






Please cite the Published Version

McGregor, R , Anderson, L , Weston, M , Brownlee, T  and Drust, B  (2024) Intensity Gradients: A Novel Method for Interpreting External Loads in Football. International Journal of Sports Physiology and Performance, 19 (8). pp. 829-832. ISSN 1555-0265

DOI: <https://doi.org/10.1123/ijsp.2023-0435>

Publisher: Human Kinetics

Version: Accepted Version

Downloaded from: <https://e-space.mmu.ac.uk/635301/>

Usage rights:  In Copyright

Additional Information: Accepted author manuscript version reprinted, by permission, from International Journal of Sports Physiology and Performance, 2024, 19, (8): 829-832, <https://doi.org/10.1123/ijsp.2023-0435>. © Human Kinetics, Inc.

Enquiries:

If you have questions about this document, contact openresearch@mmu.ac.uk. Please include the URL of the record in e-space. If you believe that your, or a third party's rights have been compromised through this document please see our Take Down policy (available from <https://www.mmu.ac.uk/library/using-the-library/policies-and-guidelines>)

1 **Abstract**

2 Purpose

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

11 Methods

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

20 Results

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

26
27 Conclusions

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

34
35 Key Words: soccer; match; training; monitoring; data

36

37

38

39

40 **Introduction**

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

49 Global navigation satellite system (GNSS) devices provide
50 many variables that can be used to measure these demands. To
51 provide a more detailed insight into the intensity distribution of
52 activity variables are often divided into “zones” that split the
53 output into a range of intensity bands. However, examining the
54 data in absolute formats (i.e., the total volume) yields little
55 information about the intensity at which volume is
56 accumulated. This can be addressed by standardising the
57 activity duration (i.e., volume per minute).² However, using
58 activity subsets for this purpose may lead to large variability in
59 outcome, with match-to-match coefficients of variation of over
60 30% found for distance covered at $>7\text{m/s}$.³ This can present a
61 challenge in interpreting the data as “noisier” metrics may
62 make distinguishing genuine insights from more spurious
63 relationships more difficult. In addition, incorporating only the
64 highest intensity slices of activity risks disregarding the impact
65 of lower intensity activity,⁴ yet including lower intensity
66 activity using the zone-based approach requires the use of
67 several metrics for each activity type and risks overwhelming
68 practitioners.⁵

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

81

82 **Methods**

83 Subjects

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

87

88 Methodology

89 10-Hz GNSS devices (Vector S7, Catapult Sports, Melbourne,
90 Australia) were used to collect external load data from 129 first
91 team and 73 academy matches, with a median of 21
92 observations per player (range: 1-123). First team players were
93 categorised by position for each match: full-backs ($n = 15$),
94 centre-backs ($n = 13$), central-midfielders ($n = 29$), wide-
95 midfielders ($n = 28$) and strikers ($n = 19$). Some players played
96 in different positions across games during the data collection
97 period and consequently appear in more than one group.

98 Intensity gradients were calculated for each player within each
99 match for velocity distance zones (0.2 - 2m/s; 2 - 4m/s; 4 -
100 5.5m/s; 5.5 - 7m/s; 7 - 15m/s), acceleration duration zones (2 -
101 3m/s²; 3 - 4m/s²; 4 - 10m/s²), and deceleration duration zones
102 (-2 - -3m/s²; -3 - -4m/s²; -4 - -10m/s²). Where the first zone
103 was very narrow (<50% of the range of the next smallest zone),
104 leading to very low volumes, this zone was excluded from the
105 calculations as the gradient approach assumes a decrease in
106 volume as intensity increases. For each variable group, the
107 intensity gradient was determined by calculating the natural log
108 of the midpoint of each zone and the natural log of the value of
109 the zone. A least squares linear regression was then conducted
110 using the zone volumes as the y axis and the zone midpoints as
111 the x axis. The resulting slope of this was recorded as the
112 intensity gradient, with a flatter slope indicating a higher
113 intensity. An example of an intensity gradient calculated for
114 velocity distance zones from one player's session is shown in
115 figure 1, returning a value of -1.85.

116

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

119 (>5.5m/s) (HID), sprint distance (>7m/s) (SD), high intensity
120 acceleration efforts (>3m/s²) (HI-Acc), and high intensity
121 deceleration efforts (<-3m/s²) (HI-Dec).

122

123 Statistical Analysis

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

133

134 Results

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

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

153

154 Discussion

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

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

192 While the gradient method appears to be a useful approach to
193 describing intensity, there are some limitations. For example,
194 despite appearing to share similarities in scale, the different
195 intensity gradients are not equivalent to one another. This is
196 because differences in zone thresholds, due to different

197 underlying metrics, lead to differences in the magnitude of the
198 slopes. The same applies to the per-minute variables, for
199 example TD/min clearly has a very different scale to HI
200 Accels/min. However, this is less clear in the gradient variables
201 as their values resemble one another while being very different
202 to the values typically encountered in GNSS data. For example,
203 the gradients being negative numbers is less intuitive than
204 simple per-minute values and may present challenges when
205 introducing the concept to coaches and players. Transforming
206 the gradient variables to positive numbers, where the higher the
207 value the greater the intensity, may help to alleviate this but it
208 is likely that stakeholder education would be the most effective
209 strategy.

210

211 **Practical Applications**

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

215

216 **Conclusions**

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

227

228 **Acknowledgements**

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

232

233

234 **References**

- 235 1. Harper DJ, Kiely J. Damaging nature of decelerations: Do
236 we adequately prepare players? *BMJ Open Sport & Exercise*
237 *Medicine*. 2018;4(1):e000379.
238 doi:<https://doi.org/10.1136/bmjsem-2018-000379>
- 239 2. Houtmeyers KC, Robberechts P, Jaspers A, et al. Differential
240 Ratings of Perceived Exertion: Relationships With External
241 Intensity and Load in Elite Men’s Football. *International*
242 *Journal of Sports Physiology and Performance*.
243 2022;17(9):1415-1424. doi:[https://doi.org/10.1123/ijsp.2021-](https://doi.org/10.1123/ijsp.2021-0550)
244 0550
- 245 3. Gregson W, Drust B, Atkinson G, Salvo V. Match-to-Match
246 Variability of High-Speed Activities in Premier League Soccer.
247 *International Journal of Sports Medicine*. 2010;31(04):237-242.
248 doi:<https://doi.org/10.1055/s-0030-1247546>
- 249 4. Bangsbo J, Iaia FM, Krstrup P. Metabolic Response and
250 Fatigue in Soccer. *International Journal of Sports Physiology*
251 and *Performance*. 2007;2(2):111-127.
252 doi:<https://doi.org/10.1123/ijsp.2.2.111>
- 253 5. Windt J, MacDonald K, Taylor D, Zumbo BD, Sporer BC,
254 Martin DT. “To Tech or Not to Tech?” A Critical Decision-
255 Making Framework for Implementing Technology in Sport.
256 *Journal of Athletic Training*. 2020;55(9):902-910.
257 doi:<https://doi.org/10.4085/1062-6050-0540.19>
- 258 6. Rowlands AV. Moving Forward With Accelerometer-
259 Assessed Physical Activity: Two Strategies to Ensure
260 Meaningful, Interpretable, and Comparable Measures. *Pediatric*
261 *Exercise Science*. 2018;30(4):450-456.
262 doi:<https://doi.org/10.1123/pes.2018-0201>

263

264

265

266

267

268 **Figures and Tables**

269 Figure 1: Example Intensity Gradient Calculation

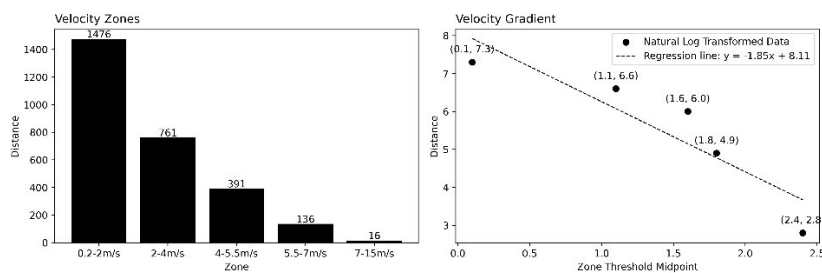
270 Figure 2: Category Means with 95% Confidence Intervals and
271 Significance Matrices with Effect Sizes. Metric abbreviations:
272 Total distance (TD); high intensity distance (>5.5m/s) (HID);
273 sprint distance (>7m/s) (SD); high intensity acceleration efforts
274 (>3m/s²) (HI-Acc); high intensity deceleration efforts (<-3m/s²)
275 (HI-Dec). Playing level abbreviations: First Team (FT);
276 Academy (AC). Position abbreviations: full-backs (FB); centre-
277 backs (CB); central-midfielders (CM); wide-midfielders (WM);
278 forwards (ST). Black squares on the matrices indicate a
279 significant difference between categories. Effect sizes for
280 differences between each category are shown on each square.

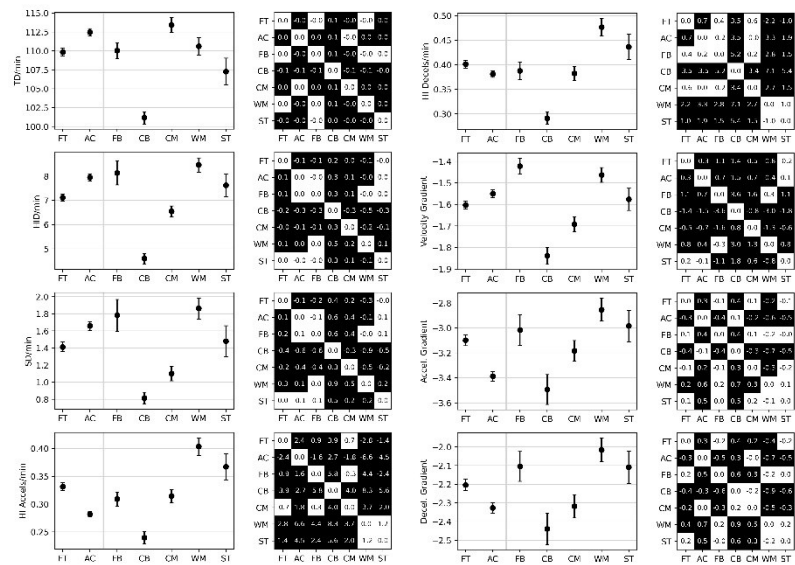
281 Table 1: Within-Subject Coefficients of Variation. Metric
282 abbreviations: Total distance (TD); high intensity distance
283 (>5.5m/s) (HID); sprint distance (>7m/s) (SD); high intensity
284 acceleration efforts (>3m/s²) (HI-Acc); high intensity
285 deceleration efforts (<-3m/s²) (HI-Dec).

286

287

288





289

290

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%

291

292