Original Article

Relationship between internal and external load metrics in professional male basketball players

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ABSTRACT

Quantifying both external and internal training loads that athletes are exposed to during training sessions is often recommended to assess multifactorial sport-specific demands. Thus, the purpose of the present study was to determine the relationship between a widely used subjective marker of internal load (rate of perceived exertion - RPE) and external load variables obtained from an innovative inertial measurement unit (IMU) device within a cohort of professional male basketball players. Twenty-one athletes competing in the first- and second-tier national basketball leagues in Europe wore an IMU device (i.e., Vert™) during their regular practice session and reported an RPE score (Borg CR-10 scale) immediately post-practice. The findings of this study reveal the presence of a strong significant relationship (r = 0.714) between *Stress* and RPE. However, weak non-significant relationships (r = 0.198-0.287) were observed between RPE and all jump-related metrics (*Jumps, Jumps 15+, Jumps 20+, Average Jump Height*) as well as *Active Minutes* (r = 0.330), indicating that an increase in internal load is more dependent on the type of activity that players perform rather than the duration of the practice session. Overall, these findings may help sports scientists and strength and conditioning practitioners detect changes in training load throughout a competitive season in male basketball players and ultimately improve the acute and chronic training-adaptation monitoring process.
Keywords: Performance analysis of sport, Monitoring, Jump, Stress, Training.

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INTRODUCTION

Training can be viewed as the process of systematically performing exercises to improve physical, technical, and tactical abilities yielding improvements in performance (Berdejo-del-Fresno & Gonzalez-Rave, 2014). In sports settings, the psychophysiological demands of training and competition, along with the athlete's response to such demands, is referred to as "*training load*". Training load is viewed as being either external or internal in nature. External load represents the amount of physical activity performed by the athlete and is a variable that is commonly manipulated during training sessions to elicit desired physiological adaptations (Coutts et al., 2021). Conversely, the internal load is representative of the aforementioned psychophysiological responses that the body initiates to cope with the demands of the external load (Halson, 2014).

In practice, quantifying both external and internal training loads is often recommended to assess multifactorial sport-specific demands. One of the commonly utilized technologies for measuring external training loads that athletes are exposed to during practice sessions and/or games are inertial measurement units (IMU; Benson et al., 2020; Cabarkapa et al., 2022; Charlton et al., 2016; French & Ronda, 2021; Svilar et al., 2018a; Svilar et al., 2018b). A recently published study revealed that an IMU device (i.e., Vert™) was a promising testing modality for monitoring external load metrics in youth basketball players (Benson et al., 2020). Further, in a team sport such as volleyball, which requires repetitive jumping actions, the same IMU device was able to highlight the position-specific differences in external load measures within a cohort of professional male athletes (Cabarkapa et al., 2022). However, there is a lack of scientific literature examining the use of IMU technology in professional-level basketball players.

On the other hand, internal load monitoring is commonly performed by observing physiological and psychological metrics in conjunction with one another to gain cumulative insight into an athlete's training adaptations (Halson, 2014). Often-used metrics to objectively quantify internal load experienced by basketball players during practice and/or competition are heart rate, blood lactate, and salivary hormonal measurements (Andre et al., 2018; Cabarkapa et al., 2023; deArruda et al., 2019; Montgomery et al., 2010; Luebbers et al., 2022; Sansone et al., 2019). However, despite the appeal of objective physiology-based variables, these approaches for monitoring internal load in athletes may be cost-prohibitive, time-consuming, and sometimes not feasible in a field setting. Thus, subjective measures of athlete well-being, such as rate of perceived exertion (RPE), have been proposed as an alternative assessment modality capable of detecting changes in internal loads that athletes are exposed to (Saw et al., 2016). The Borg CR-10 scale method of measuring RPE has been shown to possess strong relationships with objective measures of internal load (e.g., heart rate and blood lactate; Foster et al., 2001; Foster et al., 2021; Hadad et al., 2017). This lends credence to RPE as being a time-efficient testing modality that has been widely used for the assessment of internal load in basketball players (Lupo et al., 2017; Montgomery et al., 2010; Moreira et al., 2012; Paulauskas et al., 2019; Sansone et al., 2019; Svilar et al., 2018a; Svilar et al., 2018b).

Thus, considering the lack of scientific literature focused on examining training loads in an elite cohort of athletes, the purpose of the present study was to determine the relationship between a widely utilized subjective marker of internal load (i.e., RPE) and external load variables obtained from an innovative IMU device (i.e., Vert™) within in a cohort of professional male basketball players.

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MATERIALS AND METHODS

Participants

Twenty-one professional male basketball players (x̄ ± SD; age = 25.5 ± 5.7 years, height = 194.6 ± 10.1 cm, body mass = 93.3 ± 9.1 kg) competing in the first- and second-tier national basketball league in Europe volunteered to participate in the present study. All players were free of musculoskeletal injuries and cleared for participation in team activities by their respective sports medicine staff. Testing procedures performed in this investigation were previously approved by the University's Institutional Review Board, and all athletes signed an informed consent document.

Procedures

Upon arrival at the gym, athletes were briefly familiarized with the testing procedures, as well as IMU device and RPE scale. Then, all athletes were given an IMU device (Vert™, Mayfonk Athletic, Fort Lauderdale, FL, USA) to place around the waist (i.e., iliac crest) and secure it with a manufacturer-provided elastic band (i.e., small through extra-large size). A research assistant was present to assure that the IMU device was appropriately positioned. The IMU device wirelessly collected data from the start to the end of the practice session at 1000 Hz via a smartphone application (Vert™, Mayfonk Athletic, Fort Lauderdale, FL, USA) installed on iPad Pro (Apple Inc., Cupertino, CA, USA). Following familiarization with the testing procedures, all athletes performed a standardized 15-minute warm-up protocol consisting of dynamic stretching exercises (e.g., A-skip, side shuffle, forward lunges, knee hugs) administered by their respective strength and conditioning coaches and proceeded with participation in their regular training sessions. The practice consisted of individual and team shooting drills, 3-on-0 and 5-on-0 offensive actions, and 5-on-5 play, including full-court transition. The overall practice time was approximately two hours (i.e., ~18:00-20:00 hours).

Variables

The external load metrics obtained from the IMU device at the end of the training session were the following: *Stress* (i.e., an algorithm-derived metric used to quantify the percentage of high-impact movements; ≤15% low; 16-21% medium; ≥22% high), *Active Minutes* (i.e., the total amount of time performing dynamic movements), *Jumps* (i.e., the total number of jumps performed during a training session), *Jumps 15+* (i.e., a number of jumps above 15 in / 38.1 cm), *Jumps 20+* (i.e., a number of jumps above 20 in / 50.8 cm), and *Average Jump Height* (i.e., the average vertical jump height across the overall training session).

The internal load was measured via the Borg CR-10 scale for RPE (Borg, 1998). A score of "*1*" indicated minimal exertion, and a score of "*10*" indicated maximal exertion. The RPE score for each athlete was assessed immediately upon the completion of the practice session.

Statistical analysis

Descriptive statistics (x̄ ± SD) were calculated for each dependent variable examined in the present study. Pearson product-moment correlation coefficients were used to measure the strength of a linear regression between internal (i.e., RPE) and external load metrics (i.e., *Stress*, *Active Minutes*, *Jumps*, *Jumps 15+*, *Jumps 20+*, and *Average Jump Height*), separately for each variable (i.e., r = 0.10-0.30 weak correlation, r = 0.31-0.50 moderate correlation, and r > 0.50 strong correlation). Statistical significance was set a priori to $p < .05$. All statistical analyses were completed with SPSS (Version 26.0; IBM Corp., Armonk, NY, USA).

RESULTS

RPE ($\bar{x}$ ± SD; 5.76 ± 1.67) revealed a strong statistically significant correlation with *Stress* (21.2 ± 7.8%; r = 0.714, R^2 = .509, p < .001), and a weak non-statistically significant relationship with *Active Minutes* (80.0 ± 4.3 min; r = 0.330, R^2 = .109, p = .144), *Jumps* (86.9 ± 42.7; r = -0.287, R^2 = .082, p = .208), *Jumps 15*+ (30.1 ± 21.4; r = -0.198, R^2 = .039, p = .389), *Jumps 20*+ (13.3 ± 12.8; r = -0.232, R^2 = .054, p = .312), and *Average Jump Height* (20.1 ± 3.5 cm; r = -0.231, R^2 = .053, p = .313). See Figure 1.

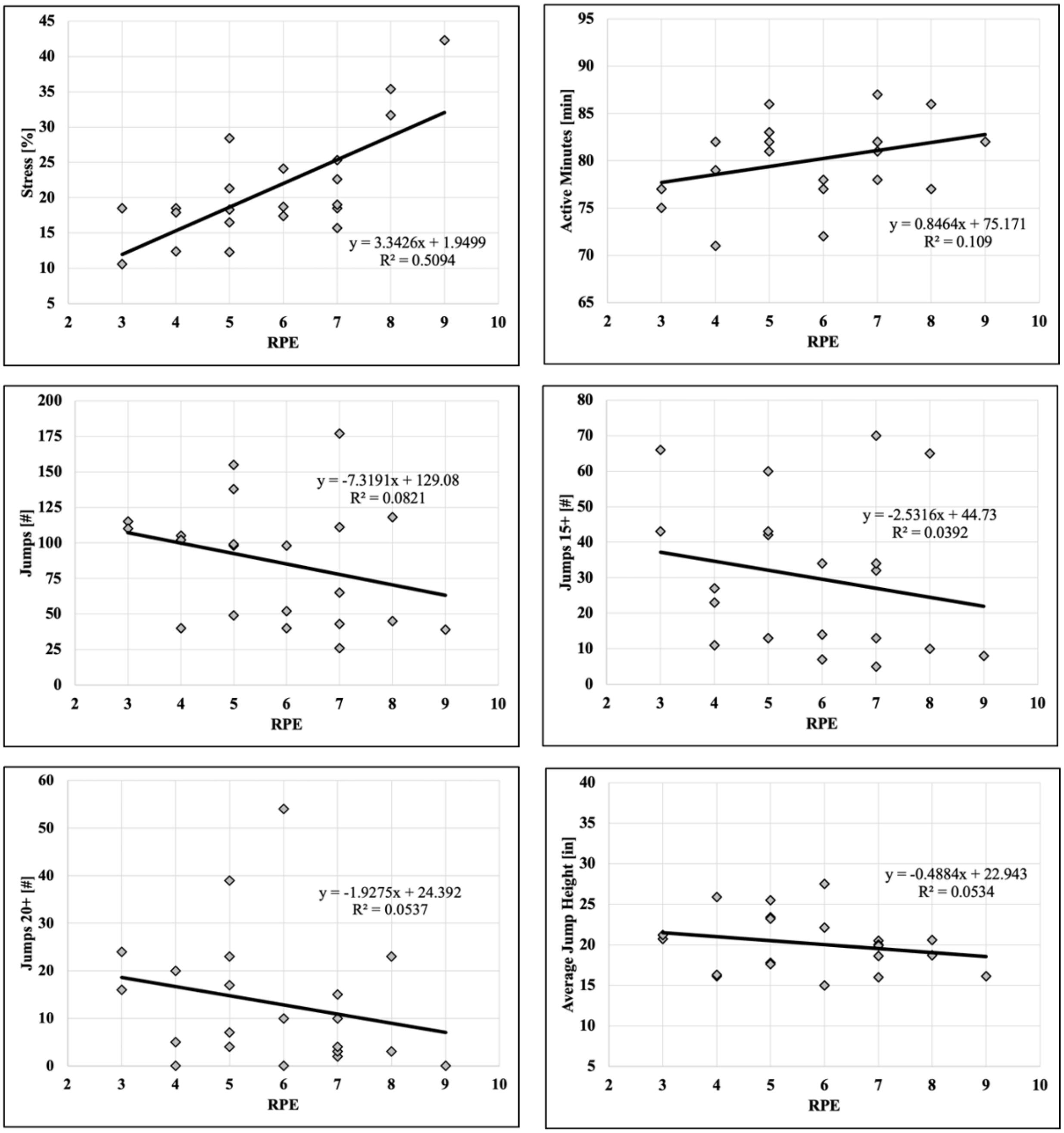

Figure 1. Graphical representation of the relationship between internal and external load metrics.

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DISCUSSION

The purpose of the present study was to determine the relationships between the RPE as a subjective marker of internal load and *Stress*, *Active Minutes, Jumps*, *Jumps 15+*, *Jumps 20+*, and *Average Jump Height* as external load metrics obtained from a wearable IMU device (i.e., Vert™) during a regular practice session in a cohort of professional male basketball players. Our results reveal a strong significant association between the RPE and *Stress*, and weak and non-significant correlations between the RPE and the remaining external load variables (i.e., *Active Minutes, Jumps*, *Jumps 15+*, *Jumps 20+*, *Average Jump Height*).

To the best of our knowledge, this is the first study that used an innovative IMU device (i.e., Vert™) for monitoring external load in elite male basketball players. While commonly being used in volleyball (Cabarkapa et al., 2022), Benson et al. (2020) found that the same device was a reliable and appropriate testing modality for estimating jump load in youth basketball players during both game and practice sessions. However, it should be noted that usage of other IMU technologies (e.g., Catapult™) for monitoring the athletes' workloads has been more prevalent in basketball (Conte et al., 2022; Scanlan et al., 2014; Schelling & Torres, 2016; Svilar et al., 2018a). For example, Svilar et al. (2018a) used a tri-axial accelerometer technology (i.e., Catapult™) and session RPE to quantify both external and internal loads in professional male basketball athletes playing at some of the top levels of competition in Europe (e.g., ACB League, Euroleague). The authors found that external load variables (e.g., player load, acceleration, deceleration, change of direction) were strongly correlated with session RPE ($r = 0.71$-0.93; Svilar et al., 2018a). These findings are in direct agreement with our results indicating that *Stress*, as the algorithm-derived metric used to quantify the percentage of high-impact movements, was strongly associated with RPE ($r = 0.71$). However, in the same study, Svilar et al. (2018a) found a moderate positive correlation between the total number of jumps performed during the practice session and RPE ($r = 0.38$), which is contradictory to the findings of the present investigation. Our results showed a weak non-significant relationship between RPE and all jump-related variables (i.e., *Jumps*, *Jumps 15+*, *Jumps 20+*, *Average Jump Height*). Based on previous research reports showing that a greater number of lateral movements and bouts of intermittent activity can increase RPE by 13-25% (Dellal et al., 2010; Greig et al., 2006; Scanlan et al., 2014; Williford et al., 1998), we can assume that this discrepancy may be largely attributed to the design of the practice session. For example, it is likely that players with a lower number of jumps performed more high-intensity horizontal/lateral movements (e.g., sprints, change of directions) that ultimately resulted in an increase in *Stress* metric as well as the post-practice reported RPE.

Another interesting observation based on the results of the present study pertains to a weak and non-statistically significant relationship between *Active Minutes* and RPE. This may imply that an increase in internal load (i.e., RPE) is more dependent on the type of activity that players perform (i.e., intensity) rather than the overall duration of the practice session. For example, time-consuming practice sessions that last 1-2 hours, where players are practicing 5-on-0 offensive actions will likely induce lower training loads than 30 min sessions where players are working on individual skill development and are required to repetitively perform a high-intensity change of direction and jumping movements. In line with these observations, previous research has shown that RPE values are considerably affected by an increase in training intensity (Aoki et al., 2017; Jeong et al., 2011). Higher RPE has been reported during preseason practice sessions that consisted of more change of direction movements, accelerations, decelerations, and position-specific basketball actions than during the competitive season when the practice workloads decreased (Aoki et al., 2017; Jeong et al., 2011). Therefore, when quantifying the overall training load that basketball players are exposed to, it is important for practitioners to include both internal and external load metrics. This may allow for adequate planning and/or modification of training regimens targeted toward optimizing on-court athlete performance.

While these findings offer additional insight into athlete training load monitoring, it should be noted that this study is not without limitations. The training history, as well as position-specific differences, are not examined in the present study and warrant further investigation. Also, future research should focus on examining if the identical findings remain applicable to other levels of basketball competition as well as if they are gender specific.

CONCLUSION

In conclusion, the findings of the present study reveal the presence of a strong significant relationship between *Stress* as an external load metric and RPE as a subjective measure of internal load during a regular practice session in professional male basketball players. However, weak non-significant relationship was observed between RPE and jump-related metrics (i.e., *Jumps, Jumps 15+, Jumps 20+, and Average Jump Height*) as well as *Active Minutes*, indicating that an increase in internal load is more dependent on the type of activity that players perform rather than the overall duration of the practice session. Overall, these findings may help sports scientists and strength and conditioning practitioners in detecting changes in training load throughout a competitive season in male basketball players and ultimately improve the acute and longitudinal training-adaptation monitoring process.

AUTHOR CONTRIBUTIONS

Conceptualization – D. V .C., and D.C.; Methodology – D. V .C., and D.C.; Formal analysis – D. V .C., D. C., and D. A. E.; Data curation – D. V. C., and D. C.; Writing – original draft preparation – D. V. C., D. C., and D. A. E.; Writing – review and editing – A. C. F., and D. C.

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DISCLOSURE STATEMENT

No potential conflict of interest were reported by the authors.

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