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CASE STUDY

Return to Play in Elite Rugby Union: Application of Global Positioning System Technology in Return-to-Running Programs

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Global positioning systems (GPS) are widely used in sport settings to evaluate the physical demands on players in training and competition. The use of these systems in the design and implementation of rehabilitation and return-to-running programs has not yet been elucidated. ***Objective:*** To demonstrate the application of GPS technology in the management of return to play in elite-club Rugby Union. ***Design:*** Case series. ***Setting:*** Professional Rugby Union club team. ***Participants:*** 8 elite Rugby Union players (age 27.86 ± 4.78 y, height 1.85 ± 0.08 m, weight 99.14 ± 9.96 kg). ***Intervention:*** Players wore GPS devices for the entire duration of a club game. ***Main Outcome Measures:*** Variables of locomotion speed and distance were measured. ***Results:*** Differences in physical demands between playing positions were observed for all variables. ***Conclusions:*** An analysis of the position-specific physical demands measured by GPS provides key information regarding the level and volume of loads sustained by a player in a game environment. Using this information, sports-medicine practitioners can develop rehabilitation and return-to-running protocols specific to the player position to optimize safe return to play.

Keywords: GPS, rehabilitation, game demands

Rugby Union is a dynamic contact sport requiring players to perform a variety of open- and closed-skill activities in a game environment with minimal stops in play. A Rugby Union team consists of 15 players (8 forwards, 7 backs) assuming a wide spectrum of physical attributes and anthropometric profiles, which are in part owing to the specialized nature of their roles. Each field position requires specific demands and skills, and in the professional era, players in all positions are required to exhibit high levels of agility, speed, and aerobic endurance, in combination with tactical and technical astuteness. Recently the International Rugby Board has begun implementing new rules to maintain Rugby Union's fundamental values of an open and dynamic running game, thus encouraging a more spectator-friendly sport with fewer set pieces and more frequent scoring opportunities.[1] Coupled with the increase in ball-in-play time,[2] this has resulted in many teams developing a higher volume and intensity of running in the game, therefore placing increased importance on the ability of players to operate at higher work rates with shorter recoveries to complement their tactical and technical ability.

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Time–motion technology is an emerging field in professional Rugby Union in the analysis of locomotion and game tasks. Notational (subjective), digital (objective), and global positioning system (GPS) technology have all been successfully used to describe the common movement patterns and tasks that players perform in the game.[3–7] Most time–motion studies in Rugby Union have used the notational method. The recent introduction of GPS technology to the sport has allowed for the communication of real-time information and the ability to monitor the physical game demands of multiple players in different field positions simultaneously. However, these time–motion studies have not considered or discussed the specific application of these technologies to return to play (RTP) from injuries related to the measured physical demands of the game. Creighton et al[8] recently defined RTP as the "medical clearance of an athlete for full participation in sport without restriction (strength and conditioning, practice and competition)."[(p380)] They propose a 3-step decision model outlining a broad range of components that require consideration before RTP, including the evaluation of health status, evaluation of participation risk, and decision modification. Controlling all the variables associated with this model is beyond the scope of a single sports practitioner, but using a graded progressive approach to player rehabilitation enhances the ability to RTP in a safe and effective manner. In a survey of New Zealand club teams, coaches indicated that the ability to complete position-specific drills, injury-specific tests, sprint tests (acceleration/deceleration), walk/jog/run patterns, and tackling drills were the top 5 fitness-test elements used for RTP assessment.[9] The quantification of loads in the RTP environment is often difficult. A potential application of GPS technology is the ability to objectively quantify the sport-specific stage of the rehabilitation paradigm that would assist in the progression of running activity to mirror physical game demands, as well as in making informed and objective RTP decisions.

Many studies provide a basis for a rehabilitation process based on strength and functional performance measures; however, few if any have provided an objective method of detailing return-to-running programs as part of this procedure. The purpose of this case series was to outline the demands of elite Rugby Union player positions and provide a rationale for the design of return-to-running programs that facilitate the RTP process postinjury employing GPS technology.

Methods

Participants

Eight male professional Rugby Union players (age 27.86 ± 4.78 y, height 1.85 ± 0.08 m, weight 99.14 ± 9.96 kg) who played the entire duration of a single Magners League game participated in this study. The Magners League is a club-level Rugby Union competition comprising 12 clubs from Ireland, Scotland, Wales, and Italy and has being recently replaced by the Rabodirect Pro 12 competition. Each player wore a GPS device (SPI Pro, GPSports Systems, Canberra, ACT, Australia; weight 0.08 kg, dimensions 48 × 20 × 87 mm) for the duration of the game (no player was substituted) and played different field positions:

Forwards: loose head prop, lock, open-side flanker, and scrum-half

Backs: fly-half, inside center, wing, and fullback

All players had previously been familiarized with the device in training. Ethical approval was obtained from the local university human research ethics committee, and players provided informed consent.

Procedures

The function of GPS devices in sport and in Rugby Union has previously been described.[3,4,10] The GPS device in this study was protected using a plastic case and secured between the shoulder blades and upper thoracic spine using a custom-built harness. Higher sampling rates have been advocated in improving the reliability and validity of GPS devices,[10] and therefore data were sampled at a rate of 5 Hz. Real-time information was communicated wirelessly from the GPS device to a pitch-side laptop, where it was stored in raw format on a laptop computer. The GPS device contains a gyroscope and digital compass to track the direction and orientation of the player during the game. From the raw-data files, locomotion data were extracted and then classified into parameters based on previous investigations as standing, nonpurposeful movement, or static-based work (0–0.5 m/s); walking (0.6–1.7 m/s); low-intensity running (1.8–3.6 m/s); medium-intensity running (3.7–5.0 m/s); high-intensity running (5.1–6.7 m/s); and maximal-speed running (≥6.8 m/s).[3,4] Data were subsequently separated into variables including the distance covered, entries into speed zones, and the amount of time and distance in the speed zones for individual player positions. All data were input into Microsoft Excel 4 (Version 7, Microsoft Corp, Redmond, WA), and data were formatted into tables for comparison.

Results

The backs covered a greater total distance than the forwards, with the scrum-half completing the most (7183.7 m) and the loose head prop the least (6206.2 m; Table 1). The winger recorded the highest peak speed (31.1 km/h) of any position and the lock the lowest (21.1 km/h), with the open-side flanker recording the highest peak speed of the 3 forwards (28.4 km/h). The forwards displayed similar total time (Table 2) and distance (Table 3) in the standing and nonpurposeful movements and walking zones. However, the loose head prop and lock spent longer durations and covered more distance in the lower-intensity running zone than the open-side flanker, with this trend reversed in the higher-speed running zones. The backs spent less time and covered less distance walking than the forwards, with the fullback spending the longest time and covering the greatest distance of the backs in this zone. The lock and the scrum-half were the only 2 players not to complete any running in the maximal running zone.

The loose head prop recorded the highest number of entries in both standing and nonpurposeful movement (1040 m) and walking zones (1737 m), with the center (732 m) and fullback (1230 m) the lowest. Conversely,

Table 1 Total Distance, Average Distance, and Peak Speed

	Loose head prop	Lock	Open-side flanker	Scrum-half	Fly-half	Inside center	Wing	Fullback
Total distance (m)	6206.2	6422.6	6480.7	7183.7	6721.9	6650.1	7167.3	6487.7
Average distance (m/min)	67.0	69.4	70.0	77.6	72.6	71.8	78.2	69.9
Peak speed (km/h)	25.1	21.1	28.4	23.0	28.8	27.8	31.1	28.1

Table 2 Time Spent in Speed Zone (min)

Speed zone	Loose head prop	Lock	Open-side flanker	Scrum-half	Fly-half	Inside center	Wing	Fullback
0–0.5 m/s	33.47	33.36	34.20	30.15	23.56	30.21	19.04	21.59
0.6–1.7 m/s	32.17	32.34	32.56	32.12	45.34	36.28	48.38	50.51
1.8–3.6 m/s	21.31	19.40	17.16	20.47	17.32	18.50	18.06	13.50
3.7–5.0 m/s	4.22	6.35	6.07	8.10	3.37	5.12	4.38	4.22
5.1–6.7 m/s	0.56	0.28	2.02	1.35	2.02	1.52	2.02	1.40
≥6.8 m/s	0.05	0	0.17	0.0	0.11	0.05	0.28	0.11

Table 3 Distance Covered in Speed Zone (m)

Speed zone	Loose head prop	Lock	Open-side flanker	Scrum-half	Fly-half	Inside center	Wing	Fullback
0–0.5 m/s	217.0	218.2	194.2	200.9	167.9	152.6	166.3	181.1
0.6–1.7 m/s	1841.4	1828.6	1864.6	2877.8	1712.4	2216.7	2770.0	2897.8
1.8–3.6 m/s	2920.2	2765.4	2356.6	2519	2712.9	2508.7	2495.2	1882.3
3.7–5.0 m/s	954.8	1475.7	1385.5	882.7	1712.4	1174.7	969.2	976.7
5.1–6.7 m/s	260.4	134.7	595.6	645.9	416.3	550.9	607.5	472.2
≥6.8 m/s	12.4	0	84.2	57.4	0	46.5	159.1	77.6

Table 4 Frequency of Entries Into Speed Zones

Speed zone	Loose head prop	Lock	Open-side flanker	Scrum-half	Fly-half	Inside center	Wing	Fullback
0–0.5 m/s	1040	986	994	873	958	732	814	775
0.6–1.7 m/s	1737	1502	1608	1480	1589	1547	1286	1230
1.8–3.6 m/s	908	792	877	875	802	1045	686	648
3.7–5.0 m/s	244	315	342	341	239	306	273	243
5.1–6.7 m/s	50	48	97	80	84	97	78	65
≥6.8 m/s	4	0	7	0	10	12	17	6

the loose head prop (50) and lock (48) had the lowest number of entries into high-intensity zones compared with the overall average of the backs (81; Table 4). Similarities existed between the number of entries in the high-intensity running zone (97) for the inside center and open-side flanker. The winger had the highest number of entries (17) in the maximal speed zone.

Discussion

Rugby Union is a multisprint, multiactivity sport where players alternate between bouts of intense efforts such as sprints, tackles, rucks, and mauls with periods of jogging, walking, and standing.[11] Despite the increased popularity in the use of GPS in Rugby Union in a clinical setting, only 2 studies have previously reported on the use of this technology to measure the physical demands of Rugby Union in 2 player positions.[3,4] The principal finding of the current study is that differences in these demands were observed using GPS technology in 8 player positions in an elite-club Rugby Union game. During the course of a game, players are required to use a range of energy systems combining low-intensity activity with intermittent bouts of various anaerobic high-intensity movements and power-based tasks in offense and defense phases of play. The application of these GPS data in the design of return-to-running programs may facilitate the objective RTP of a player postinjury.

In the sport of Rugby Union, injured players are generally progressed from rehabilitation sessions comprising noncontact running activity to contact activity and then training games before competitive games. To safely

RTP after injury, a player must perform a progressive rugby-specific training program based on his positional demands.[12] Return-to-running programs integrated into these rehabilitation sessions are widely used; however, there is a paucity in the literature of scientific studies validating these programs[13] and it is incorrect to apply general data to an individual player or injury. For example, the physical locomotion demands of the winger in this game would contrast considerably with those of the loose head prop, with differences in variables including total distance (7163.3 vs 6206.2 m) and maximal speed (31.1 vs 25.1 km/h), as well as the time spent, distance covered, and frequency of entry into specific speed zones. Therefore, the frequency, intensity, and duration of running efforts by each player position evidently differ. The use of GPS to measure and profile these game demands for a player or position enables their objective replication in a controlled rehabilitation setting. An example of how this profile can be created is outlined following, using the winger, who has sustained a hamstring injury. Applying the data collected in this study or indeed data collected on a player throughout an entire season, similar profiles may be created for other positions in elite Rugby Union, enabling therapists to design RTP protocols for different types and severities of injury. Throughout this process, the speed, distance, and volume of running can be monitored in real time using GPS without the constraints of timing gates to measure speed, combined with the player's subjective response. This process may also be applied to club-level players using similar time–motion data on this player population.

Sample Return-to-Running Program for a Winger After Hamstring Injury

Wingers are generally explosive and evasive runners who are primarily responsible for finishing attacking moves in try scoring and for covering in defense. A profile of physical locomotion demands for the winger extracted from this match's GPS data is outlined in Tables 1 to 4. He covered a total distance 7167.3 m, with the majority of his time spent (85.48 min) and distance covered (5431.5 m) under 3.6 m/s, interspersed with higher-intensity running. Previous studies have reported that the winger position sustains a high incidence of thigh injuries, namely hematomas and hamstring strains.[7,12] Data from the Rugby Football Union indicate that players sustaining a new or recurring hamstring injury have an average severity of 14 or 25 days lost, respectively.[14] Depending on the number of days lost for this player, a return-to-running program after a hamstring injury will therefore require the use of both aerobic and anaerobic energy systems for similar durations and distances to attain appropriate game-level fitness.

Table 5 outlines a sample return-to-running program based on game demands for a player. The program is divided into 5 phases to reflect the typical duration of a new hamstring injury and the healing process. The speed zones employed in the data analysis are used to progressively manage the intensity of efforts, while distances and duration for each session mirror physical game demands. These variables can be modified as required by the therapist depending the player's own physical capacities, as well as his progress throughout the rehabilitation. An exacerbation of symptoms associated with the injury would result in progression of activities being suspended until clinical tests returned to preaggravation levels. Sessions can be easily conducted on a rugby pitch (typical dimensions 70×100 m)[1] using cones or markers and would typically take place on alternate days interspersed with rehabilitation, weights, additional cardiovascular fitness (eg, bike, cross-trainer), and recovery activity. The program does not describe specific rehabilitation exercises, as they depend on the clinical intuition of the therapist and the player's functional abilities; however, the inclusion of a dynamic warm-up with injury-specific rehabilitation exercises for each phase is advised. Emphasis on correct running posture and technique to enhance movement efficiency is also advocated.

Phases I and II

The primary goals of these phases are to return the player to pain-free movement and subsequently develop his ability to run at medium intensities. Depending on the severity and duration of the injury, the player will require high levels of aerobic endurance training to sustain intensity and workload for the duration of a match. The development of the maximum intake capacity of oxygen (VO_{2max}), which allows for the delivery of oxygen to counteract accumulated oxygen debt, is necessary to improve aerobic capacity. The primary benefit of a high aerobic capacity is that it facilitates faster recovery, therefore reducing the rest interval and enabling the player to work at a higher intensity.[11] Typically the player would start with gentle walking (0.6–1.7 m/s) and progress to light jogging activity (1.8–3.6 m/s). Once the player is pain free, the intensity and volume of running may be increased, with pyramid sessions and submaximal-tempo efforts with fluctuating accelerations and decelerations at speeds of less than 5.0 m/s incorporated to develop aerobic capacity while replicating typical work and rest periods. Weaving runs over broad progressing to narrow curves could be introduced at this stage. Uphill runs can be used to focus on running technique (ie, arm/hip drive, forward trunk lean), while downhill recovery can be used for reeducation of tibial deceleration during knee extension. Initial distances covered would be short owing to the low intensity of the sessions (eg, 2–2500 m), but this can be progressed as appropriate for the player up to a total distance of 5 to 5500 m, similar to the distance observed at below 3.6 m/s in the game. Depending on player position, the time spent and distance covered in each zone can alternate between that zone with the recovery taking place in the zone below.

Table 5 Sample Return-to-Running Program for Winger Position After Hamstring Injury

Phase	Goal of phase	Average distance (m/s)	Sample sessions	Total session distance (m)	Total session duration (min)	Therapist notes
I (days 0–3)	Unrestricted pain-free walking, low-intensity jogging	0.6–1.7	Session type: walk/jog 15 min @ 1.0 m/s 8 × 60 s on/60 s off on: @ 1.5 m/s off: @ 1.0 m/s 5 min @ 1.0 m/s	2500	40	Straight line on flat surface, eg, treadmill.
		1.8–3.6	Session type: pyramid dynamic warm-up + technique drills 10 min @ 2.0 m/s 2 sets × 30, 60, 90, 120, 90, 60, 30 s on, same time as rep off on: @ 3.0–3.5 m/s off: @ 2.0 m/s 5 min @ 2.5 m/s	5000–5500	50	Straight line on flat surface, progress with broad weaving.
II (days 4–6)	Medium-intensity jogging with moderate accelerations and decelerations on flat and hilly surfaces	3.7–5.0	Session type: tempo dynamic warm-up + technique drills 10 min @ 2.0 m/s 8 × 45 s on/30 s off on: 15 s @ 4.0 m/s, 15 s @ 5.0 m/s, 15 s @ 4.0 m/s off: 30 s @ 2.0 m/s 10 min @ 2.0 m/s	4000–4500	40–50	Straight line initially and then progress with broad and narrow weaving.
			Session type: hill runs (3–7% gradient) dynamic warm-up + technique drills 15 min @ 2.0–3.0 m/s 8 × progressively increasing pace within repetition uphill 30 s on/jog back down off on: @ 4.0 m/s increasing to 5.0 m/s off: @ 3.0 m/s 10 min @ 3.0 m/s	4500–5500	50–60	Focus on running technique with arm and leg drive on uphill and deceleration on downhill.

<table>
<tr><td>III (days 7–9)</td><td>Return to high-intensity running and agility with fast accelerations and decelerations</td><td>5.1–6.7</td><td>Session type: speed intervals and agility
dynamic warm-up + technique drills
10 min @ 2.0–3.0 m/s
5 min @ 3.0–4.0 m/s
sled drills, eg, 2–4 sets (run 10 m pushing sled with 25% body weight, turn 180° and run 10 m) or 2–4 sets (run/on all fours 20 m pulling sled with 25% body weight)
reps as per below table
<table>
<tr><th>Reps</th><th>Accelerate</th><th>Sustain</th><th>Decelerate</th></tr>
<tr><td>4</td><td>20 m to 5 m/s</td><td>20 m @ 5 m/s</td><td>20 m</td></tr>
<tr><td>4</td><td>30 m to 6 m/s</td><td>20 m @ 6 m/s + cut left to right</td><td>5 m</td></tr>
<tr><td>4</td><td>30 m to 5 m/s + cut left to right</td><td>20 m @ 5 m/s</td><td>10 m</td></tr>
<tr><td colspan="4">60–90 s off @ 1.0 m/s between reps</td></tr>
</table></td><td>3500–4700</td><td>60–70</td><td>Introduce cutting movements with acceleration and sustained running. Alternate decelerations to mimic game scenarios. Integrate wrestling and grappling activity on 10-min sections.</td></tr>
<tr><td>IV (days 10–12)</td><td>Partial team training: return to sprinting and controlled sport-specific skills, small-sided games</td><td>5.1–6.7</td><td>Session type: mixed-pace intervals and game-based tasks
dynamic warm-up + technique drills
10 min @ 2.0–3.0 m/s
5 min @ 3.0–4.0 m/s
reps as per below table
<table>
<tr><th>Reps</th><th>Accelerate</th><th>Decelerate</th><th>Accelerate</th><th>Decelerate</th></tr>
<tr><td>4</td><td>30 m to 5 m/s + cut left to right</td><td>10 m + receive pass</td><td>30 m to 5 m/s + give pass</td><td>20 m</td></tr>
<tr><td>4</td><td>30 m to 5.5 m/s + receive pass</td><td>10 m + cut left to right</td><td>20 m to 6 m/s + kick ball</td><td>20 m</td></tr>
<tr><td>2</td><td>20 m to 5 m/s</td><td>5 m + hit tackle bag</td><td>10 m to 5 m/s</td><td>Run backward for 10 m + hit tackle bag</td></tr>
<tr><td colspan="5">60–90 s off @ 1.0 m/s between reps</td></tr>
</table></td><td>3500–4700</td><td>60–70</td><td>Add light plyometrics into warm-up. Introduce game-specific conditioning, eg, power and tackle bag and passing drills incorporated into occasional off period to simulate game-type activity under fatigue.</td></tr>
<tr><td>V (days 13–17)</td><td>Full team training: return to GBT, controlled and uncontrolled sport-specific skills and contact</td><td>GBT</td><td>Team training activity under supervision</td><td>4000–4500</td><td>Team training</td><td>Integrate player into team training, control volume in first 1–2 sessions.</td></tr>
</table>

Abbreviations: GBT indicates game-based training.

Phases III and IV

The primary goals of these phases are to progress to running at higher intensities and volumes and to incorporate game-based tasks specific to the player. As player function and fitness improve after injury, the progressive return to higher-intensity activity including sprinting or contact work is strongly advocated. Volume at medium intensities is maintained to further improve aerobic capacity coupled with high-intensity intervals (5.1–6.7 m/s) including accelerations, sustained efforts, and decelerations. Owing to these high-intensity efforts, the total distance completed in some sessions will be lower than in earlier phases to allow focus on these higher-intensity efforts with adequate recovery (eg, 3–4500 m). Heidersheit et al[15] recommend incorporating sport-related movements specific to the athlete with intensity and speed near maximum before RTP for players with hamstring injuries. Linear speed or agility tests using timing gates or timed point-to-point runs do not accurately replicate movement patterns that occur in a game environment. A major advantage of GPS is the ability to quantify speed and distance in multiple directions and tasks that are game specific. This is particularly pertinent in relation to the anaerobic system as it is used in short, high-intensity bursts commonly surrounding the ball. The winger in this game completed more high-intensity sprints ≥6.8 m/s than any other position, with an average distance of 9.3 m/sprint. Therefore, an emphasis should be placed on the number of sprint activities at this intensity undertaken by the player as part of his rehabilitation from this injury. Multiple intervals replicating the speed and distance with typical game-recovery periods can be used with game-specific skills such as cutting, passing, and kicking incorporated into these intervals. These tasks could also be achieved as part of a tip/touch rugby session with teammates or onside/offside games. While GPS data are beneficial for measuring locomotion, they currently do not quantify the work a player undertakes during numerous static-based tasks, for example, tackling, rucking, mauling. In a recent investigation, Gabbett et al[16] concluded that small-sided games with intermittent wrestling provide collision-sport athletes a game-specific physiological and skill-training stimulus. The inclusion of tackling drills, wrestling, or grappling-type tasks simulates the demanding contact nature of the game and can also be undertaken in these phases as part of a controlled rehabilitation. The player may also use sled and tire drills in this phase to replicate the pushing and pulling activities required during a game.

Phase V

Players who have been injured and return to competitive play prematurely face a heightened risk of damage and injury.[9] Indeed, Brooks et al[12] have reported that over 50% of recurring hamstring injuries occur within 1 month after the initial injury. Therefore, the final phase of RTP is imperative to ensure that the player is fully integrated into full team training and ready for game activity. Completing game-based tasks in a fatigued state by incorporating varying intensities of running and tactical team moves or plays, as well as controlled and uncontrolled activities, will replicate game-specific sprinting and simulate game demands and is likely to result in a safe and effective RTP. GPS can be used to monitor specific sessions in real time and therefore provide immediate feedback on player speed and stresses to ensure that he is receiving an appropriate physiological stimulus. For example, the winger recorded a peak speed of 31.1 km/h in the game. As part of his RTP criteria, the player should potentially achieve a percentage of this velocity, providing the coaching and medical staff, and indeed the player, with objective information on his ability to load structures safely while undertaking game-based tasks.

Conclusions

The requirements for playing Rugby Union include endurance, speed, agility, power, flexibility, and sport-specific skill.[6] The GPS data presented in this case series are typical of a report generated from a game and may be also applied in other sporting codes for the rehabilitation of players using this technology. The small sample size and the number of games analyzed generalize these study findings. Data were collected from a single game, and there may be variability in the measures presented if more games were included. Further studies in this novel area with a greater number of players, injuries, and games are now required. However, this case series outlines the use of GPS in measuring the physical demands of elite Rugby Union and its potential in enhancing player rehabilitation through the progressive loading of players on a return to functional activity as part of a return-to-running program. The ability of GPS data to provide activity profiles for unit positions and position categorizations offers multiple clinical applications to elite Rugby Union teams. For players to safely RTP from injury, it is crucial that they demonstrate adequate levels of these physical capacities to perform at optimal levels to minimize the risk of reinjury. Using GPS to assist in the analysis of game demands, as well as the design and implementation of player- and position-specific return-to-running programs, may facilitate the RTP for elite Rugby Union players after injury.

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