Abstract

Purpose

Global navigation satellite system device-derived metrics are commonly represented by discrete zones with intensity often measured by standardising volume to per-minute of activity duration. This approach is sensitive to imprecision in duration measurement and can lead to highly variable outcomes – transforming data from zones to a gradient may overcome this problem. The purpose of this study was to critically evaluate this approach for measuring team sport activity demands.

Methods

Data were collected from 129 first team and 73 academy matches from a Scottish Premiership football club. Gradients were calculated for velocity, acceleration and deceleration zones, along with per-minute values for several commonly used metrics. Means and 95% confidence intervals were calculated for playing level as well as first team positional groups. Within-subjects coefficients of variation were also calculated for match level, position, and individual groups.

Results

The gradient approach showed consistency with per-minute metrics when measuring playing level and position groups. With coefficients of variation of 10.8% - 26.9%, the gradients demonstrated lower variability than most per-minute variables, which ranged from 10.7% - 84.5%.

Conclusions

Gradients are a potentially useful way of describing intensity in team sports and compare favourably to existing intensity variables in their ability to distinguish between match types and position groups, providing evidence that gradient variables can be used to monitor match and training intensity within team sports.

Key Words: soccer; match; training; monitoring; data

Introduction

Team sports players perform a range of distinct movement demands, such as linear running, decelerations, and changes of direction, each of which may provoke distinct physiological responses in athletes.[1] Player movement tracking using microelectronic devices is common within professional sport as practitioners seek to quantify the external load demands experienced by players in these movements to help optimise performance and recovery.

Global navigation satellite system (GNSS) devices provide many variables that can be used to measure these demands. To provide a more detailed insight into the intensity distribution of activity variables are often divided into "zones" that split the output into a range of intensity bands. However, examining the data in absolute formats (i.e., the total volume) yields little information about the intensity at which volume is accumulated. This can be addressed by standardising the activity duration (i.e., volume per minute).[2] However, using activity subsets for this purpose may lead to large variability in outcome, with match-to-match coefficients of variation of over 30% found for distance covered at >7m/s.[3] This can present a challenge in interpreting the data as "noisier" metrics may make distinguishing genuine insights from more spurious relationships more difficult. In addition, incorporating only the highest intensity slices of activity risks disregarding the impact of lower intensity activity,[4] yet including lower intensity activity using the zone-based approach requires the use of several metrics for each activity type and risks overwhelming practitioners.[5]

Such issues are common in areas where the concept of intensity is relevant (e.g., physical activity) as research has described activity intensity by transforming data from a series of zones into a gradient.[6] This is calculated by finding the gradient of a regression slope calculated on the values of each zone and the midpoints of the thresholds. This approach may be useful in team sports to create measures that avoid the issues discussed above with currently used intensity metrics. The aim of this paper is to critically evaluate the validity of the intensity gradient approach for describing intensity in team sports by comparing a series of gradients to commonly used per-minute variables in football match play.

Methods

Subjects

Using an observational approach, data were collected from 97 male professional football players playing in the first team (n = 49) and academy teams (n = 48) of a Scottish Premiership club.

Methodology

10-Hz GNSS devices (Vector S7, Catapult Sports, Melbourne, Australia) were used to collect external load data from 129 first team and 73 academy matches, with a median of 21 observations per player (range: 1-123). First team players were categorised by position for each match: full-backs (n = 15), centre-backs (n = 13), central-midfielders (n = 29), wide-midfielders (n = 28) and strikers (n = 19). Some players played in different positions across games during the data collection period and consequently appear in more than one group.

Intensity gradients were calculated for each player within each match for velocity distance zones (0.2 - 2m/s; 2 - 4m/s; 4 - 5.5m/s; 5.5 - 7m/s; 7 - 15m/s), acceleration duration zones (2 – 3m/s^2; 3 – 4m/s^2; 4 – 10m/s^2), and deceleration duration zones (-2 – -3m/s^2; -3 – -4m/s^2; -4 – -10m/s^2). Where the first zone was very narrow (<50% of the range of the next smallest zone), leading to very low volumes, this zone was excluded from the calculations as the gradient approach assumes a decrease in volume as intensity increases. For each variable group, the intensity gradient was determined by calculating the natural log of the midpoint of each zone and the natural log of the value of the zone. A least squares linear regression was then conducted using the zone volumes as the y axis and the zone midpoints as the x axis. The resulting slope of this was recorded as the intensity gradient, with a flatter slope indicating a higher intensity. An example of an intensity gradient calculated for velocity distance zones from one player's session is shown in figure 1, returning a value of -1.85.

Per-minute values were calculated for the following external load variables: total distance (TD), high intensity distance

(>5.5m/s) (HID), sprint distance (>7m/s) (SD), high intensity acceleration efforts (>3m/s²) (HI-Acc), and high intensity deceleration efforts (<-3m/s²) (HI-Dec).

Statistical Analysis

All analysis was conducted in a Python environment (v3.8.5). Means and 95% confidence intervals were calculated for each match type and each position. Differences were considered significant where confidence intervals did not overlap. Effect sizes for paired comparisons were also calculated using Cohen's d with pooled standard deviation. In addition, within-subject coefficients of variation for match classification, position group and individual players were calculated using a root mean square approach.

Results

Figure 2 shows the means and 95% confidence intervals for each match type and position for all per-minute and gradients variables. This shows that patterns of activity present in the per-minute variables are also reflected by the gradient variables with Academy matches higher than First Team matches for HID/min and SD/min, as well as for the Velocity Gradient. Positional differences showed full backs and wide-midfielders consistently had the highest values in both per-minute and gradient metrics, with centre backs the lowest. This suggests that the gradient metrics demonstrate a large degree of consistency with similar per-minute metrics when evaluating match intensity.

Coefficients of variation for each category group for each intensity metric are shown in in Table 3, with TD/min demonstrating the lowest variability, and SD/min the highest. The gradient variables consistently demonstrated a variability comparable with TD/min and significantly lower than the other per-minute variables.

Discussion

The aim of this paper was to critically evaluate gradient variables for describing intensity in soccer. Gradients were comparable to the per-minute variables in terms of the ability to detect between-match and between-positional differences. The differences between levels and positions present in the established variables are also present in the gradient variables, indicating that gradients are potentially useful for comparisons across matches and position groups. Since the gradients and per-minute values are composed of the same underlying information, consistency in match and positional differences could be expected possibly calling into question the usefulness of the gradient metrics. However, the gradients can describe the same information with fewer variables, meaning they may be a useful way of reducing the number of variables in a dataset, and reducing the burden on practitioners, without requiring the use of complex techniques such as principal component analysis.

For each gradient variable, the relative variability was higher than TD/min, but significantly lower than the other per-minute variables. This pattern was present across match types, position groups and individual players. Since the underlying information is common across both approaches it is likely that the lower variability is due to the gradients being composed of the whole activity profile, rather than a narrow slice of activity. This is supported by the observation that SD/min had the highest relative variability. This may be due to a skewed distribution as a consequence of SD being the uppermost zone. Zone thresholds are absolute, which may make it more challenging for slower players to achieve greater distances in the highest zone, leading to greater overall variability. In addition, the sensitivity of the per-minute variables to imprecision in duration measurement likely also contributes to the higher variability of these variables. The gradient variables are robust to this as they are determined based on the values of each zone relative to each other. The gradients therefore seem to have the advantage of being able to capture varying movement demands without the disadvantage of excessive statistical noise, further demonstrating the value of the method.

While the gradient method appears to be a useful approach to describing intensity, there are some limitations. For example, despite appearing to share similarities in scale, the different intensity gradients are not equivalent to one another. This is because differences in zone thresholds, due to different underlying metrics, lead to differences in the magnitude of the slopes. The same applies to the per-minute variables, for example TD/min clearly has a very different scale to HI Accels/min. However, this is less clear in the gradient variables as their values resemble one another while being very different to the values typically encountered in GNSS data. For example, the gradients being negative numbers is less intuitive than simple per-minute values and may present challenges when introducing the concept to coaches and players. Transforming the gradient variables to positive numbers, where the higher the value the greater the intensity, may help to alleviate this but it is likely that stakeholder education would be the most effective strategy.

Practical Applications

Gradient variables may be used to reduce practitioner burden by reducing the number of variables when monitoring match and training intensity within team sports.

Conclusions

The results of this study demonstrate that gradients are a potentially useful way of describing intensity in team sports and compare favourably to existing intensity variables in their ability to distinguish between match types and position groups. In addition, each gradient metric showed relatively low variability compared to most per-minute variables. Future research may wish to investigate the utility and potential applications of gradient variables in more detail, such as their relationship to internal load, or how they can be operationalised in the planning and monitoring of training.

Acknowledgements

The authors would like to thank the participating players and the teams' coaching staff for their cooperation and commitments during data collection procedures.

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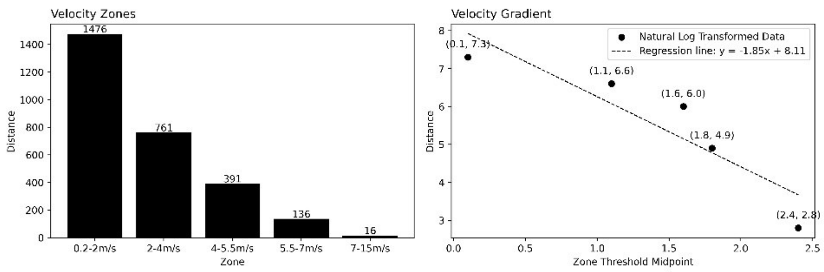
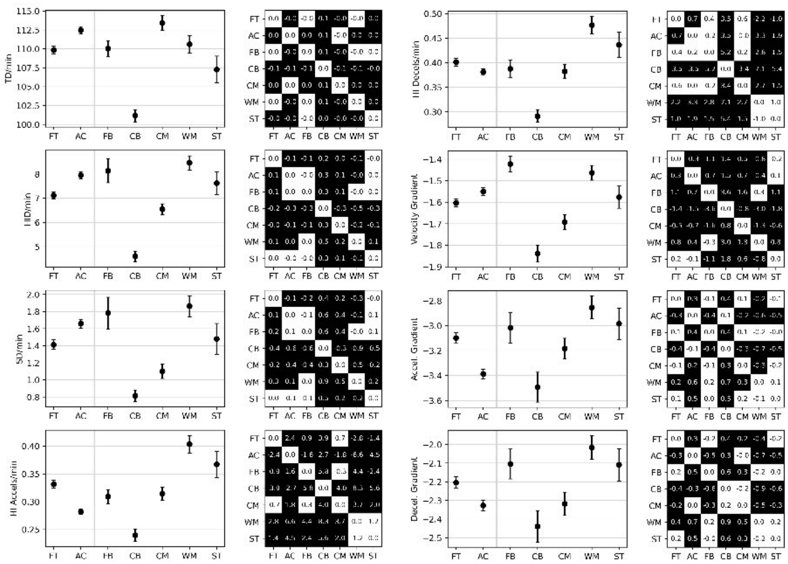
Figures and Tables

Figure 1: Example Intensity Gradient Calculation

Figure 2: Category Means with 95% Confidence Intervals and Significance Matrices with Effect Sizes. Metric abbreviations: Total distance (TD); high intensity distance (>5.5m/s) (HID); sprint distance (>7m/s) (SD); high intensity acceleration efforts (>3m/s²) (HI-Acc); high intensity deceleration efforts (<-3m/s²) (HI-Dec). Playing level abbreviations: First Team (FT); Academy (AC). Position abbreviations: full-backs (FB); centre-backs (CB); central-midfielders (CM); wide-midfielders (WM); forwards (ST). Black squares on the matrices indicate a significant difference between categories. Effect sizes for differences between each category are shown on each square.

Table 1: Within-Subject Coefficients of Variation. Metric abbreviations: Total distance (TD); high intensity distance (>5.5m/s) (HID); sprint distance (>7m/s) (SD); high intensity acceleration efforts (>3m/s²) (HI-Acc); high intensity deceleration efforts (<-3m/s²) (HI-Dec).





Variable	Within-Match Type	Within-Position	Within-Player
TD/min	10.7%	10.8%	14.8%
HID/min	44.1%	41.2%	45.2%
SD/min	82.1%	80.3%	84.5%
HI-Acc/min	47.0%	45.5%	43.6%
HI-Dec/min	44.7%	42.8%	44.2%
Velocity Gradient	26.9%	22.6%	26.6%
Acceleration Gradient	11.2%	11.0%	17.2%
Deceleration Gradient	10.9%	10.8%	17.2%