High-speed running density: a new concept

Peter Tierney [1,2], **Shane Malone** [3], **Eamonn Delahunt** [2,4]

[1]Leinster Rugby, Dublin, Ireland,[2]School of Public Health, Physiotherapy and Sports Science, University College Dublin, Dublin, Ireland,[3]Irish Rugby Football Union, Dublin, Ireland, and [4]Institute for Sport and Health, University College Dublin, Dublin, Ireland

High-speed | Team sport | Density

Headline

Currently, there is no described method of distinguishing between HSR volume (distance covered) and HSR intensity (m.min^{-1}) to provide an enhanced degree of specificity for rehabilitation running or conditioning sessions. As such we propose the concept of HSR density.

Aim. High-speed running (HSR) is an important running metric that can be derived from data recorded by global positioning system (GPS) technology units. Traditionally, HSR has been used in the description and analysis of match-related running demands in team sports; with the transition from low-speed running to HSR set at absolute thresholds (such as $\geq$ 5.5 m.s^{-1}) (1) or as a percentage of a player's recorded maximum running speed.(2) Practitioners commonly use HSR as a key load management metric because of its relationship to injury risk in Australian rules football(3) and soccer.(4) HSR metres per minute (m.min^{-1}) has been reported as a measure of HSR intensity in rugby union(1), work rate in soccer(5) and as a distinguishing factor in the success of attacking 22 entries in rugby union.(6) HSR has further been described as an important criteria in the return to participation (RTP) process following injury(7), although research in this area is limited.

HSR intensity (m.min^{-1}) is typically described as being minimal in early-stage rehabilitation sessions (8) compared to average match demands (Table 1). However, unpublished data from our research group, collected during the return to sport (RTS) process following injuries suggests that this may not necessarily be the case; HSR can exceed 30 m.min^{-1} for an early-stage linear interval-based session (Table 2). This is considerably higher than match-demands, and worst-case scenario demands based on recently published literature in rugby union (9). The specificity of HSR accumulated during these early-stage rehabilitation sessions may be low, yet necessary for testing and developing tissue tolerance post-injury.

The average HSR distance covered per HSR effort for the scrum half position in matches is described in Table 1; it will typically vary between 12 m – 18 m accord all rugby union positions. Compare this to an interval run (for example 75 m linear run in under 15 seconds) during which a player might accumulate up to 50 m per HSR effort. As such, there may be a need to re-think how we quantify match and training demands with respect to HSR intensity.

The aim of this report is to propose and introduce the concept of HSR density (Equation 1). Density, in physics, is defined as mass per unit volume. For the purpose of this investigation, and application to sports science, we define mass as the number of HSR efforts, and volume as the total HSR distance covered. HSR density is a composite metric, it considers both HSR volume and efforts combined, rather than each by itself. We have then multiplied this by 100, which results in *density* as a percentage; an easier figure to discuss and utilise than a small decimal, or ratio.

$$\text{Eq.1: HSR density}(\%) = \frac{\text{number of HSR efforts}}{\text{HSR volume}} * \frac{100}{1}$$

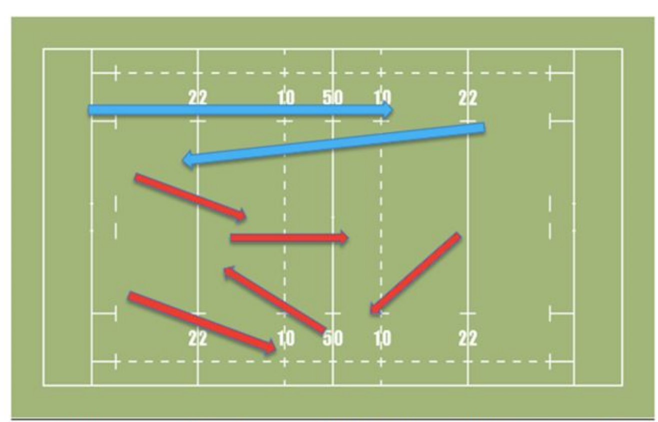
HSR density may aid practitioners in deciphering the 'type' of running accumulated through HSR, and offers greater context for the distances covered in training and competition. This is particularly evident in the return to sport process following injury.

Methods

Athletes. This brief report involved a male professional rugby union scrum half (age = 24 years, body mass = 81 kg, height = 1.75 m) competing during the 2016/17 season. Data were collected as routine conditions of employment (i.e. the club's training and matches), however ethical approval was received from the UCD Human Research Ethics Committee (LS-18-14-Tierney-Del).

Methodology. Data from a male professional rugby union scrum half were collected via GPS technology (10 Hz S5, Catapult Innovations, Scoresby, VIC, Australia), downloaded through the manufacturer software (Catapult Sports Openfield) and exported to Microsoft Excel for further analysis. The S5 GPS unit has a sampling frequency of 10Hz. The GPS unit was worn in a bespoke pocket fitted in the player's training and match jerseys, between the scapulae. The dwell time (minimum effort duration) was set at 0.2 s to detect a HSR effort; this was the manufacturer recommended and default setting. Research has recommended that *"practitioners maintain consistency as much as possible in their data processing"* with respect to setting dwell times. (10) In this case the HSR threshold was set at 5.0 m.s^{-1} (60% of the individual's maximum velocity) (2).

In Table 2 we provide details of different phases of the RTS continuum for this player following a mild hamstring muscle injury.



Athlete	HSR volume (m)	HSR intensity (m.min^{-1})	Number of HSR efforts	HSR density (%)
Athlete 1	80	8.0	2	2.5
Athlete 2	50	5.0	5	10.0

Fig. 1. HSR efforts (arrows) marked out on a pitch with 2 players' movements during a 10-minute block in a rugby union training session.

Table 1. Average HSR match demands for a scrum half in rugby union.

Position	HSR volume (m)	HSR intensity ($m.min^{-1}$)	HSR efforts (count)	HSR density (%)	HSR m per effort (m)
Scrum half	812	8.6	47	5.8	17.3

HSR = high-speed running; m = metres; $m.min^{-1}$ = meters per minute.

Table 2. HSR volume, HSR intensity and HSR density for our scrum half (case) during return to participation and return to sport.

Session Type	HSR volume (m)	HSR intensity ($m.min^{-1}$)	HSR efforts (count)	HSR density (%)
RTP (estimated)	454	30.3	16	3.5
RTP 1	556	21.3	38	6.8
RTP 2	267	15.2	12	4.5
RTP 3 – rugby	637	8.2	32	5.0
RTP 4 – rugby	559	9.2	36	6.4
Captain's run	276	9.2	18	6.5
RTS	671	9.2	47	7.0

HSR = high-speed running; RTP = return to participation; RTS = return to sport. RTP 1 (out and back intervals, agility) and RTP 2 (agility, repeated speed, position-specific acceleration/deceleration drill). RTP 3 and RTP 4 and captain's run were team-based sessions. RTS (match) was 72.6 minutes in duration. There was also 1 run prior to RTP 1 during which the player did not wear a GPS unit; this was a linear-based interval run, in which previous session data looked as follows: HSR volume = 454 m, HSR intensity = 30.3 $m.min^{-1}$, HSR efforts = 16, HSR density = 3.5%.

Statistical Analysis

HSR density was correlated with HSR volume, HSR efforts, HSR intensity and session duration (minutes) (Table 3) from 143 GPS data files (all session types). Pearson correlation analysis was performed in R Studio (Version 1.1.383), with the calculation of R-squared values and 90% confidence intervals. Results of the correlation analysis were interpreted using the scale recommended by Hopkins (11).

Results

A strong relationship exists between HSR density and HSR volume (r = *-0.51*; large). A poor relationship exists between HSR density and HSR efforts (r = *-0.27*; small). A moderate relationship exists between HSR density and HSR intensity (r = *-0.31*; moderate). A poor relationship exists between HSR density and session duration (r = *-0.22*; small). The associated R-squared (R^2) values for HSR density and the other variables are as follows: HSR volume (R^2 = 0.26), HSR efforts (R^2 = 0.07), HSR intensity (R^2 = 0.10), session duration (R^2 = 0.05). The R-squared values illustrate that HSR density likely provides additional information to that provided by HSR volume, HSR efforts and HSR intensity.

Discussion

The aim of this report was to propose and introduce the concept of HSR density. We observed low association between HSR density and other HSR metrics (Table 3). In Table 2 we present HSR volume and HSR intensity for different phases of the RTS continuum for this player following a mild hamstring muscle. If comparing these sessions using HSR intensity, the early RTP sessions (Table 2; RTP estimated, RTP 1 and RTP 2) would be deemed more strenuous than the team-based sessions (Table 2; RTP 3, RTP 4 and captain's run) and RTS (Table 2; RTS). However, this may not be the case as the HSR accumulated from unopposed and unconstrained running sessions is much easier to achieve than the HSR accumulated through team vs. team scenarios. Indeed, the HSR intensity of these running-based rehabilitation sessions (Table 2; 15.2 – 30.3 $m.min^{-1}$) exceeds the HSR intensity of the most demanding passage of rugby union match play (i.e. the worst case scenario; between 4.9 – 14.1 $m.min^{-1}$, depending on position) described by Reardon and colleagues.(9)

When we apply the new concept of HSR density, we establish a different interpretation of the sessions; in general the team-based sessions (Table 2; RTP 3, RTP 4 and captain's run) and RTS (Table 2; RTS) would be regarded as more dense than the majority of early RTP sessions (Table 2; RTP estimated and RTP 2). This is likely the result of the context at which the HSR is achieved. HSR achieved in team-based sessions and matches is influenced by spatial limitations, opposition players, tactics and rules, whereas HSR achieved from longer interval runs is unconstrained by such factors. As such, the use of HSR density may provide new insights into the interpretation of HSR as a GPS derived running metric for team sports. We propose that HSR density may be utilized by practitioners to distinguish between HSR completed in varying RTP or conditioning sessions that would elicit large HSR volumes and HSR intensities, but which are in fact, less dense than the HSR accumulated in team-based sessions and matches. We believe that HSR density may improve the understanding and development of sport specific conditioning and rehabilitation to ensure that team sport players are prepared for the most *'dense'* periods of game-play. HSR density may then help better guide load management decisions, where it would provide further context related to how the HSR volume was accumulated.

When comparing players' *'work-rate'* in training, practitioners typically consider either HSR volume or HSR intensity ($m.min^{-1}$). In Figure 2 and Table 4 we present hypothetical data for a 10-minute block in a rugby union training session to further illustrate our point. This training block compares the HSR accumulated by two players of the same position. Player 1 (blue) has higher HSR volume and HSR intensity ($m.min^{-1}$) and may traditionally be regarded as *"having worked harder"*

Table 3. Correlation between HSR density, HSR volume, HSR intensity and session duration.

	Correlation (r)	R-squared	90% CI
HSR density & HSR volume	-0.51	0.26	(-0.61, -0.40)
HSR density & HSR efforts	-0.27	0.07	(-0.39, -0.14)
HSR density & HSR intensity	-0.31	0.10	(-0.43, -0.18)
HSR density & session duration	-0.22	0.05	(-0.35, -0.09)

HSR = high-speed running; CI = confidence interval.

Table 4. HSR volume, HSR intensity and HSR density of two players during a 10-minute block in a rugby union training session.

	HSR volume (m)	HSR intensity (m.min^{-1})	HSR efforts (count)	HSR density (%)
Player 1	80	8.0	2	2.5
Player 2	50	5.0	5	10

HSR = high-speed running

than player 2 (red). However, player 2 (red) has performed more HSR efforts and has a higher HSR density, which may show *"greater intent and a denser block of work"* when compared to player 1 (blue).

We believe that low density HSR may build a player's tolerance and prepare him/her for more specific, and more dense drills. Hence, we propose that the RTP process following injury should include high volumes of high-speed linear running. Once the player has tolerated this, we propose that in preparation for RTS, that he/she should be exposed to more *dense* conditioning drills that will better prepare him/her for the demands of game-play.

Practical Applications

- The addition of HSR density to a GPS report provides greater context as to how the HSR volume of a session has been accumulated.
- HSR density may provide a scale of progression in a player's conditioning program upon return from injury.
- We suggest that low HSR density performed during RTP sessions will underprepare players for the high density work which characterizes sport-specific training and match play.
- However, we also suggest that low HSR density may be a training mode for enhancing HSR tolerance and improving robustness prior to completing higher density work.

Limitations

- The data described in this case report may be solely representative of the population reported uppon.
- Factors that may influence the data include, the style of team training and match-play, prescription of rehabilitation running and conditioning, as well as the selected HSR threshold.

References

1. Suárez-Arrones LJ, Portillo LJ, González-Ravé JM, Muñoz VT, Sanchez F. Match running performance in Spanish elite male rugby union using global positioning systems. Isokinetics & Exercise Science. 2012; 20: 77-83.

2. Reardon C, Tobin DP, Delahunt E. Application of Individualized Speed Thresholds to Interpret Position Specific Running Demands in Elite Professional Rugby Union: A GPS Study. PLoS One. 2015; 10: e0133410.

3. Duhig S, Shield AJ, Opar D, Gabbett TJ, Ferguson C, Williams M. Effect of high-speed running on hamstring strain injury risk. British Journal of Sports Medicine. 2016; 50: 1536-1540.

4. Bowen L, Gross AS, Gimpel M, Li FX. Accumulated workloads and the acute:chronic workload ratio relate to injury risk in elite youth football players. British Journal of Sports Medicine. 2017; 51: 452-459.

5. Carling C, Espié V, Le Gall F, Bloomfield J, Jullien H. Work-rate of substitutes in elite soccer: a preliminary study. Journal of Science and Medicine in Sport. 2010; 13: 253-255.

6. Tierney P, Tobin DP, Blake C, Delahunt E. Attacking 22 entries in rugby union: running demands and differences between successful and unsuccessful entries. Scandinavian Journal of Medicine and Science in Sports. 2017; 27: 1934-1941.

7. Reid LC, Cowman JR, Green BS, Coughlan GF. Return to play in elite rugby union: application of global positioning system technology in return-to-running programs. Journal of Sport Rehabilitation. 2013; 22: 122-129.

8. Blanch P, Gabbett TJ. Has the athlete trained enough to return to play safely? The acute:chronic workload ratio permits clinicians to quantify a player's risk of subsequent injury. British Journal of Sports Medicine. 2016; 50: 471-475.

9. Reardon C, Tobin DP, Tierney P, Delahunt E. The worst case scenario: Locomotor and collision demands of the longest periods of gameplay in professional rugby union. PLoS One. 2017; 12: e0177072.

10. Varley MC, Jaspers A, Helsen WF, Malone JJ. Methodological Considerations When Quantifying High-Intensity Efforts in Team Sport Using Global Positioning System Technology. International Journal of Sports Physiology and Performance. 2017; 12: 1059-1068.

11. Hopkins WG. Spreadsheets for analysis of validity and reliability. Sportscience. 2015;19. sportsci.org/2015/ValidRely.htm2015:36-42.