INERTIAL MOVEMENT DEMANDS COMPARISON BETWEEN WINNING AND LOSING QUARTERS IN YOUTH BASKETBALL PLAYERS

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Abstract:

The aim of the present study was to compare the relative external load demands of youth male basketball players between winning and losing quarters and across quarters characterized by different score differentials (close, balanced, and unbalanced). Data were collected from 11 male basketball players Under 18 on the same team during 21 official games over two competitive seasons. External load demands of each quarter were recorded using microsensors to derive values for the following variables: PlayerLoad (PL), frequency of total and high-intensity accelerations (ACC), jumps, decelerations (DEC), changes of direction (COD), and total inertial movement analysis (IMA) events combined. K-means clustering was applied to the score-differential values to derive three data-driven categories (close, balanced, and unbalanced). Subsequent comparisons between winning and losing quarters and across these score-differential categories under winning or losing quarters were examined using linear mixed-effects models. Standardized Cohen's effect sizes were computed to quantify the magnitude of all pairwise contrasts. For all variables, the mixed-effects models showed no statistically significant differences between winning and losing quarters (all $p > 0.05$). Within losing quarters, small but statistically significant differences were found between the close and balanced quarters for total IMA ($p < 0.001$, $d = 0.36$) and COD ($p < 0.001$, $d = 0.35$). No significant differences were observed across score-differential categories within the winning quarters (all $p > 0.05$). Overall, these results indicate that neither quarter outcome nor score margin substantially affects total or high-intensity external load, highlighting the need for future research to examine the influence of other contextual factors—such as opponent quality and game location—on physical demands in youth basketball players.

Keywords: *basketball, accelerometer, team sport, match load, youth players*

Introduction

Basketball is an intermittent team sport characterized by frequent changes of direction, typically occurring every 2-3 seconds (Stojanović, et al., 2018). Notably, the demands of basketball vary across different playing positions: guards, forwards, and centres (De Saá Guerra, González, Manso, & Rodríguez, 2016; Svilar, Castellano, Jukic, & Casamichana, 2018). Frequent changes of direction and movement demands among basketball players have been well-documented for many years through inertial movement analysis (Petway, Freitas, Calleja-González, Leal, & Alcaraz, 2020) and time-motion analysis (Ben Abdelkrim, El Fazaa, & El Ati, 2007). Over the last decade, basketball practitioners worldwide have increasingly adopted micro-technology such as wearable sensors, to precisely track players movements such as accelerations, decelerations, changes of direction, and jumps (García, Castellano, Vicens-Bordas, Vázquez-Guerrero, & Ferioli, 2023; Salazar, Castellano, & Svilar, 2020; Zamora, Capdevila, Lalanza, & Caparrós, 2021). Modern wearable sensors are lightweight and compact, typically integrated into a GPS vest, allowing players to wear them comfortably during training and competition. For practitioners, this technology allows the real-time tracking of numerous parameters via computers or tablets during practice, thus enabling them to conduct detailed post-practice movement analyses. The application of modern micro-technology has opened a new chapter in external load monitoring for both training and competition (Ballesta, Abruñedo, & Caparrós, 2019).

Winning a basketball game is determined by various factors. From the players' perspective, key performance determinants include physical capacities, technical execution, and tactical decision-making (Stojanović, et al., 2018). From the coaches' perspective, key factors include effective communication, tactical decision-making, anticipatory judgment, and experience-based subjective assessment of players' physical condition (Zhang, et al., 2019). The execution of these technical–tactical behaviours is sustained throughout the game and depends critically on players' ability to maintain the physical intensity required during the competition (Ballesta, Abruñedo, & Caparrós, 2019). When players become fatigued and can no longer match the opponent's pace, declines in physical performance may translate into diminished competitive effectiveness and, ultimately, influence match outcome (Fox, Green, & Scanlan, 2020). Recent studies have explored the external demands of basketball games, with significant findings regarding the differences in physical demands in the different competitive levels (Petway, et al., 2020). Evidence from a U18 European male competition showed that players in the bottom four teams accumulated higher relative running distances ($m \cdot min^{-1}$) compared with players in the top four teams (Pino-Ortega, et al., 2019). Similarly, studies involving semi-professional adult male players found that the frequency of high-intensity accelerations per minute was higher in losses than in wins (Fox, Green, & Scanlan, 2020). However, despite fluctuations in overall external workload, peak demands across rolling periods from 15 seconds to 5 minutes were consistent, showing only trivial-to-small effects when comparing winning with losing quarters (Pérez-Chao et al., 2023). This evidence indicates that although players experienced more high-intensity efforts in losing games, the magnitude of peak demands across different time intervals remains stable, irrespective of match outcome (Pérez-Chao et al., 2023). This suggests that higher physical output—such as increased accelerations—does not necessarily translate into winning, underscoring the likely contribution of other determinants, including tactical organisation and decision-making processes. Although extensive research has examined how contextual factors—such as scoreline, game location, and opponent quality influence quarter outcome (García, Fernández, Illa, Reche, & Vázquez-Guerrero, 2022; Sampaio, Lago, Casais, & Leite, 2010), there is limited evidence on how quarter results themselves influence players' physical demands (Fox, et al., 2020; Pérez-Chao, et al., 2023). When the score margin is small, game intensity typically increases, requiring players to increase their physical output to either preserve the lead or reduce the score gap. (Fox, et al., 2020). When a team is losing, players often increase their physical intensity to reduce the score gap, whereas when a team is leading, they may prioritize maintaining control—either by stabilizing defensive organization or by controlling the pace of the game (Pérez-Chao, et al., 2023).

To date, only two studies in basketball have examined how quarter outcome affects movement demands, highlighting a substantial gap in the existing literature. (Fox, et al., 2020; Pérez-Chao, et al., 2023). More evidence is required to clarify how match outcome shape players' physical demands. Furthermore, determining whether specific types of physical demands vary according to match outcome within quarters would provide valuable insights for designing more effective training and match strategies. Therefore, this study aimed to compare the relative external load demands experienced by youth male basketball players between winning and losing quarters, as well as across quarters—whether won or lost—characterized by different score differentials (close, balanced, and unbalanced). Based on previous literature, we hypothesized that lost quarters would show higher average movement demands, or alternatively, that no significant differences would be observed between winning and losing quarters.

Material and methods

Participants

A total of 11 male youth basketball players (mean ± standard deviation [SD]: age: 16.52 ± 0.71 years; height: 198.7 ± 6.9 cm; body mass: 83.2 ± 12.0 kg) were recruited to participate in this study. All players belonged to the youth academy of a EuroLeague club and competed in both the under-18 (U18) regional league and the Spanish fourth division. The weekly training structure comprised 3–4 team-based technical–tactical sessions, 1–2 individualized skill sessions, two strength and power conditioning sessions, and 1–2 official matches, which were generally scheduled on weekends.Only players who averaged more than 8 minutes of court time per game and were injury-free were included in the study. All participants voluntarily provided written informed consent, and all procedures complied with the ethical standards of the Declaration of Helsinki (Harriss & Atkinson, 2015). This investigation was carried out as part of a routine monitoring programme embedded within a broader doctoral research project. Ethical approval covering all study procedures was obtained from the Ethics Committee of the University of the Basque Country (UPV/EHU; reference: M10_2018_027). No identifiable personal information was collected, and all procedures conformed to national and international ethical standards for human experimentation.

Procedures

An observational, longitudinal study design was used, where players were monitored during games and practices across the 2019-20 and 2020-21 seasons. Following the implementation of rigorous selection criteria and logistical considerations, 21 official league matches across two seasons were included in the final analysis. Specifically, only regular-season official league matches were considered, and all friendly games were excluded. Eligible matches were further restricted to those in which no more than eight players were available for selection, each player accumulated more than 8 minutes of total playing time and completed at least one quarter with ≥4 minutes of uninterrupted participation, and the monitoring equipment could be transported and operated by the principal investigator. Games for which data collection was not feasible due to equipment limitations were omitted. All included fixtures were official league matches conducted in accordance with FIBA rules and held on weekends (Saturday or Sunday) throughout the competitive period. To assess contextual influences, each quarter was categorized based on match outcome (win vs. loss) and the corresponding score-differential margin. Following Csataljay, et al. (2012), Three competitive scenarios were established according to quarter-level score differentials: (i) close quarters (<5 points), indicating high competitive balance; (ii) balanced quarters (5–12 points), reflecting moderate superiority by one team; and (iii) unbalanced quarters (>12 points), representing a clear advantage for one team. This categorization facilitated the evaluation of physical demands based on quarter-level competitiveness instead of limiting analyses to the overall match outcome. All external load variables were captured using inertial microsensor units (Catapult ClearSky T6, Catapult Innovations, Melbourne, Australia) incorporating accelerometer, magnetometer and gyroscope sensors, sampling at 100Hz. The devices were placed in custom-made vests positioned on the centre of the upper back using adjustable harnesses, in accordance with the manufacturer's recommendations. Physical demands were reported as PlayerLoad (PL), representing the square root of the change in acceleration across the x, y, and z axes (Openfield v8, Catapult Innovations, Melbourne, Australia), as well as total inertial movement analysis (IMA) variables. In addition, within IMA variable reported, the following measures were also included: accelerations ([ACC] -45° to 45° direction), decelerations ([DEC] -135° to 135° direction), changes of direction ([COD], -135° to -45° direction for left and 45° to 135° direction for right), and jumps. The frequency of all IMA variables was quantified for both total and high-intensity events. High-intensity counts were defined as ACC, DEC, and COD exceeding 3.5 $m\cdot s^{-2}$, and jumps exceeding 40 cm according to the previous study (Zhang, et al., 2025a). All IMA metrics and PL values were normalized to individual playing time, being reported as counts or arbitrary units per minute. Playing time derived from devices included all in-game stoppages such as free throws, fouls, and out-of-bounds periods, but excluded breaks between quarters, time-outs, and periods when players were substituted out of the game (Zhang, et al., 2025a). This combination of external load variables has been previously used in team sports and basketball research showing acceptable reliability (Svilar & Jukić, 2018). It effectively represents both overall intensity and the common movement patterns encountered in basketball games (Petway, et al., 2020).

Statistical analysis

Data are presented as mean ± standard deviation (SD) for all variables. Prior to model fitting, the normality of residuals was assessed using the Shapiro-Wilk test. Differences in external-load variables across quarter categories (close, balanced, unbalanced) were examined separately for winning and losing quarters using linear mixed-effects models. In each model, quarter competitiveness was included as a fixed effect, and player and game were included as random intercepts to account for repeated measures within players and games. Pairwise comparisons between categories (close vs. unbalanced, close vs. balanced, unbalanced vs. balanced) were quantified using Cohen's d effect sizes with 1,000 bootstrap resamples to obtain 95% confidence intervals. Effect size thresholds were defined as follows: <0.20, trivial; 0.20-0.49, small; 0.50-0.8, medium; >0.8, large (Cohen, 1988). All statistical proceeds were performed using JASP software (Universidad de Ámsterdam, https://jasp-stats.org/). Statistical significance was set at $p< 0.05$.

Results

Table 1 presents mean ± SD of all the analyzed variables across winning and losing quarters for the entire team, alongside effect size comparisons. No statistically significant differences were observed in any IMA variables between the winning and losing quarters.

Table 2 shows the differences among losing quarters categorized by the final score margin. Small differences were observed in total IMA ($p<0.001$, $d = 0.36$) and total COD ($p<.001$, $d = 0.35$) between the close and balanced quarters. In contrast, most variables exhibited similar values across winning quarters, with no significant differences detected (Table 3).

Table 1. Descriptive statistics of external loads recorded during winning and losing quarters

Variables (AU·min^{-1})	Losing (Mean ± SD)	Winning (Mean ± SD)	P	ES
PlayerLoad	10.77 ± 1.89	10.95 ± 1.60	.42	-0.11
Total IMA	23.92 ± 8.89	23.98 ± 8.63	.96	-0.01
Total ACC	3.01 ± 1.21	2.98 ± 1.18	.81	0.03
High-intensity ACC	0.60 ± 0.33	0.61 ± 0.39	.88	-0.02
Total DEC	3.46 ± 1.65	3.47 ± 1.61	.97	-0.01
High-intensity DEC	0.61 ± 0.40	0.63 ± 0.41	.72	-0.06
Total COD	17.44 ± 7.01	17.53 ± 6.77	.92	-0.01
High-intensity COD	1.10 ± 0.92	1.06 ± 0.78	.84	0.04
Total jumps	1.61 ± 0.61	1.71 ± 0.62	.06	-0.15
High-intensity jumps	0.21 ± 0.18	0.19 ± 0.17	.59	0.09

Note. AU = arbitrary units, ES = effect size, IMA = inertial movement analysis events, ACC = accelerations, DEC = decelerations, COD = changes of direction.

Table 2. External load variables across losing quarters with different score differentials (close, balanced, and unbalanced)

Variables (AU·min^{-1})	Losing quarters			Effect size		
	Close	Unbalanced	Balanced	C vs. U	C vs. B	U vs. B
PlayerLoad	10.84±1.98	10.73±1.64	10.69±1.97	0.06	0.07	0.02
Total IMA	25.07±8.21	24.07±9.04	23.91±9.83	0.12	0.36***	0.13
Total ACC	3.13±1.18	2.99±1.11	2.84±1.33	0.12	0.14	0.12
High-intensity ACC	0.60±029	0.63±0.33	0.56±0.39	-0.08	0.13	0.19
Total DEC	3.63±1.69	3.48±1.66	3.19±1.57	0.09	0.17	0.18
High-intensity DEC	0.66±0.42	0.60±0.38	0.62±0.36	0.15	0.14	0.11
Total COD	18.30±6.38	17.60±7.20	15.88±7.61	0.10	0.35***	0.19
High-intensity COD	1.37±0.87	1.10±0.79	0.89±0.49	0.08	0.19	0.12
Total jumps	1.70±0.61	1.77±0.60	1.71±0.60	0.19	0.11	0.17
High-intensity jumps	0.23±0.18	0.19±0.16	0.20±0.18	0.18	0.13	-0.13

Note. *p≤.05, **p≤.01, ***p≤.001. AU = arbitrary units, IMA = inertial movement analysis events, ACC = accelerations, DEC = decelerations, COD = changes of direction. C = close quarter, U = unbalanced quarter, B = balanced quarter.

Table 3. External load variables across winning quarters with different score differentials (close, balanced, and unbalanced).

Variables (AU·min^{-1})	Winning quarters			Effect size		
	Close	Unbalanced	Balanced	C vs. U	C vs. B	U vs. B
PlayerLoad	10.79±1.52	10.89±1.69	11.23±1.64	-0.07	-0.18	-0.2
Total IMA	24.72±8.04	24.87±8.44	24.96±9.46	0.03	0.04	0.02
Total ACC	2.99±1.03	2.88±1.15	3.01±1.37	0.11	-0.02	-0.10
High-intensity ACC	0.60±0.37	0.56±0.40	0.63±0.40	0.12	-0.08	-0.19
Total DEC	3.54±1.53	3.65±1.77	3.27±1.64	-0.07	0.17	0.03
High-intensity DEC	0.67±0.40	0.64±0.42	0.57±0.43	0.07	0.14	0.17
Total COD	17.18±6.50	17.35±6.43	17.69±7.26	0.13	0.11	0.09
High-intensity COD	1.12±0.70	0.97±0.62	1.02±0.94	0.11	0.12	-0.06
Total jumps	1.71±0.55	1.71±0.63	1.75±0.71	0.17	-0.06	-0.12
High-intensity jumps	0.19±0.17	0.19±0.18	0.19±0.16	0.03	0.01	-0.03

Note. *p≤.05, **p≤.01, ***p≤.001. AU = arbitrary units, IMA = inertial movement analysis events, ACC = accelerations, DEC = decelerations, COD = changes of direction. C = close quarter, U = unbalanced quarter, B = balanced quarter.

Discussion and conclusions

The aim of the present study was to compare the relative external load demands experienced by youth male basketball players between winning and losing quarters, as well as across quarters—whether won or lost—characterized by different score differentials (close, balanced, and unbalanced). The results showed no statistically significant differences in any IMA variable when quarters were classified by their final outcome. However, within the losing quarters, small but statistically significant differences emerged, with both total IMA and total COD values being higher in close quarters than in balanced quarters. In contrast, no significant differences were observed across score-differential categories within the winning quarters.

In the present study, no meaningful differences were observed in any of the analysed variables when comparing winning and losing quarters. Consistent with Fox et al. (2021), these findings suggest that quarter outcomes may not be directly associated with variations in physical performance. Notably, previous study has identified rebounding performance as a key determinant of quarter outcome (Csataljay, et al., 2012). When considered in relation to physical performance, one might assume that a higher number of jumps would play a key role in winning quarters. However, the present findings do not support this assumption. Beyond physical abilities and jumping capacity, factors such as positioning, anticipation of the shot, and reading the rebound trajectory appear to be crucial determinants of rebounding success. (Zhang, et al., 2019). Taken together, the evidence indicates that, regardless of the scoreboard, technical and tactical factors, contextual elements, and player motivation are likely to have a significant influence on quarter outcome than physical demands. (Vázquez-Guerrero, et al., 2019; Zhang, et al., 2025b).

Within the losing quarters, close quarters demonstrated significantly higher total IMA and total COD values compared with balanced quarters. These findings indicate that close score situations place more physical demands on players, likely due to the increased intensity and urgency of the game. When the score is close, both teams tend to increase their competitive intensity to either protect a narrow lead or reduce a small margin, which leads to more frequent high-intensity actions such as accelerations, quick changes of direction, and defensive efforts (Sansone et al., 2021). In contrast, balanced quarters, characterized by moderate score differences, are typically associated with lower physical intensity due to reduced competitive pressure (Zhang, et al., 2017). These findings align with the broader understanding that the partial score and competitiveness of a game significantly influence the physical demands placed on players (Fox, et al., 2020; Pérez-Chao, et al., 2023). Conversely, in games with a larger score difference, teams may reduce their physical efforts by controlling the game pace or by prioritizing the maintenance of the lead (Piñar, et al., 2022).

The average external demands observed in the youth basketball players in the present study were higher than those reported in a recent investigation of Australian semi-professional players (Fox, et al., 2020). The differences between competition levels and between players from different leagues should be viewed in light of the developmental context of the present study. As youth athletes, these players typically experience higher training volumes and more intensive skill-development workloads than semi-professional adults, which likely contributes to more physical demands observed in this study (Zhang, et al., 2025c). Conversely, differences in playing styles across leagues may also help explain the variation in external load demands observed among players (Zhang, et al., 2018). The external load values observed in our study were generally higher than those previously reported for elite players using the same micro-technology, with the exception of PL, which was greater in elite players (Svilar & Jukić, 2018). These differences have been reported previously and may be attributed to the superior technical proficiency and more efficient decision-making of higher-level players, which allow them to better optimize their physical efforts during competition (Sampaio, et al., 2015). Notably, research based on IMA variables derived from micro-technology is inherently limited by the device used, as comparisons can only be made with studies employing the same system. Different manufacturers apply distinct algorithms, which can produce substantially different outputs (Tuttle, et al., 2024).

We acknowledge several limitations that should be considered when interpreting the findings of this study. The most notable limitation is the relatively small sample size, which may restrict the generalizability of the results. Furthermore, only one team was monitored during the competitive period; assessing both competing teams would provide a more complete understanding of how physical demands relate to quarter outcome. In addition, several unmeasured factors—such as tactical strategies, individual player characteristics, and the competitive level of the opposition—may have influenced the external load patterns observed. Finally, weekly training loads completed by the team prior to each match were not recorded, which could have affected players' physical responses during games.

In conclusion, this study found a small but significant increase in total IMA and COD values during close quarters compared with balanced quarters within the losing context, indicating that physical demands rise when the game becomes more competitive. No significant differences in external-load variables were observed across close, balanced, and unbalanced quarters within the winning context. In addition, accelerometer-derived measures did not differ between winning and losing quarters. Taken together, these findings suggest that, although an adequate physical load is necessary for performance, technical execution, tactical organization, and psychological factors may have a significant influence on quarter outcome.

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