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Human Kinetics
BRIEF REPORT

Interunit Reliability of Firstbeat Sport Sensors as Accelerometer-Based Tracking Devices in Basketball

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Purpose: The aim of this study was to assess the interunit reliability of the movement load (ML) derived from the Firstbeat Sport sensors during basketball training sessions. ***Methods:*** Eight professional male basketball players (age 25.5 [4.7] y, stature 199 [8] cm, body mass 96.6 [7.8] kg, body fat 10.0% [2.2%]) were recruited to participate in this study. A total of 50 individual training sessions were recorded on one or multiple occasions (range: 1–21 individual sessions for each player) while players were wearing 2 Firstbeat Sport sensors firmly affixed to their chest roughly at the base of the sternum via textile straps. ML was calculated via Firstbeat Sports software for the entire basketball training sessions and for the following basketball-specific activity types: 5-on-5 full court (5v5, n = 30), 5-on-5 half-court plus 2 courts back and forth (5v5 1/2 + 2, n = 26), and 5-on-5 half-court (5v5 1/2, n = 26). ***Results:*** Linear mixed models revealed no statistical differences in ML data recorded using different sensors during the entire training sessions and the selected basketball-specific activity types (all $P > .05$, trivial). The coefficient of variation calculated as percentage and intraclass correlation coefficient calculated for the entire training sessions and basketball-specific activity types ranged from 2.51% to 5.97% and from .98 to 1.00, respectively. ***Conclusions:*** The ML derived from the Firstbeat Sport sensor showed acceptable interunit reliability when considering the full training sessions and basketball-specific activities in professional basketball. Overall, basketball practitioners can use Firstbeat Sport sensors interchangeably to monitor the external load of professional basketball players during training sessions.

Keywords: inertial movement unit, monitoring training load, workload, external load, small-sided games

Monitoring training load is considered a key aspect in basketball.[1] To this purpose, wearable microtechnologies such as inertial movement units (IMUs) can provide a practical way to monitor players' external loads. These devices are usually embedded within the wearable devices and are composed by triaxial accelerometers, magnetometers, and gyroscopes capable of measuring inertial accelerations in 3 axes to estimate a vector magnitude named differently (ie, PlayerLoad, movement load [ML], accumulated load) depending on the formula adopted by the various proprietary software.[2]

To take well-informed decisions using the load generated by IMU devices, it is important that they have acceptable degrees of validity (ie, the ability to measure what it is intended to measure)[3] and reliability (ie, reproducibility of the measure of interest on separate occasions).[4] Reliability can be divided into "intraunit" reliability (also named "test–retest"), which refers to the consistency or stability of measurements or assessments within a single unit and "interunit" reliability, which is particularly important when comparing the measures of different devices (ie, players) within a team. Previous studies[2,5] assessing the interunit reliability of accelerometer-based measures such as PlayerLoad and accumulated load demonstrated low coefficient of variations (CVs) ranging from 0.9% to 5.9% in team sports. Nevertheless, these studies only referred to the load measure derived from the devices of some specific brands (ie, Catapult Sport, Kinexon Sports & Media), while little information is available for other brands. For instance, the Firstbeat Technologies Oy, which designed a chest belt heart rate monitor incorporating an accelerometer recording at 50 Hz, also provides measurements of external load named "movement load" (ML) derived from the triaxial accelerations the athlete performs. Although the popularity and usage of Firstbeat Sport sensors to monitor external load is increasing within basketball clubs and in basketball research,[6] little information is available about their interunit reliability. This information could provide valuable insights for basketball scientists and practitioners when deciding to compare the between-player match or training load. Therefore, the aim of this study was to assess the interunit reliability of the ML derived from the Firstbeat Sport sensors during basketball training sessions.

Methods

Participants

A total of 8 professional, male basketball players (age: 25.5 [4.7] y, stature: 199 [8] cm, body mass: 96.6 [7.8] kg, body fat: 10.0% [2.2%]) were recruited from the same basketball team competing in the Italian first division (ie, Serie A) to participate in this study. All players were over 18 years of age and volunteered to participate after being informed of the study procedures, risks, and benefits. The study was approved by the independent institutional review board of MAPEI Sport Research Center (approval number: IRBMS062024001) in accordance with the Declaration of Helsinki.

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Design and Methodology

An observational study was designed to assess the interunit reliability of Firstbeat Sport sensors (Firstbeat Technologies Oy) during the 2023–24 in-season phase (March and April 2024). The monitored sessions encompassed those performed during each microcycle from game day –5 to game day –2, while the game day –1 sessions and official games were not monitored. During the team training sessions, players wore—at the same time—2 Firstbeat Sport sensors firmly affixed to their chest roughly at the base of the sternum via textile straps. Sensors pairs were randomly assigned to each player before the beginning of the practice. ML (in arbitrary units) was calculated via Firstbeat Sports software (version 2.50.3; Firstbeat Technologies Oy) as the sum of accelerations across the 3 movement axes using the triaxial accelerometer component sampling at 50 Hz with the following formula[6]:

$$\text{Movement load} = \sqrt{\frac{(A_{y1} - A_{y-1})^2 + (A_{x1} - A_{x-1})^2 + (A_{z1} - A_{z-1})^2}{300}},$$

where A_y, A_x, and A_z are the orthogonal components measured from the triaxial accelerometer.

A total of 50 individual training sessions were recorded with players wearing the sensors pairs in one or multiple occasions (range: 1–21 individual sessions for each player) across the data collection period. Sessions were structured with a general 10- to 15-minute warm-up, followed by technical–tactical drills with and without contacts (eg, 3-to-5 vs 0 or 3-to-5 vs 3-to-5) + different types of 5v5. ML was calculated for the entire basketball training sessions (each ~30–90 min) and for the following basketball-specific activity types: 5-on-5 full court (5v5), 5-on-5 half court plus 2 courts back and forth (5v5 1/2 + 2), and 5-on-5 half court (5v5 1/2). A detailed description of these basketball-specific activity types is shown in Figure 1. ML data were recorded by the Firstbeat Sport sensors (Firstbeat Technologies Oy) and automatically uploaded to the Firstbeat Cloud. Raw data were then downloaded and processed via Microsoft Excel software (version 2410).

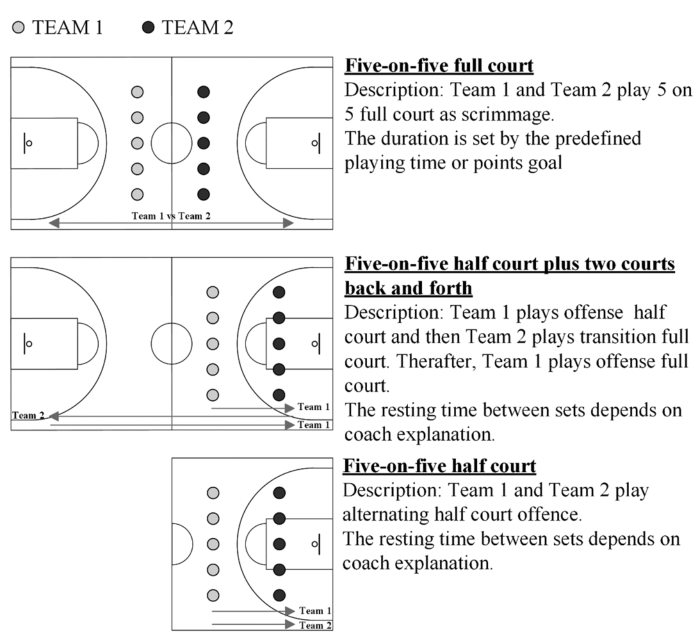

Figure 1 — Description of the adopted drills.

Statistical Analysis

The interunit reliability of the ML retrieved from the Firstbeat Sport sensors was measured following various statistical approaches. Descriptive statistics were assessed as estimated marginal means with 95% CIs. Successively, linear mixed models (LMMs) were used to examine differences in ML according to sensors, accounting for individual repeated measures. Before running LMMs, all assumptions were verified, and the normality of the residuals was also assessed using the Kolmogorov–Smirnov test. Within each LMM, sensor (2 levels) was used as fixed effect, while sensor pair and player were included as random effects including a random intercept and fixed slope. The LMM analyses were run using the jamovi software (version 2.3.21, retrieved from https://www.jamovi.org). The *t* statistics calculated from the LMM were then converted into Cohen *d* effect sizes and associated 95% CI using the Rstudio software (version 4.2.1). Effect sizes were interpreted as follows: <0.2, trivial; 0.20 to 0.59, small; 0.60 to 1.19, moderate; 1.2 to 1.99, large, and ≥2.0, very large.[7] An alpha level of $P < .05$ was set a priori for statistical significance. Furthermore, the typical error expressed as a CV and the intraclass correlation coefficient (ICC) with 95% CI were calculated using customized spreadsheets[8] via the log-transformed variable.

Results

Descriptive data and statistical analyses are reported in Table 1. No statistical differences were observed in ML data recorded using different sensors during the entire training sessions and the selected basketball-specific activity types (all Ps > .05, trivial). The CV calculated as percentage and ICC were determined for the entire training sessions and basketball-specific activity types and ranged from 2.51% to 5.97% and from .98 to 1.00, respectively.

Discussion

This study aimed at assessing the interunit reliability of the ML calculated using Firstbeat Sport sensors in professional basketball revealing high interunit reliability of these sensors during basketball activities. Although there is a plethora of commercially available IMU devices measuring external load through vectors summarizing accelerometry-based data,[9] there is limited information whether these measures possess acceptable interunit reliability. A previous study[5] reported a CV of 2.5% and an ICC of .98 when analyzing the interunit reliability of the accumulated load measured by the IMUs designed by the Kinexon Sport & Media during ice-hockey activities. Similarly, the interunit reliability of the PlayerLoad designed by the Catapult Sport company showed high interunit reliability with CVs ranging between 0.9% and 5.9% during Australian football matches,[10] handball training sessions,[11] and team sports circuits.[12] Despite the different position of the Firstbeat Sport sensors compared with devices previously analyzed (ie, chest vs back), our results overlap with those reported in previous investigations (CVs = 2.51%–5.97% and ICCs = .98–.99), suggesting that ML possesses acceptable levels of interunit reliability similar to other accelerometer-based measures already in regular use.

Interestingly, to the best of our knowledge, this is the first study assessing the interunit reliability of accelerometer-based measures during basketball activities encompassing the full training session and various basketball-specific activity types. Overall, monitoring professional basketball players during their regular

Table 1 Movement-Load Data (Estimated Marginal Means and 95% CIs) Measured During Different Basketball Activity Types According to Applied Sensors Alongside Statistics

	Movement load, AU		Linear mixed model analyses			Reliability analyses	
Activity type	Sensor 1	Sensor 2	ES (95% CI)	Interpretation	*P*	ICC (95% CI)	CV% (95% CI)
Training session (n = 50)	191.1 (137.1 to 245.1)	189.2 (135.2 to 243.3)	−0.04 (−0.44 to 0.35)	Trivial	.825	.99 (.99 to 1.00)	2.51 (2.09 to 3.14)
5v5 (n = 30)	31.4 (19.5 to 43.3)	31.5 (19.6 to 43.3)	0.00 (−0.50 to 0.51)	Trivial	.995	1.00 (.99 to 1.00)	3.44 (2.73 to 4.65)
5v5 1/2 + 2 (n = 26)	51.9 (39.8 to 64.0)	51.8 (39.6 to 63.9)	−0.01 (−0.55 to 0.54)	Trivial	.982	.99 (.98 to 1.00)	4.21 (3.29 to 5.86)
5v5 1/2 (n = 26)	40.5 (21.7 to 59.4)	39.9 (21.1 to 58.8)	−0.05 (−0.59 to 0.49)	Trivial	.857	.98 (.96 to .99)	5.97 (4.65 to 8.33)

Abbreviations: AU, arbitrary unit; CV%, coefficient of variation as a percentage; ES, effect size; ICC, intraclass correlation coefficient. Note: n indicates the number of individual sessions recorded for each activity type.

training sessions denotes a high degree of ecological validity of our design, resulting in detailed results for basketball practitioners using the Firstbeat Sport sensors to assess the external load of this basketball population. While our results indicated interesting information for basketball practitioners regarding the interunit reliability of the investigated sensors in measuring ML, future studies are warranted to assess their validity and intraunit reliability to assess whether the ML can be used confidentially to monitor external load in basketball and other team sports. Although this study presents interesting insight about the interunit reliability of the Firstbeat Sport sensors, it should be considered that our analysis was only focusing on basketball players, limiting the generalizability of the results to other team sports encompassing different movement patterns. Therefore, future investigations should provide a more comprehensive analysis of the intraunit reliability of these devices across other team sports.

Practical Applications

This study is particularly relevant from a practical standpoint providing valuable information for basketball scientists and practitioners. First, due to its high interunit reliability, the ML derived from the Firstbeat Sport sensors can be used to compare between-players external loads. Moreover, in case it is not possible to use the same device for the same player across the season to monitor ML as a measure of external load, our data suggest the possibility for individual players of wearing different sensors in different training sessions since the limited interunit variability may impact marginally on the monitoring process.

Conclusions

The movement load derived from the Firstbeat Sport sensor showed high interunit reliability when considering the entire training sessions and various basketball-specific activity types in professional basketball. Overall, basketball practitioners can use Firstbeat Sport sensors interchangeably to monitor the external load of professional basketball players during their training sessions.

References

1. Fox JL, Scanlan AT, Stanton R. A review of player monitoring approaches in basketball: current trends and future directions. *J Strength Cond Res*. 2017;31(7):2021–2029. doi:10.1519/JSC.0000000000001964
2. Crang ZL, Duthie G, Cole MH, Weakley J, Hewitt A, Johnston RD. The validity and reliability of wearable microtechnology for intermittent team sports: a systematic review. *Sports Med*. 2021;51(3):549–565. doi:10.1007/s40279-020-01399-1
3. Malone JJ, Lovell R, Varley MC, Coutts AJ. Unpacking the black box: applications and considerations for using GPS devices in sport. *Int J Sports Physiol Perform*. 2017;12(suppl 2):S218–S226. doi:10.1123/ijspp.2016-0090
4. McGraw KO, Wong SP. Forming inferences about some intraclass correlation coefficients. *Psychol Methods*. 1996;1(1):30–46. doi:10.1037/1082-989X.1.1.30
5. Gamble ASD, Bigg JL, Pignanelli C, Nyman DLE, Burr JF, Spriet LL. Reliability and validity of an indoor local positioning system for measuring external load in ice hockey players. *Eur J Sport Sci*. 2023;23(3):311–318. doi:10.1080/17461391.2022.2032371
6. Ferioli D, Alcaraz PE, Freitas TT, et al. The reliability and discriminant validity of physical, technical, and perceptual-physiological measures during a game-specific basketball activity simulation protocol. *Front Psychol*. 2024;15:339. doi:10.3389/fpsyg.2024.1414339
7. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*. 2009;41(1):3–12. doi:10.1249/MSS.0b013e31818cb278
8. Hopkins WG. Spreadsheets for analysis of validity and reliability. *Sportscience*. 2015;10:42. https://sportsci.org/2015/ValidRely.htm;19:36-42
9. Gómez-Carmona CD, Pino-Ortega J, Sánchez-Ureña B, Ibáñez SJ, Rojas-Valverde D. Accelerometry-based external load indicators in sport: too many options, same practical outcome? *Int J Environ Res Public Health*. 2019;16(24):5101. doi:10.3390/ijerph16245101
10. Boyd LJ, Ball K, Aughey RJ. The reliability of MinimaxX accelerometers for measuring physical activity in Australian football. *Int J Sports Physiol Perform*. 2011;6(3):311–321. doi:10.1123/ijspp.6.3.311
11. Luteberget LS, Holme BR, Spencer M. Reliability of wearable inertial measurement units to measure physical activity in team handball. *Int J Sports Physiol Perform*. 2018;13(4):467–473. doi:10.1123/ijspp.2017-0036
12. Johnston RJ, Watsford ML, Pine MJ, Spurrs RW, Sporri D. Assessment of 5 Hz and 10 Hz GPS units for measuring athlete movement demands. *Int J Perform Anal Sport*. 2013;13(1):262–274. doi:10.1080/24748668.2013.11868646