

Research article

Low External Workloads Are Related to Higher Injury Risk in Professional Male Basketball Games

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Abstract

The primary purpose of this study was to identify potential risk factors for sports injuries in professional basketball. An observational retrospective cohort study involving a male professional basketball team, using game tracking data was conducted during three consecutive seasons. Thirty-three professional basketball players took part in this study. A total of 29 time-loss injuries were recorded during regular season games, accounting for 244 total missed games with a mean of 16.26 ± 15.21 per player and season. The tracking data included the following variables: minutes played, physiological load, physiological intensity, mechanical load, mechanical intensity, distance covered, walking maximal speed, maximal speed, sprinting maximal speed, maximal speed, average offensive speed, average defensive speed, level one acceleration, level two acceleration, level three acceleration, level four acceleration, level one deceleration, level two deceleration, level three deceleration, level four deceleration, player efficiency rating and usage percentage. The influence of demographic characteristics, tracking data and performance factors on the risk of injury was investigated using multivariate analysis with their incidence rate ratios (IRRs). Athletes with less or equal than 3 decelerations per game (IRR, 4.36; 95% CI, 1.78-10.6) and those running less or equal than 1.3 miles per game (lower workload) (IRR, 6.42; 95% CI, 2.52-16.3) had a higher risk of injury during games ($p < 0.01$ in both cases). Therefore, unloaded players have a higher risk of injury. Adequate management of training loads might be a relevant factor to reduce the likelihood of injury according to individual profiles.

Key words: Game tracking, multivariate analysis, decelerations, distance, injury prevention.

Introduction

Injuries are a significant issue in professional sports such as basketball (Deitch, 2006). A detrimental effect in performance (Busfield et al., 2009) and a significant number of games missed due to injury at the end of the season have been highlighted in several studies on different professional male basketball leagues (Caparrós et al., 2016; Podlog et al., 2015). Moreover, a significant inverse association between games missed due to injury and the percentage of won games at the end of the competitive season has also been confirmed in the past in professional male basketball (Podlog et al., 2015). Patellofemoral inflammation is the most significant injury regarding lost competition days, while ankle sprain is the most common injury among professional male basketball players (Drakos et al., 2010). The monetary impact that these sports injuries have

on professional teams and franchises is not negligible. In the NBA, during the 2000-2015 period, losses between 10 and 50 million dollars per team and season due to injuries were reported (Talukder et al., 2016). Nevertheless, despite apparent interest and enormous research and practical efforts to prevent injuries, there is still no practical solution to decrease the injury incidence significantly in this family of sports.

To address this issue, a relationship between competitive schedule congestion and the occurrence of sports injuries has been studied previously (Drew and Finch, 2016; Teramoto et al., 2016). Increased incidence of sports injuries in specific periods within a season has been reported in some sports (Carling et al., 2016; Folgado et al., 2015). Level of competition and gender also seem to play a significant role in the epidemiological incidence (Anderson et al., 2003; Deitch, 2006; Gabbett and Domrow, 2007). High-level athletes are more prone to injuries due to competing demands. Thus, NBA players chances to suffer a game-related injury are twofold when compared to their collegiate counterparts (Deitch, 2006). Nevertheless, an increase in the number of sports injuries is observed at a sub-elite level too (Gabbett and Domrow, 2007).

A substantial number of initiatives have been presented to study the incidence of injuries in team sports (Drew and Finch, 2016; Ullah et al., 2012). Novel approaches to prevent and manage sports injuries tend to use technology consistently during competition. Player tracking (Sampaio et al., 2015), accelerometry (Colby et al., 2014) and global positioning systems (GPS) (Casamichana et al., 2013; Dellaserra et al., 2014; Rossi et al., 2017) are today's sports standard tools. Although the use of these technologies can be useful in all disciplines, they have spread mainly in team sports such as basketball (Caparrós et al., 2016; Sampaio et al., 2015), soccer (Casamichana et al., 2013; Osgnach et al., 2010), Australian football (Carey et al., 2016; Colby et al., 2014) and rugby (Gabbett and Domrow, 2007; Gabbett and Jenkins, 2011). In this processes, professional teams and researchers take advantage of technological innovations by using data obtained in stadiums and competition venues (Mangine et al., 2014; Sampaio et al., 2015). For instance, top football teams seem to rely on external training load variables such as acceleration, total distance, distance covered above specific speeds and metabolic power to make their decisions when managing training and competition loads (Nassis and Gabbett, 2017). The advantage is that average and peak speeds, accelerations or decelerations values (Casamichana et al.,

2013), total distance traveled or the total number of high-intensity efforts performed while in training or competition (Carling et al., 2010) can be determined by the use of different electronic devices and systems, fairly frequent in elite sport. That is the case of player tracking, a technology that provides kinematic variables, while also enables a better understanding of physiological, technical and tactical variables (Mangine et al., 2014; Sampaio et al., 2015).

This data is essential in the field of injury prevention because different values of external and internal training loads can be employed to establish ratios that may indicate that the athlete is has been situated in a risk area (Gabbett, 2016). A vast body of literature has previously used external loads to find a consistent association between ratio values and the risk of injury (Colby et al., 2014; Drew and Finch, 2016; Gabbett and Jenkins, 2011; McNamara et al., 2017). The use of the acute:chronic workload ratio (ACWR) has allowed a better understanding of the relationship of workload and risk of injury (Gabbett and Jenkins, 2011; Hulin et al., 2013; 2016; Murray et al., 2017) in sports such as cricket (McNamara et al., 2017), football (Bowen et al., 2017) and rugby (Gabbett and Jenkins, 2011; Hulin et al., 2016). However, to our knowledge, only one study using this methodology has been conducted in professional basketball (Weiss et al., 2017). While providing an interesting starting point for workload-injury research in this sport, it was limited to one playing season. Given the popularity of this discipline, it seems of interest to establish whether a relationship exists between player workloads and injury risk in professional basketball by using data from more than one competitive season to reinforce the strength of statistical models.

The primary purpose of this study was to identify possible risk factors for injury related to variables from game tracking data in professional basketball to improve specific preventive strategies.

Methods

An observational, retrospective cohort study was conducted between October and April during three consecutive regular seasons, obtaining data from a total of 2613 observations and 246 games from 33 different players of a professional male basketball team. The use of these data attended to the standards of the Declaration of Helsinki, revised in Fortaleza (World Medical Association, 2013). Players were assigned an individual identifier code with the identity concealed, ensuring player anonymity was maintained.

Data collection was based on the methodology of the UEFA consensus statement for epidemiological studies (Häggglund et al., 2005). A time-loss injury was defined as any injury (contact and non-contact) occurring during a practice session or game which caused an absence for at least the next practice session or competition. Time-loss from associated injuries was retrospectively determined by the number of days of absence from participation.

All study data were available to the general public in open-access websites and included the demographic characteristics of the players, player tracking, injury and performance values. Tracking data were obtained from the website of the company STATS (<http://stats.com/>), responsible of the

game tracking process in the competition (SportsVU, Northbrook, IL, USA) following the trend of previous studies (Embiricos and Poon, 2014; Hu et al., 2011; Lofti et al., 2011; Maymin, 2013; Siegle et al., 2013; Tamir and Oz, 2006). Injury information was obtained from public resources (www.rotoworld.com, www.cbs.com and <http://www.basketball-reference.com/>), following the same procedure with the performance data (<http://stats.com/> and <http://www.basketball-reference.com/>). Again, several studies in the past have used this information showing its reliability (Gesbert et al., 2016; Maheswaran et al., 2012; Yonggangniu and Zhao, 2014). These records contained both non-tracking and tracking data. The different databases were then collated to assign the specific information about each game to each specific player. All 23 tracking and non-tracking variables presented by the companies designing the software were selected. Tracking variables were categorized into four main groups: physiological variables, speed and distance variables, mechanical load variables, and motor variables (Table 1).

Time-loss injuries suffered during regular season games were included in the study. There are no other exclusion criteria. Minutes and games played by every player were considered on the unbalanced study design with repeated measures. Given that not all of the players were observed for the same number of seasons, and that the number of games per season varied from one player to another. The possible risk variables for injuries considered were height, mass, age, season year, season month, won/lost game and home/away venue, minutes played, and the additional variables shown in Table 1.

Statistical analysis

A descriptive analysis of all variables of interest was carried out. In the case of categorical variables, absolute and relative frequencies were presented. For quantitative variables, measures of central tendency (mean and median) and statistical dispersion (standard deviation, percentiles 25th (P25), percentiles 75th (P75), and range) were calculated. To study the risk factors from the games tracking data variables, a generalized linear mixed model (GLMM) was conducted assuming the frequency of the injuries followed a Poisson's distribution. The same statistical approaches have been previously applied (Casals et al. 2015). Following the studies of Bolker (2009), Vanderbogaerde (2010) and Casals (2014), a list of relevant information and basic characteristics of the GLMM model were reported. The model expression for player i in his j th games is the following: $\log(\lambda_{ij}) = \log(m_{ij}) + X_{ij} \beta + u_i$ where $Y_{ij} \sim \text{Po}(\lambda_{ij})$. λ_{ij} is the number of injuries, m_{ij} is the number of minutes exposures of player, which is the offset of this model, and X_{ij} includes all independent variables of interest. The vector β contains the fixed effects, whereas u_i is the random effect corresponding to player i . The random effects are assumed to be independent and normally distributed: $u_i \sim N(0; \sigma^2)$, where σ^2 is the variance of random effect. The model accounted for repeated measures and the fact that the values of X_{ij} could change from one game to the next.

The simplification of the model was performed by backward selection of variables from the full model, and

models were compared using the likelihood ratio test (LRT) until a minimal adequate model was obtained. Model selection was based on the Akaike Information Criterion (AIC). To estimate the model variables we used the Gauss-Hermite quadrature (GHQ) with 5 points (Bolker, 2009). The statistical significance of the fixed effects associated with the covariates included in the model was assessed using the Wald test. The correlation and the main possible interactions among the covariates were checked in the final model. A possible over-dispersion in the model was studied using Pearson’s dispersion parameter (Bolker, 2009). Measures of association were calculated using incidence rate ratios (IRR) with 95% confidence intervals (CI). To prevent overfitting, a cross-validation procedure was completed using leave-one-out cross-validation (LOOCV). In the LOOCV, the prediction model is trained on data

from all of the participants except one, which is “held out” and used as the test dataset. The process is repeated until all participants have served as the test data set. Moreover, the performances of estimation models were evaluated by the commonly used measures of goodness-of-fit: RMSE (Root Mean Square Error) and MAE (Mean Absolute Error). Finally, to assess the predictive or discriminatory ability of the model we performed the area under the curve (AUC) (Lopez-Raton et al., 2014).

Statistical significance was set at $p < 0.05$. To improve the interpretability of the clinical finding, suggestions made by Cook (2016) were followed, and continuous data were divided into categories (a dichotomized variable based on the approach of CatPredi library in R (Barrio et al., 2015). Also, facilitation of data interpretation was achieved by providing the IRR.

Table 1. Description of selected tracking and non-tracking (performance) factors.

TRACKING FACTORS (http://stats.com/)	
Acronym or name	Description
Physiological variables	
Physiological Load (Phy_Load)	Every 0.25 second throughout the course of a game the product of a player’s mass, velocity and distance. Phy_Load = mass*average velocity*distance
Physiological Intensity (Phy_Int)	Physiological load, divided by every minute he plays. Phy_Int = Phy_Load /minutes played
Speed and distance variables	
Defensive average speed (Def_Average_Speed)	Average Speed Run on Defense (ml/h)
Offensive average speed (Off_Average_Speed)	Average Speed Run on Offense (ml/h)
Distance	Total distance run (ml)
Mechanical Load variables	
Mechanical Load (Mech_Load)	Measures the change of speed by a player throughout the course of the game. These are identified as accelerations and decelerations, derived from the changing of speeds throughout the locomotor activities (walk, jog, run, sprint, max). Each level includes a weighting factor to account for the severity of the acceleration and deceleration
Mechanical Intensity (Mech_Int)	Mechanical Load/minutes played
Acceleration (acc)	Increase in intensity that is maintained for at least one second
Level one acceleration (Acc_1)	0.5 m/s ² acceleration
Level two acceleration (Acc_2)	1 m/s ² acceleration
Level three acceleration (Acc_3)	2 m/s ² acceleration
Level four acceleration (Acc_4)	4 m/s ² acceleration
Deceleration (Dec)	Decrease in intensity level that is maintained for at least one second
Level one deceleration (Dec_1)	0.5 m/s ² deceleration
Level two deceleration (Dec_2)	1 m/s ² deceleration
Level three deceleration (Dec_3)	2 m/s ² deceleration
Level four deceleration (Dec_4)	4 m/s ² deceleration
Locomotor variables	
Walk maximal speed (WALK_MAX)	player individually achieved 0-20% of maximal speed
Run maximal speed (RUN_MAX)	player individually achieved 40-60% of maximal speed
Sprint maximal speed (SPRINT_MAX)	player individually achieved 60-80% of maximal speed
Maximal speed (MAX_MAX)	player individually achieved >80% of maximal speed
NON-TRACKING FACTORS (www.basketball-reference.com)	
Acronym or name	Description
Performance variables	
Player efficiency rating (PER)	Rating of a player's per-minute productivity $(1 / MP) * [3P + (2/3) * AST + (2 - factor * (team_AST / team_FG)) * FG + (FT * 0.5 * (1 + (1 - (team_AST / team_FG)) + (2/3) * (team_AST / team_FG))) - VOP * TOV - VOP * DRB% * (FGA - FG) - VOP * 0.44 * (0.44 + (0.56 * DRB%)) * (FTA - FT) + VOP * (1 - DRB%) * (TRB - ORB) + VOP * DRB% * ORB + VOP * STL + VOP * DRB% * BLK - PF * ((lg FT / lg PF) - 0.44 * (lg FTA / lg PF) * VOP)]$
Usage percentage (Usg%)	An estimate of the percentage of team plays used by a player while he was on the floor: $100 * ((FGA + 0.44 * FTA + TOV) * (Tm MP / 5)) / (MP * (Tm FGA + 0.44 * Tm FTA + Tm TOV))$

tm: team; lg: league; min: minutes played; AST: number of assists; 3P: number of three-point field goals made; FG: number of field goals made; FGA: number of field goals attempted; FT number of free throws made; FTA: number of free throws attempted; VOP: value of possession in reference to the league; TOV: number of turnovers; RB: number of rebounds; ORB: number of offensive rebounds; DRB: number of defensive rebounds; TRB: number of total rebounds; RBP, percentage of offensive or defensive; lg: team pace value; MP: minute played

All statistical analyses were performed with the statistical package R (The R Foundation for Statistical Computing, Vienna, Austria), version 3.3.3. In particular, the R package lme4 (Bates, 2014) was used to fit the GLMM.

Results

The demographic characteristics of the 33 professional basketball players included in this study were: mean \pm SD age of 24.9 ± 2.9 years, a height of 1.95 ± 0.09 m and a weight of 98.9 ± 12 kg. The team played 82 games every

regular season, with a total exposure of 58457 minutes during all 7-month seasons (3 consecutive seasons). The team played an average of 3.4 games weekly during the competition. Data on tracking and non-tracking (performance) factors are shown in Table 2.

A total of 29 time-loss injuries were recorded throughout the study, involving 11 players, and accounting for 244 total missed games (MG) with a mean \pm SD of 16.26 ± 15.21 per player and season. Of these, nine were in season 1, five were in season 2, and 15 were in the third season (Table 3).

Table 2. List and descriptive statistics of physiological and mechanical load, speed and distance, locomotor and performance variables.

Variables	Mean	SD	Minimum	P25	Median	P75	Maximum
Minutes	22.6	10.6	0.1	14.7	22.9	31.9	48.6
Phy_Load	740.6	354.3	0.9	479.4	739.2	1025.2	1613.4
Phy_Int	32.8	4.2	2.4	30.5	33	35.6	55.4
Mech_load	811.4	364.7	1.5	547	833.5	1113	1698.5
Mech_Int	36.7	4.5	3.9	33.9	36	38.8	64.9
Distance	1.6	0.7	0	1.1	1.6	2.2	3.4
Walk_Max	3.6	0.2	2.5	3.6	3.6	3.7	4.1
Run_Max	10.9	0.6	7.6	10.7	10.9	11.2	12.3
Sprint_Max	14.5	0.8	10.1	14.3	14.6	15	16.3
Max_Max	18.1	1.0	12.7	17.9	18.2	18.7	20.4
Off.Average Speed	4.5	0.4	0	4.3	4.5	4.7	12.9
Def.Average_Speed	3.9	0.5	0	3.7	3.9	4.1	16.7
Acc_1	233.4	111.5	0	152.0	233.0	324.5	561.0
Acc_2	79.4	39.1	0	50.0	79.0	110.0	194.0
Acc_3	14.5	7.7	0	9.0	14.0	20.0	54.0
Acc_4	0.7	1.0	0	0	0	1.0	6.0
Dec_1	153.0	72.8	1.0	99.0	153.0	210.0	364.0
Dec_2	103.6	46.7	0	70.0	107.0	141.0	223.0
Dec_3	6.5	4.1	0	4.0	6.0	9.0	29.0
Dec_4	0.3	0.6	0	0	0	0	4.0
PER	14.8	11.8	-41.4	7.7	14.7	21.6	210.8
Usg%	18	8.1	0	12.7	17.9	22.8	116.4

Minutes: minutes played; Phy_Load: physiological load; Phy_Int: physiological intensity; Mech_Load: mechanical load; Mech_Int: mechanical intensity; Distance: distance; WALK_MAX: walk maximal speed; RUN_MAX: run maximal speed; SPRINT_MAX: sprint maximal speed; MAX_MAX: maximal speed; Off_Average_speed: offensive average speed; Def_Average_Speed: defensive average speed; Accel_1: level one acceleration; Accel_2: level two acceleration; Accel_3: level three acceleration; Accel_4: level four acceleration; Decel_1: level one deceleration; Decel_2: level two deceleration; Decel_3: level three deceleration; Decel_4: level four deceleration; PER: player efficiency rating; Usg%: usage percentage.

Table 3. Injury frequency by the different demographic variables studied.

Variables	Injuries					
	All	No	%	Yes	%	
	N = 2577	N = 2548		N = 29		
Season	Season 1	856	847	98.9	9	1.1
	Season 2	890	885	99.4	5	0.6
	Season 3	831	816	98.2	15	1.8
Month	October	90	89	98.9	1	1.1
	November	480	475	99	5	1
	December	475	466	98.1	9	1.9
	January	474	470	99.2	4	0.8
	February	371	368	99.2	3	0.8
	March	507	500	98.6	7	1.4
	April	180	180	100	0	0
Age	<25	1582	1568	98.7	20	1.3
	25-27	520	515	99	5	1
	>27	469	465	99.1	4	0.9
Court	Home	1290	1275	98.9	15	1.2
	Road	1287	1273	98.9	14	1.1
Win game	No	1227	1211	98.7	16	1.3
	Yes	1350	1337	99	13	1

Table 4. Multivariate analysis using the generalized linear mixed model for predictors of injuries in professional basketball players. This model includes minutes as an offset, and player as a random effect.

Variables	Estimate	SE	IRR (95% CI)	p-value
Intercept	-9.58	0.64		< 0.001
Deceleration ≥ 3	1.47	0.45	4.36 (1.78-10.6)	0.0012
Distance ≤ 1.3	1.86	0.47	6.42 (2.52-16.3)	< 0.001
Variance of random effect (player)	2.01			

SE: standard error; IRR: Incidence rate ratio

Table 5. A classification confusion matrix for the model.

		Observed	
		No Injured	Injured
Predicted	No injured	2287	12
	Injured	261	17

The multivariate analysis using the GLMM for risk factors of injuries in professional basketball is shown in Table 4. The variables that remained significantly associated with risk of injury in the final model were a lower number of decelerations and less distance (Table 4). The player-level variance was 2.01. Based on RMSE and MAE values, the calibration model (0.10 and 0.02, respectively) was similar to the measure of the validation model (0.10 and 0.01). Given that these measures are comparable, we can conclude that there is no overfitting. The AUC value of the model showed a satisfactory performance (AUC: 0.84; 95% CI: 0.77 - 0.91), exhibiting reasonable to good discrimination. Table 5 illustrates the classification confusion matrix. As can be seen, the percentage of instances well classified was $(2287+17)/2548 = 90.42\%$, where no-injuries are classified as acceptable. However, a low injury rate causes sensitivity to drop to lower values (58%).

Discussion

The present study investigated the relationship between tracking and non-tracking (performance) data and injuries in professional basketball. The main finding of this study was that a lower number of decelerations and less distance covered were significantly associated with injury during professional basketball games.

Related to external load (Mendez-Villanueva, 2013; Soligard et al., 2017) a few of the variables analyzed here were strongly related to injury (Ullah et al., 2012) on competition (Carling et al., 2012; Cross et al., 2016; Hulin et al., 2016; Murphy et al., 2012; Talukder et al., 2016), the variables that were significant in the multivariate analysis are quantitative. However, the correct interpretation of the statistical analysis has to be done in a multifactorial dimension (Carey et al., 2016; Colby et al., 2017; Ullah et al., 2012) and consider correlated data. The strength of the model is the association established within the variables presented. It takes into account variability of players and minutes played (used as an offset in the model). Acceleration and decelerations are two of the main variables that define basketball (Abdelkrim et al., 2007; Chaouachi et al., 2009; Maymin, 2013; Scanlan et al., 2014). Third level decelerations were found to be a risk factor: players who achieved fewer than three decelerations, and covered less than 1.3 miles were at higher risk of injury. Players undergoing lower workloads had a higher risk of injury than the rest of the roster (Gabbett, 2016; Blanch and Gabbett,

2016; Gabbett and Jenkins, 2011). Our findings of lower workloads increasing the risk of injury agree with recent findings. Despite the fact that many previous studies have analyzed the impact in the number of injuries of excessive training loads imposed on players (Caparrós et al., 2016; Gabbett and Ullah, 2012) the protective effect of proper load management, as well as an adverse effect of excessively diminished training loads, have also been observed in the past (Gabbett, 2016). Adequate levels of training might have a protective effect on the athlete, also decreasing their risk of injury. The development of a minimum amount of chronic quantitative workload (distance) and acute qualitative workload (decelerations) seems an important factor to prevent injuries (Talukder et al., 2016; Soligard et al., 2017). Regarding intensities as a risk factor, a minimum amount of high-intensity decelerations per game are needed to keep the player on optimal performance (Gabbett, 2016). It might be argued that its total number can be related to the minutes that a player is on the court during the game. However, the capability to maintain higher intensities might be associated with other factors as readiness, performance, freshness, fatigue (Soligard et al., 2017) or the opponents match up. A player can achieve accelerations (Schelling and Torres, 2016), but the risk factor might be related to its capability to decelerate at higher intensities, and to how player's muscles can recover from those repeated efforts. Regarding speed parameters, same conclusions are described using GPS technology (Gabbett et al., 2013; Rossi et al., 2017).

Failure to perform high-intensity decelerations, to provide the players with a minimum cumulative distance, or to achieve adequate in-game or between-games recovery increases the chances of injury. Workload between-games (Gabbett, 2011; 2016; Gabbett et al., 2013; Purdam et al., 2015; Scanlan et al., 2014) could also be managed with this model. According to previously accumulated workloads, this value allows the modification of individual training plans on two main areas: on-court practices and strength and conditioning workouts. According to the tracking data, deceleration thresholds can be customized on the accelerometer software, having the option to manage distance and decelerations during practices. By the other hand, to identify the role of decelerations as a risk factor (as eccentric muscle action) (Hydahl and Hubal, 2014), highlights the importance of strength workouts (Pull and Ranson, 2007) and neuromuscular recovery (Hyldahl and Hubal, 2014) and its control (Mooney et al., 2013) as preventive

tools.

In most sports, players are not involved in more than two games per week. However, in the professional basketball competitions observed in this study, an average of 3.4 matches were played per week for 24 weeks (Teremoto et al., 2016; Podlog et al., 2015). Therefore, the right management of player workloads is a critical strategy to avoid injuries (Drew and Finch, 2016; Gabbett, 2011; 2016) at specific periods of the season (Ferioli et al., 2018; Windt et al., 2017), and according to individual profiles. For certain players, increasing their participation in the competition is needed (Carey et al., 2016), or they may have higher chances of injury later during critical stages of the season. Acute workloads have to be specifically considered according to the players' age (Gabbett, 2016) and the period of the season. "Spikes" in workload, which are sometimes unavoidable, should be carefully controlled using individualized recovery protocols (Bengtsoon et al., 2013; Gabbett and Ullah, 2012; Hulin et al., 2013).

Decelerations are related to the ability to change direction (Tous-Fajardo et al., 2016) and are more unpredictable because they are related to opponents' matchups. A decrease in the number of decelerations can be used to identify fatigue (Lorenz and Reiman, 2011), especially in periods of accumulation of high chronic workload. A low number of them can be related to strength imbalance, and non-safe force values (Croisier et al., 2008).

Finally, at present no variables could be related to performance. Future studies investigating the relationship between player performance metrics and the overall team performance (wins or losses) are warranted.

Limitations of the study

The present study has some limitations. First, all data were obtained from public open-access resources, potentially limiting the external validity of the results. Therefore, studies with the involvement of data coming from professional teams are needed. Second, tracking and non-tracking data were obtained during games. Data from practice sessions should be incorporated to adequately apply in-season workload plans, as suggested by Carey et al. (2017). It might offer a cause-effect relationship that could be potentially established between workload and injury on experimental designs. This limitation needs to be highlighted from the results obtained in our study. The present is an observational study; it is not an experimental design. In experimental designs, we can control factors and, thus, conclusions could establish causality, but in our current context, this is not possible. Regarding the validity of the model built, we can observe a similar strong performance metrics (AUC = 0.85) in other basketball studies (Talukder et al., 2016), even if not based on tracking parameters. Recent research on these specific parameters (Carey et al., 2017) offers similar model performance (AUC = 0.84), even is related to Australian football. Therefore, this model identifies risk factors but some limitations are suggested in a predictive level. This fact is probably due to a low injury rate and the lack of better injury definition. However, our effort tries to achieve a deeper understanding of injury prediction to several other recent studies (Bahr 2016; Carey et al., 2017; Fanchini et al., 2018; Hewett, 2017; Jovanovic,

2017; Rossi et al., 2017).

The strengths of this study are its specificity for professional basketball and the fact that it used well-established technology to identify risk factors for injury (Foster et al., 2017). However, use and applicability of technology is in some aspects sports-specific (Bangsboo et al., 2006; Gabbett and Jenkins, 2011; Hagglund et al., 2010; Hopkins et al., 2009; Hugues and Franks, 2004). Therefore, conclusions from technology-based investigations should take into account the context in which the research is conducted (Fuller, 2007; Ullah et al., 2012). Regarding methodology, a positive aspect of this study is that the model used (GLMM) tries to control for repeated measures (correlated data among the same players). Ignoring correlation of data when fitting the model may lead to biased estimates and misinterpretation of results (Casals, 2015). The study highlights the need for a correct balance between competitive schedule, team workload design and in-season recovery process. Further research should be conducted to determine how internal and external factors may be related to injury risk and performance.

Practical applications

Tracking systems, which can be easily incorporated into regular practice sessions and games, can provide useful information for the coaching staff to prevent injuries to professional basketball players. Athletes with lower external workload should be identified so that appropriate prevention strategies can be individually applied to avoid injuries.

Conclusions

Unloaded players, regarding the number of decelerations and total distance covered, have a greater risk of injury. Increasing external workload may likely reduce the risk of injury in professional basketball. More studies are needed to confirm these findings so that adequate prevention programs can be implemented to decrease the number of injuries in professional basketball and other sports.

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References

- Abdelkrim, N. B., El Fazaa, S. and El Ati, J. (2007) Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. *British Journal of Sports Medicine* **41**(2), 69-75.
- Anderson, L., Triplett-McBride, T., Foster, C., Doberstein, S. and Brice, G. (2003) Impact of training patterns on incidence of illness and injury during a women's collegiate basketball season. *Journal of Strength and Conditioning Research* **17**, 734-738.
- Bahr, R. (2016) Why screening tests to predict injury do not work—and probably never will...: a critical review. *British Journal of Sports Medicine* **50**(13), 766-780.
- Bangsbo, J., Mohr, M., Poulsen, A., Perez-Gomez, J. and Krstrup, P. (2006) Training and Testing in the Elite Athlete. *Journal of Exercise Science and Fitness* **4**(1), 1-18.
- Barrio, I., Rodríguez-Álvarez, M.X. and Arostegui, I. (2015) Categorization of Continuous Variables in a Logistic Regression Model Using the R Package CatPredi.
- Bates, D., Maechler, M., Bolker, B. and Walker, S. (2014) *lme4: Linear mixed-effects models using Eigen and S4*. R package version 1.1-7.

- Blanch, P. and Gabbett, T.J. (2016) Has the athlete trained enough to return to play safely? The acute: chronic workload ratio permits clinicians to quantify a player's risk of subsequent injury. *British Journal of Sports Medicine* **50(8)**, 471-475.
- Bolker, B., Brooks, M., Clark, C., Geange, S., Poulsen, J., Stevens, M. and White, J.S.S. (2009) Generalized linear mixed models: a practical guide for ecology and evolution. *Trends Ecology Evolution* **24(9)**, 127-135.
- Borresen, J., and Lambert, M. I. (2009). The quantification of training load, the training response and the effect on performance. *Sports Medicine*, **39(9)**, 779-795.
- Bowen, L., Gross, A.S., Gimpel, M. and Li, F.-X. (2017) Accumulated workloads and the acute:chronic workload ratio relate to injury risk in elite youth football players. *British Journal of Sports Medicine* **51(5)**, 452-459.
- Busfield, B.T., Kharrazi, F.D., Starkey, C., Lombardo, S.J. and Seegmiller, J. (2009) Performance Outcomes of Anterior Cruciate Ligament Reconstruction in the National Basketball Association. *Arthroscopy - Journal of Arthroscopic and Related Surgery* **25(8)**, 825-830.
- Caparrós, T., Alentorn-geli, E., Myer, G.D., Capdevila, L., Samuelsen, K. Hamilton, B. and Rodas, G. (2016) The Relationship of Practice Exposure and Injury Rate on Game Performance and Season Success in Professional Male Basketball. *Journal of Sports Science and Medicine* **15**, 397-402.
- Carey, D.L., Ong, K.L., Whiteley, R., Crossley, K.M., Crow, J. and Morris, M.E. (2017) Predictive modelling of training loads and injury in Australian football. arXiv preprint arXiv:1706.04336.
- Carey, D.L., Blanch, P., Ong, K.-L., Crossley, K.M., Crow, J. and Morris, M.E. (2016) Training loads and injury risk in Australian football—differing acute: chronic workload ratios influence match injury risk. *British Journal of Sports Medicine* **51(16)**, 1215-1220.
- Carling, C., Gall, F.L. and Reilly, T.P. (2010). Effects of Physical Efforts on Injury in Elite Soccer. *International Journal of Sports Medicine* **31**, 180-185.
- Carling, C. and Court, M. (2012) Match & motion analysis of soccer. In: *Science and Soccer, developing elite performers*. Ed: Williams, M. London: Routledge. 173-198.
- Carling, C., McCall, A., Le Gall, F. and Dupont, G. (2016) The impact of short periods of match congestion on injury risk and patterns in an elite football club. *British Journal of Sports Medicine* **50**, 764-768.
- Casals, M., Girabent-Farres, M. and Carrasco, J. (2014) Methodological quality and reporting of generalized linear mixed models in clinical medicine (2000-2012): a systematic review. *PLOS One* **9(11)**, e112653.
- Casals, M., Langohr, K., Carrasco, J.L. and Rönnegard, L. (2015) Parameter estimation of Poisson generalized linear mixed models based on three different statistical principles: a simulation study. *SORT-Statistics and Operations Research Transactions* **39**, 281-308.
- Casals, M. and Finch, C.F. (2016) Sports Biostatistician: a critical member of all sports science and medicine teams for injury prevention. *Injury Prevention*, BMJ Online First: 30 December 2016.
- Casamichana, D., Castellano, J., Calleja-Gonzalez, J., San Roman, J. and Castagna, C. (2013) Relationship between indicators of training load in soccer players. *Journal of Strength and Conditioning Research* **27**, 369-374.
- Chaouachi, A., Brughelli, M., Chamari, K., Levin, G.T., Ben Abdelkrim, N., Laurencelle, L. and Castagna, C. (2009) Lower Limb Maximal Dynamic Strength and Agility Determinants in Elite Basketball Players. *Journal of Strength and Conditioning Research* **23(5)**, 1570-1577.
- Colby, M.J., Dawson, B., Heasman, J., Rogalski, B. and Gabbett, T.J. (2014) Accelerometer and GPS-Derived Running Loads and Injury Risk in Elite Australian Footballers. *Journal of Strength and Conditioning Research* **28**, 2244-2252.
- Colby, M.J., Dawson, B., Peeling, P., Heasman, J., Rogalski, B., Drew, M.K., Stares, J., Zouhal, H. and Lester, L. (2017) Multivariate modelling of subjective and objective monitoring data improve the detection of non-contact injury risk in elite Australian footballers. *Journal of Science and Medicine in Sport* **20(12)**, 1068-1074.
- Cook, C. (2016) Predicting future physical injury in sports: it's a complicated dynamic system. *British Journal of Sport Medicine* **50(22)**, 1356-1357.
- Croisier, J.L., Ganteaume, S., Binet, J., Genty, M. and Ferret, J.M. (2008) Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *The American Journal of Sports Medicine* **36(8)**, 1469-1475.
- Cross, M., Williams, S., Trewartha, G., Kemp, S. and Stokes, K. (2016) The influence of in-season training loads on injury risk in professional rugby union. *International Journal of Performance Analysis in Sport* **11(3)**, 350-355.
- Deitch, J.R. (2006) Injury Risk in Professional Basketball Players: A Comparison of Women's National Basketball Association and National Basketball Association Athletes. *American Journal of Sports Medicine* **34(7)**, 1077-1083.
- Dellaserra, C.L., Gao, Y. and Ransdell, L. (2014) Use of integrated technology in team sports: a review of opportunities, challenges, and future directions for athletes. *Journal of Strength and Conditioning Research* **28**, 556-573.
- Drakos, M.C., Domb, B., Starkey, C., Callahan, L. and Allen, A.A. (2010) Injury in the National Basketball Association. *Sports Health: A Multidisciplinary Approach* **2(4)**, 284-290.
- Drew, M.K. and Finch, C.F. (2016) The Relationship Between Training Load and Injury, Illness and Soreness: A Systematic and Literature Review. *Sports Medicine* **46**, 861-883.
- Embricos, A. and Poon, G. (2014) Single-view 3D reconstruction of basketball scenes. Retrieved on the 16th of September 2017 Available form from URL: http://web.stanford.edu/class/cs231a/prev_projects_2015/basketball.pdf.
- Fanchini, M., Rampinini, E., Riggio, M., Coutts, A. J., Pecci, C. and McCall, A. (2018) Despite association, the acute: chronic workload ratio does not predict non-contact injury in elite footballers. *Science and Medicine in Football*, 1-7.
- Ferrioli, D., Bosio, A., Bilsborough, J. C., Torre, A. L., Tornaghi, M. and Rampinini, E. (2018) The Preparation Period in Basketball: Training Load and Neuromuscular Adaptations. *International Journal of Sports Physiology and Performance* **18**, 1-28.
- Folgado, H., Duarte, R., Marques, P. and Sampaio, J. (2015) The effects of congested fixtures period on tactical and physical performance in elite football. *Journal of Sports Sciences* **33**, 1238-1247.
- Foster, C., Rodriguez-Marroyo, J. and Koning, J. (2017) Monitoring Training Loads: The Past, the Present, and the Future. *International Journal of Sports Physiology and Performance* **12(Suppl 2)**, S22 -S28.
- Fuller, C.W., Junge, A. and Dvorak, J. (2011) Risk Management: FIFA's Approach for Protecting the Health of Football Players. *British Journal of Sports Medicine* **46(1)**, 11-17.
- Fuller, C.W. (2007) Managing the risk of injury in sport. *Clinical Journal of Sport Medicine* **17(3)**, 182-187.
- Gabbett, T.J. (2016) The training-injury prevention paradox: should athletes be training smarter and harder? *British Journal of Sports Medicine* **50(5)**, 273-280.
- Gabbett, T.J., Stein, J.G., Kemp, J.G. and Lorenzen C. (2013) Relationships between tests of physical qualities and physical match performance in elite rugby league players'. *Journal of Strength and Conditioning Research* **27(6)**, 1539-1545.
- Gabbett, T., Polley, C., Dwyer, D., Kearney, S. and Corvo, (2014) Influence of field position and phase of play on the physical demands of match-play in professional rugby league forwards. *Journal of Science and Medicine in Sport* **17(5)**, 556-561.
- Gabbett, T.J. and Ullah, S. (2012) Relationships between running loads and soft-tissue injury in elite team sport athletes. *Journal of Strength and Conditioning Research* **26(4)**, 953-960.
- Gabbett, T.J. and Jenkins, D.G. (2011) Relationship between training load and injury in professional rugby league players. *Journal of Science and Medicine in Sport* **14**, 204-209.
- Gabbett, T.J. and Domrow, N. (2007) Relationships between training load, injury, and fitness in sub-elite collision sport athletes. *Journal of Sports Science* **25**, 1507-1519.
- Gesbert, V., Carrel, J., Philippe, R.A. and Hauw, D. (2016) Elite volleyball coaches' experience using a statistical information system. *International Journal of Performance Analysis in Sport* **16(2)**, 612-632.
- Nassis, G.P. and Gabbett, T.J. (2017) Is workload associated with injuries and performance in elite football? A call for action. *British Journal of Sports Medicine* **51(6)**, 486-487.
- Häggglund, M., Waldén, M., Bahr, R. and Ekstrand, J. (2005) Methods for epidemiological study of injuries to professional football play-

- ers: developing the UEFA model. *British Journal of Sports Medicine* **39**(6), 340-346.
- Häggglund, M., Waldén, M., Tii, L. and Pruna, R. (2010) The Importance of Epidemiological Research in Sports Medicine. *Apunts. Medicina de l'Esport*. **45**(166), 57-59.
- Hewett, T.E. (2017) Prediction of Future Injury in Sport: Primary and Secondary Anterior Cruciate Ligament Injury Risk and Return to Sport as a Model. *Journal of Orthopaedic & Sports Physical Therapy* **47**(4), 228-231.
- Hopkins, W.G., Marshall, S.W., Batterham, A.M. and Hanin, J. (2009) Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise* **41**, 3-13.
- Hu, M., Chang, M., Wu, J. and Chi, L. (2011) Robust Camera Calibration and Player Tracking in Broadcast Basketball Video. *IEEE Transactions on Multimedia* **13**(2), 266-279.
- Hugues, H. and Franks, I.M. (2004) *Notational Analysis of Sport: Systems for Better Coaching and Performance in Sport*. 2nd edition. London, Taylor & Francis. 320.
- Hulin BT. (2017) The never-ending search for the perfect acute:chronic workload ratio: what role injury definition? *British Journal of Sports Medicine*. 51: 991-992
- Hulin, B.T., Gabbett, T.J., Blanch, P., Chapman, P., Bailey D. and Orchard, J.W. (2013) Spikes in acute workload are associated with increased injury risk in elite cricket fast bowlers. *British Journal of Sports Medicine* **48**, 708-712.
- Hulin, B.T., Gabbett, T.J., Lawson, D.W., Caputi, P. and Sampson, J. (2016) The acute:chronic workload ratio predicts injury: high chronic workload may decrease injury risk in elite rugby league players. *British Journal of Sports Medicine* **50**, 231-236.
- Hyldahl, R.D. and Hubal, M.J. (2014) Lengthening our perspective: morphological, cellular, and molecular responses to eccentric exercise. *Muscle & Nerve* **49**(2), 155-170.
- Jovanovic, M. (2017) Uncertainty, heuristics and injury prediction. *Aspetate Sports Medicine Journal* **6**, 18-24
- Lopez-Raton, M., Rodriguez-Alvarez, M.X., Cadarso-Suárez, C. and Gude-Sampedro, F. (2014) Optimal Cutpoints: An R Package for Selecting Optimal Cutpoints in Diagnostic Tests. *Journal of Statistical Software* **61**(8), 1-36.
- Lorenz, D. and Reiman, M. (2011) The role and implementation of eccentric training in athletic rehabilitation: tendinopathy, hamstring strains, and acl reconstruction. *International Journal of Sports Physical Therapy* **6**(1), 27-44.
- Lofti, M., Jabri, I. and Battikh, T. (2011) Basketball game systems identification by real time video processing. *IETE Journal of Research* **57**(6), 491-497.
- Maheswaran, R., Chang, Y.H., Henehan, A. and Danesis, S. (2012) Deconstructing the rebound with optical tracking data. In: *MIT Sloan Sports Analytics Conference, March 2-3, Boston, USA*. Available from URL: http://www.sloansportsconference.com/wp-content/uploads/2012/02/108-sloan-sports-2012-maheswaran-chang_updated.pdf
- Mangine, G.T., Hoffman, J.R., Wells, A.J., Gonzalez, A.A.M., Rogowski, J.P., Townsend, J., Jajtner, A.R., Beyer, K.S., Bohner, J.D., Pruna, G.J., Fragala, M.S., and Stout, J.R. (2014) Visual Tracking Speed Is Related To Basketball-Specific Measures Of Performance In NBA Players. *Journal of Strength and Conditioning Research* **28**(9), 2406-2414.
- Maymin, P. (2013) Acceleration in the NBA: Towards an algorithmic taxonomy of basketball plays. In: *MIT Sloan Sports Analytics Conference, March 2-3, Boston, USA*. <http://www.sloansportsconference.com/wp-content/uploads/2013/Acceleration%20in%20the%20NBA%20Towards%20an%20Algorithmic%20Taxonomy%20of%20Basketball%20Plays.pdf>
- McNamara, D.J., Gabbett, T.J. and Naughton, G. (2017) Assessment of Workload and its Effects on Performance and Injury in Elite Cricket Fast Bowlers. *Sports Medicine* **47**(3), 503-515.
- Mendez-Villanueva, A., Buchheit, M., Simpson, B. and Bourdon, P.C. (2013) Match play intensity distribution in youth soccer. *International Journal of Sports Medicine* **34**(02), 101-110.
- Mooney, M.G., Cormack, S., O'Brien, B.J., Morgan, W.M. and McGuigan, M. (2013) Impact of neuromuscular fatigue on match exercise intensity and performance in elite Australian football. *The Journal of Strength & Conditioning Research* **27**(1), 166-173.
- Murphy, J.C., O'Malley, E., Gissane, C. and Blake, C. (2012) Incidence of injury in Gaelic football: a 4-year prospective study. *American Journal of Sports Medicine* **40**, 2113-2120
- Murray, N.B., Gabbett, T.J., Townshend, A.D. and Blanch, P. (2017) Calculating acute:chronic workload ratios using exponentially weighted moving averages provides a more sensitive indicator of injury likelihood than rolling averages. *British Journal of Sports Medicine* **51**(9), 749-754.
- Osgnach, C., Poser, S., Bernardini, R., Rinaldo, R. and Di Prampero, P.E. (2010) Energy cost and metabolic power in elite soccer: A new match analysis approach. *Medicine and Science in Sports and Exercise* **42**, 170-178.
- Podlog, L., Buhler, C.F., Pollack, H., Hopkins, P.N. and Burgess, P.R. (2015) Time trends for injuries and illness, and their relation to performance in the National Basketball Association. *Journal of Science and Medicine in Sport* **18**, 278-282.
- Pull, M.R. and Ranson, C. (2007) Eccentric muscle actions: Implications for injury prevention and rehabilitation. *Physical Therapy in Sport* **8**(2), 88-89
- Purdam, C., Drew, M.K., Blanch, P.D., Champman, D., Gabbett, T.J., Gore, C., Hugues, D., Kelly, T., Mitchell, J., Rice, T. and Raysmith, B. (2015) Prescription of training load in relation to loading and unloading phases of training. Bruce, Australia: Australian Sports Commission.
- Rossi, A., Pappalardo, L., Cintia, P., Iaia, M., Fernandez, J. and Medina, D (2017) Effective injury prediction in professional soccer with GPS data and machine learning. *Cornwell University Library*, 23 May 2017, arXiv:1705.08079v1 [stat.ML]
- Sampaio, J.E., McGarry, T., Calleja-González, J., Jiménez Sáiz, S, Schelling, X. and Balciunas, M. (2015) Exploring game performance in the National Basketball Association using player tracking data. *PLoS One* **10**, 1-14.
- Scanlan, A.T., Wen, N., Tucker, P., Borges, N. and Dalbo, V. (2014) The relationships between internal and external training load models during basketball training. *Journal of Strength and Conditioning Research* **28**(9), 2397-2405.
- Schelling, X. and Torres, L. (2016) Accelerometer Load Profiles for Basketball-Specific Drills in Elite Players. *Journal of Sports Science and Medicine* **(15)**, 585-591.
- Siegle, M., Stevens, T. and Lames, M. (2013) Design of an accuracy study for position detection in football. *Journal of Sports Sciences* **31**(2), 166-172.
- Soligard, T., Schwelunus, M., Alonso, J.-M., Bahr, R., Clarsen, B., Dijkstra, P., Gabbett T., Gleeson, M., Häggglund, M., Hutchinson, M.R., Janse van Rensburg, C., Khan, K.M., Meeusen, R., Orchard, J.W., Pluim, B.M., Raftery, M., Budgett, R. and Engebretsen, L (2017) How much is too much? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. *British Journal of Sports Medicine* **50**, 1030-1041.
- Talukder, H., Vincent, T., Foster, B.G., Hu, B.C., Huerta A.J., Kumar, A.A., Malazarte, M., Saldana, D. and Simpson, A.S. (2016) Preventing in-game injuries for NBA players. In: *MIT Sloan Sports Analytics Conference, March 11-12, Boston, USA*. Available form URL: <http://www.sloansportsconference.com/wp-content/uploads/2016/02/1590-Preventing-in-game-injuries-for-NBA-players.pdf>
- Tamir, M. and Oz, G. (2006) *U.S. Patent Application* No. 11/909,080.
- Teramoto, M., Cross, C.L., Cushman, D.M., Maak, T.G., Petron, D.J., and Willick, S.E. (2016) Game injuries in relation to game schedules in the National Basketball Association. *Journal of Science and Medicine in Sport* **20**(3), 230-235.
- Tous-Fajardo, J., Gonzalo-Skok, O., Arjol-Serrano, J. L., & Tesch, P. (2016). Enhancing change-of-direction speed in soccer players by functional inertial eccentric overload and vibration training. *International journal of sports physiology and performance*, **11**(1), 66-73
- Ullah, S., Gabbett, T.J. and Finch, C.F. (2012) Statistical modelling for recurrent events: an application to sports injuries. *British Journal of Sports Medicine* 1287-1293.
- Vanderbogaerde, T.J. and Hopkins, W.G. (2010) Monitoring acute effects on athletic performance with mixed linear modeling. *Medicine and Science in Sports and Exercise* **42**(7), 1339-1344.
- Waldén, M., Häggglund, M., and Ekstrand, J. (2005). UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. *British Journal of Sports Medicine* **39**: 542-6.
- Weiss, K., Allen, S., McGuigan, M. and Whatman, Ch. (2017) The Relationship Between Training Load and Injury in Men's Professional Basketball Players. *International Journal of Sports Physiology and Performance* **2**, 1-20.
- Windt, J., Gabbett, T.J., Ferris, D. and Khan, K. (2017) Training load-

injury paradox: is greater preseason participation associated with lower in-season injury risk in elite rugby league players? *British Journal of Sports Medicine* **51(8)**, 645-650.

World Medical Association. (2013) World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *Journal of the American Medical Association* **310**, 2191-2194.

Yonggangniu, H.H. and Zhao, H. (2014) Application of the Sport VU Motion Capture System in the Technical Statistics and Analysis in Basketball Games. *Asian Sports Science* **3(7)**, 45-52.

Key points

- The number of decelerations and the total distance can be considered risk factors for injuries in professional basketball players.
- Unloaded players have greater risk of injury compared to players with higher accumulated external workload.
- Workload management should be considered a major factor in injury prevention programs.

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