high band ($>3.5\ \mathrm{m \cdot s^{-2}}$), tJUMPmin is total jumps per minute, hJUMPmin is jumps per minute performed at the high band (above 0.4 m), tCoDmin is total rightward/leftward lateral movements per minute, and hCoDmin is total movements registered in a rightward/leftward lateral vector per minute within the high band ($<-3.5\ \mathrm{m \cdot s^{-2}}$). NSG = no-stop game; RSG = regular-stop game.

for different ranges of acceleration varied from 0.18 to 0.20 $\mathrm{m \cdot s^{-1}}$ (24) and from 0.05 to 0.12 $\mathrm{m \cdot s^{-1}}$ (1). Furthermore, these types of variables were previously used in elite basketball investigations (22). Finally, for the purposes of this study, both validity and reliability of the JUMP variable were estimated through a regular jumping test protocol, well known to all participants from previous jumping performance measurements. While wearing simultaneously 2 microtechnology sensors, each of 6 players tested performed 10 vertical jumps (measured with Optojump photoelectric system; Microgate, Bolzano, Italy). The results of the intraclass correlation coefficient (ICC) for validity were 0.45, 0.40, and 0.82, whereas the ICC for reliability were 1.0, 0.98, and 0.51 for <20, 20–40, and >40 ranges, respectively. The overall ICC for validity and reliability was 0.85 and 0.92, respectively.

Procedures

Two types of training games were studied: the NSG and the RSG. The games were performed under the official basketball rules in the regular 5vs5 format on the full court. T1 However, some changes (Table 1) were applied to the NSG: the activity was not stopped after fouls. In this task, players were instructed to make a quick sideline or baseline ball reposition. In addition, there were no free throws in this game. The duration of NSG was 5 minutes. In case of RSG, free throws were allowed and they required the clock to be stopped. The same applied to ball-out-of-bounds. The goal of RSG was to replicate demands of a real basketball game. Therefore, the average time required to finish a 5-minute RSG was 7 minutes and 40 seconds (±40 seconds).

Depending on the training plan, the players played 2–3 sets with a typical 4-minute (±30 seconds) rest period. During rest periods, the players watched a video to analyze and discuss previous actions and were suggested to drink water ad libitum. No-stop game and RSG were a part of the team basketball practice that started out with a standardized warm-up and movement preparation followed by technical drills and no-contact tactical drills (e.g., shooting, 3vs0, and 5vs0). The duration of trainings when data were collected was 80 minutes (±3.3 minutes).

Five real basketball games (i.e., MP) were recorded during 2 official pre-season tournaments and one international cup game. Each game started with a standardized 25-minute team warm-up and movement preparation. After that, four 10-minute quarters with a 15-minute rest interval at halftime and a 2-minute break between the first and the second and between the third and the fourth quarters were monitored. Overall, game time was 103 minutes (±8 minutes and 15 seconds). The average time that the players spent in the game was 17.2 minutes (±7.6 minutes) with average 2.5 (±1) records per game lasting for 9 minutes and 20 seconds (±3 minutes and 20 seconds). Only active players (i.e., players in the game) in each quarter were included in analysis, whereas time-outs were excluded from the analysis, the same as in SG.

Data collected from RSG, NSG, and MP were downloaded and analyzed through use of Openfield software, version 1.17.

Statistical Analyses

Descriptive statistics data from trainings and games were presented using mean and *SD* (±*SD*). Data analysis was performed using Statistical Package for Social Sciences (version 23 for Windows; SPSS, Chicago, IL, USA). In addition, magnitude-based inferences (MBIs) were used to analyze the data, based on recommendations of Batterham and Hopkins (3). Differences between RSG, SG, and MP were assessed through standardized mean differences (Cohen's *d* and confidence limits at the 90%). The interpretation thresholds for standardized effect size (ES) were as follows: <0.2 (trivial), 0.2–0.6 (small), 0.6–1.2 (moderate), 1.2–2.0 (large), and >2.0 (very large). The MBI calculations were done with customized excel spreadsheet (downloaded and adapted from www.cem.org/effect-size-calculator).

Results

Table 2 shows absolute values of all external load variables (mean, *SD*, and CI at 95%) for RSG, NSG, and MP. T2

Figure 1 represents ES for 3 games compared mutually. F1 On the top of the figure, MP is compared with RSGs where it can be observed that 2 games do not differ in basically any of compared variables. The only variable that showed small difference was tACCmin (MP > RSG).

In the middle, RSG is compared with NSG. In this case, 3 variables showed trivial difference–tACCmin, hACCmin, and hDECmin. From the other 6 variables, 3 variables (i.e., hCODmin, tDECmin, and PLmin) showed small differences (NSG > RSG), and 3 showed (tCoDmin, tJUMPmin, and hJUMPmin) moderate differences (NSG > RSG).

At the bottom of the figure, MP is compared with NSG. Two variables (hCoDmin and tACCmin) showed trivial differences. Variable hDECmin showed small difference, whereas other 5 variables (tCoDmin, tJUMPmin, hJUMPmin, tDECmin, and PLmin) showed moderate difference (NSG > MP). Only one variable, hACCmin, showed moderate difference, when MP > NSG.

Discussion

The objective of this study was to compare physical demands of 2 types of 5vs5 training games and MP in elite basketball. This is the first study to investigate the aforementioned activities in elite basketball using microtechnology. The main conclusion of the study was that the constraints used in 5vs5 tasks can elicit greater physical demands than MP. That knowledge can help coaches improve the training program design and the overall periodization, as understanding which 5vs5 training drill is more physically demanding could effect players' physical condition on a game day.

The 5vs5 NSG elicits higher values of PLmin, tDECmin, tJUMPmin, hJUMPmin, and tCODmin than 5vs5 RSG and MP. In addition, hDECmin showed higher value in NSG compared with MP, and hCODmin showed greater value in NSG than in RSG. The aforementioned findings can be simply explained by intentional intensification of NSG with minimal time to rest after personal fouls and ball out-of-bounds. The absence of free throws in NSG additionally increases the intensity. Because of these demands, the players tend to engage in more decelerations, jumps, and CoD than in MP. Therefore, it can be concluded that the no-stop type of game can be used to elicit an increase in intensity (i.e., PLmin) and a greater number of movements, what eventually causes greater level of accumulated fatigue. As there was no previous research in this field, these findings could be put into practice by coaches who want to overload their teams with specific basketball movements in the 5vs5 full-court format of play.

The current study also showed trivial difference in external load parameters between MP and RSG in almost all variables. The difference was found only for tACCmin variable between MP and RSG (MP > SG). These results support the study by Torres-Ronda et al. (23) who found no differences in relative frequency of movement using time-motion analysis between MP and 5vs5 open-court game, with nearly the same rules as those applied to RSG in this study. Based on these results, coaches can be sure that the physical load as measured by external load parameters (except for the tACC variable that shows a small ES, ES = 0.30) in 5vs5 RSG will match the demands of a MP.

Finally, hACCmin variable showed moderate difference between MP and NSG (i.e., MP > NSG). It has to be recognized that in comparison of RSG and NSG, hACCmin tends to follow similar pattern when RSG > NSG. There are 2 possible rationales for these findings. The first one is the fatigue rationale (17): because of physiological causes of fatigue, it is normal to expect players who have less time to recover between intense actions on the court, such as in NSG, to accumulate fatigue sooner and therefore lose the ability to perform high-intensity actions, such as accelerations and CoD. The second one is the effort rationale, suggesting that, from psychological and motivational point of view, only a real game (in our case, a MP) involving a real opponent (i.e., not a teammate) can make players accelerate often in the high-intensity range because of their increased focus and seriousness. This is supported by previous research by Moreira et al. (16) who found differences in physical stress (using 2 internal load markers: saliva cortisol and rating of perceived exertion) between training and official games, which were obviously because of players' higher physical efforts when competing against a real opponent and in front of spectators. Moreover, the research by Torres-Ronda et al. (23) showed similar results in another internal load marker–the HR: the peak HR in MP was 97 ± 3%, whereas the intensity level of 5vs5 open-court training games was almost 10% lower (88 ± 7% peak HR).

In the end, there are several limitations of the current study that should be recognized. First, internal response variables were not included in the analysis. For this reason, although differences in demands between the games exist, the impact of those differences has not been investigated. Second, future research should investigate differences in external load parameters between official and friendly matches because the use of any kind of microtechnology is currently forbidden in official basketball competitions. Moreover, such research should look at the differences between all variables in different parts of the games, i.e., in each quarter of the game. Third, both NSG and RSG have always been a part of complex team sessions, whereas MP is conducted as a single task. Fourth, differences in playing positions should be considered when investigating 5vs5 formats of play to successfully differentiate values for guards, forwards, and centers. With the aforementioned improvements in the further research, coaches will have even more information on when and how to apply 5vs5 GS in practice.

In conclusion, findings in this investigation show that, with several training task constraints, it is possible to elicit greater or similar physical demands as those that occur during MP. Based on the data from this research, all teams that are looking for the right 5vs5 training game format could benefit from the information that the NSG could elicit more intensity and more movement frequency than that elicited in a regular MP. In the same line, the RSG will provide very similar physical demands as a MP.

Practical Applications

Modern basketball training methodology demands accurate data for all training drills, especially those that consider competition conditions. Elite teams use various training drills to simulate game demands. Data from this study serve all coaches who at a certain point need competition conditions "overload" to stimulate greater physical stress and specific type of fatigue (e.g., during pre-season camp). Finally, understanding the relationships between NSG, RSG, and MP can help coaches improve their system of short-term tapering, leading up to the game day. For example, in congested fixture during season, further to the game day (i.e., 3–4 days), coaches can use the NSG to elicit greater physiological response and fatigue, while closer to the game day (i.e., 1–2 days), a RSG could be a more appropriate choice supporting optimal physical condition on the game day.

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