

Polar Team Pro System

Polar Research and Technology

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1. Introduction

The world of team sports is evolving continuously thanks to the development of equipment technology, as well as scouting and coaching principles. For example, considering soccer, where data from a wide variety of performance tracking sources is widely available, the game at the highest level has evolved towards increased ball and player speed.

These changes have occurred concurrently with increases in, for example, stoppage time, which allows players more time to recover over the course of a game. In general, the aforementioned development means that team sports are now filled with more high intensity action than ever before. [1–3]

As the game evolves, training principles have to evolve also, which has led to the adoption of different kinds of player monitoring technology to support training in team sports. Training monitoring solutions first appeared for individual athletes. Along the road these methods were soon considered useful among coaches and quickly adopted by team sports as well.

The purpose of Polar Team Pro is to help team sport athletes and coaches optimize their training and overall performance while preventing injuries and fatigue.

When compared to the camera-based movement tracking systems that are typically installed in stadiums, Team Pro offers the same data but adds synchronized physiological information. Other advantages of Team Pro over camera-based systems are portability and ease of use. The whole system can be carried in a shoulder bag to any training or game facility. Once at location, the system works instantly and independently, allowing coaches to focus on the players and the session itself.

2. Polar Team Pro System

Polar Team Pro player tracking system consists of three parts: 1) a set of wearable sensor modules, one for each player, 2) a recharging dock and 3) cloud-based player performance analytics software available on iPad for real-time monitoring and as a connected web service for post-session analysis. (Note: iPad on Figure 1 sold separately).

The operating principle of Polar Team Pro system is very simple. During each training session or game, players wear their dedicated wearable sensor modules that measure physiological data as well as information about the player's movement on the field.



Figure 1. Polar Team Pro wearable sensors and a dock connected to an iPad for synchronization to the web service.

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PLAYERS	TRAINING LOAD	HR AVG [%]	DISTANCE	CALORIES	SPRINTS	SPEED AVG	HR ZONES	SPEED ZONES	[KM]
D 5	██████	♥ 80	↕ 8.48	🔥 944	🏃 28	🏃 4.5			
D 11	██████	♥ 77	↕ 8.50	🔥 889	🏃 41	🏃 4.5			
D 12	██████	♥ 76	↕ 8.37	🔥 855	🏃 26	🏃 4.5			
M 21	██████	♥ 76	↕ 8.41	🔥 870	🏃 32	🏃 4.4			
M 22	██████	♥ 81	↕ 7.68	🔥 974	🏃 25	🏃 4.1			
M 23	██████	♥ 77	↕ 8.18	🔥 885	🏃 22	🏃 4.3			
M 24	██████	♥ 79	↕ 7.59	🔥 927	🏃 22	🏃 4.1			
M 25	██████	♥ 75	↕ 8.70	🔥 848	🏃 13	🏃 4.6			
M 30	██████	♥ 81	↕ 7.82	🔥 981	🏃 17	🏃 4.1			
F 33	██████	♥ 82	↕ 6.96	🔥 1011	🏃 32	🏃 3.7			
F 43	██████	♥ 69	↕ 6.06	🔥 720	🏃 16	🏃 3.3			
F 48	██████	♥ 87	↕ 7.81	🔥 1106	🏃 35	🏃 4.2			

Figure 2. Single training session view in Team Pro. HR and speed zones are displayed by color codes (see text for explanation).

After the monitoring session is over, all wearable sensors are attached to the dock for data synchronization to the iPad. From the iPad the data is transferred wirelessly to the Polar Team Pro web service via iPad's built-in Wi-Fi or cellular connection.

The Polar Team Pro system provides extensive data to coaches in following main categories: heart rate, location map, distance, velocity, and acceleration.

The accompanying wearable sensors are equipped with Bluetooth technology that enables continuous data transfer with a range of up to 200 meters. This enables live monitoring of each player during the training session on the coach's iPad. The wearable sensor module also comes with internal memory capable of storing 65 hours of training data, which ensures that no data will be lost due to bad connections.

Advanced training analysis and reports are available in the Polar Team Pro web service. While coaches can analyze each player

separately or run reports over the whole team, each individual player can also access their data provided that they have a Polar Flow web service account. Coaches can also compare session data to earlier training sessions to get information about the effectiveness of the training as well as identify symptoms of injuries or overtraining.

3. Technology

The wearable module of Polar Team Pro includes a heart rate and GPS sensor as well as inertial-based movement measurement. In the following sections a description is given of how these basic measurements are processed to provide detailed information about the athlete's performance on the field.

3.1. Heart rate

Polar Team Pro supports presentation of heart rate in absolute terms, as beats per minute [bpm], and in relative terms, as percentage of the individual maximum heart rate [HR%].

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By default the maximum heart rate is calculated as $HR_{max} = 220 - \text{age}$, but it is recommended to take the maximum heart rate value from a high intensity training, game or test (e.g. intermittent yo-yo test) to reflect the true maximum HR of an individual player more accurately.

Polar Team Pro uses a five-step default categorization of HR% to divide the intensity into respective HR zones. Zone 1 is the easiest in terms of load whilst the Zone 5 is the hardest one. As default the limits for each zone are: Zone 1 = 50...60%, Zone 2 = 60...70%, Zone 3 = 70...80%, Zone 4 = 80...90%, Zone 5 = 90...100%. These limits can be adjusted by the user if needed.

The benefit of using HR Zones instead of absolute HR values is that they are comparable between athletes. Training with the intensity at Zone 3 is evenly strenuous for each athlete no matter how high or low their maximum heart rate is. Team Pro uses color coding in the graphical views to represent each HR Zone: 5 Red, 4 Yellow, 3 Green, 2 Blue, and 1 Gray. This makes it easy for the coach to see how much time each player has spent in each intensity level (Fig. 2).

Polar heart rate measurement technology has been validated in several scientific studies over the years and it provides R-R interval data in +-1 millisecond resolution. In heart rate measurement this means +- 0.4 % accuracy in bpm over the measurement range. As a result, Polar HR monitors are able to capture series of RR intervals for analysis of HR variability indexes as reliable as those obtained by ECG [4].

3.2. Movement

Player movement tracking is an integral part of any team sport training system providing information about player's location on the field and quantitative measures of player's horizontal acceleration, speed and distance travelled.

In the Polar Team Pro system player location during a training session or a game is visualized as a heat map that integrates the coordinates of players over the whole session on a map representing the playing field. The "hot" areas (reddish color) show the location where the player has spent most of his or her time.

Polar Team Pro sensor uses several adaptive data source and filtering algorithms for player acceleration, speed and distance calculation. The sensor selects the source automatically based on the available data and the quality of that information. Outdoors, where the GPS sensor can acquire satellite signals, GPS is the primary method for tracking. Polar Team Pro uses 10 Hz GPS due to its validated accuracy in measuring instantaneous velocities [5]. Indoors the GPS data is not available and all movement data is calculated from the information provided by the Inertial Measurement Unit (IMU) consisting of acceleration, gyroscope and magnetometer sensors. The implementation of the algorithms rely rather heavily on 9D Polar Electro proprietary sensor-fusion technologies.

The heat map is not available indoors as inertial sensors cannot provide exact coordinate information.

Federal Aviation Association has estimated that GPS location accuracy is less than 2.168 m in 95% of the cases [6]. The actual accuracy that user attains depends on environmental conditions, availability of satellites and building infrastructure (open field vs. blocked by buildings). Real-world GPS distance accuracy in team sports varies between 2–11% (Fig. 3) and instantaneous speed is likely to be slightly less accurate than distance (Table 1).

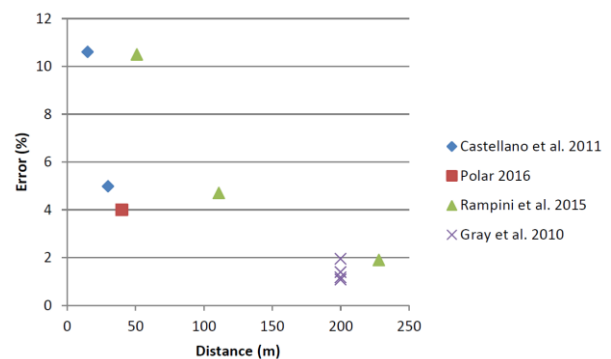


Figure 3. Comparison of GPS distance accuracy over different locomotive path lengths. Data from Polar and [7–9].

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Table 1. Results of the preliminary internal validation of Polar Team Pro GPS accuracy. SEE = standard error of the estimate.

Measure	Mean of the reference	SEE
Distance	40 m	4%
Max. speed	6.4 m/s	10%

Mean number of satellites in the internal validation of Polar Team Pro GPS accuracy was 9.8 (Table 1). Thus external conditions were not optimal, but rather something that the user can realistically expect in real world. The maximum speed was measured in the middle of a 40 m linear running track with optic gates set 2 m apart.

3.3. Physiological information

Besides heart rate and movement information, Polar Team Pro offers more refined information about the training session in order to make it easier for coaches to evaluate the effect of the training and plan the next training sessions.

Estimation of **calorie consumption** is simply a measure of the energy used during the training session or game. Proper refueling is, of course, essential to recover from energy consuming training and some professional teams may have their own nutritionist for whom this information is of great interest.

Training load is a Polar specific feature to quantify training intensity by combining several information sources such as heart rate, calorie consumption, mechanical impact and duration of the exercise, into an easily understandable format. Training load is presented as an estimate of the time needed to recover from the training and can range from mild exercise needing only 1 hour recovery to extreme requiring at least 48 hour recovery.

Training load is further enhanced with **Recovery Status** that takes into account also the strain of everyday life outside of team training and estimates in real-time how recovered the athlete is at any given time after the training. This feature is only available to athletes that use Polar devices also outside of team training. (Recovery status is available provided that player has compatible personal Polar watch and a Polar Flow account.)

Training guidance based on Recovery Status has been examined in competitive cyclists, triathletes and runners [10,11] as well as in professional soccer players [10].

4. Team Pro Validity

The validity and reliability of Polar Team Pro System has been studied for the assessment of distance and velocity by Giersch et al. (24) and Huggings et al (unpublished). The results of these studies showed good validity for total distance measured during jogging and running. During high speed sprints Team Pro slightly underestimated total distance.

5. Coaching the team

The basic offering of Polar Team Pro was described in the previous sections: heart rates and training intensity of each player, as well as the movements both as figures and visual heat maps. Surveys from Europe, the United States and Australia show that this type of monitoring during all training sessions is already becoming the norm [12] within team sports.

The next logical step is the move from individual athletic monitoring to coaching the entire team and turning that into a winning combination of both. This is where Polar Team Pro system can be of benefit.

5.1 Focusing on the content

As a consequence of increased player congestion in the middle of the field, attacking play in soccer has moved towards the wings, where players may find it easier to create numerical advantage opportunities. This has resulted in different kinds of playing tactics and strain when comparing midfielders and wingers: while central defenders and midfielders pass the ball more, wingers do more intense sprints [13,14].

Polar Team Pro system helps coaches to see the intensity of any training session on a team level as

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well as individual information of all players listed on the same view.

As opposed to running more on average, modern soccer teams demonstrate a higher frequency of skilled playing actions such as successful passes [15–17]. While there might be a tradeoff between intensity and decision-making, a great coach may want to follow the intensity of the training session too. By setting clear objectives, and following them with Polar Team Pro, the coach can guide the team through the content of the training, be that intense pressing or intelligent passing practice.

In summary, the detailed information of team training systems has increased the coaches' ability to evaluate whether the preferred actions are transferred from training to the game.

5.2. Injury prevention

Preventing injuries in professional sports is indispensable as injury rates correlate negatively with team success [18]. Current mean injury rate in elite soccer is 27 injuries per 1000 h of play leading to 12% unavailability of players at any given moment and around 50 injuries per team over the season [19]. Thus it has been suggested that for injury prevention factors, such as training load, playing style and continuity of medical and technical staff should be considered and further investigated [19]. Polar Team Pro system provides information that can help coaches to make educated decision when to increase or decrease training intensity in order to protect a player from an injury.

Traditionally athletes have used screening and preventive actions outside sport-specific training in order to avoid injuries. Such methods include muscle balance testing and eccentric muscle training. The downside of these methods is that they bring additional resource costs and there is scientific evidence that they lack effectiveness [20,21]. Thus coaches and sport scientists have become increasingly interested in quantifying athletes' training load upon the actual sport-specific training regime, and using this information for injury prevention.

Research has shown that both high and low acute training loads can predispose athletes to injury. However, it seems to be the acute:chronic ratio, defined as the training load from the past week divided by the training load from the last four weeks, that is the strongest advisor. So far the best estimate that scientists can agree with is that athletes should maintain acute:chronic training load within the range 0.8–1.3 to gain positive training adaptation and still stay free of injuries [22].

Polar Team Pro offers all the tools required to monitor athletes' training load both internally (heart rate) and externally (acceleration, speed, distance) during the actual sport-specific training regime. Also, since the player is not isolated from the team, as happens with most traditional recovery methods, training with Team Pro may offer a psychological edge for those who are willing to use it.

5.3. Training specificity

Total distance during a training session or a game is easy to measure but may not be of great importance in team sports. This is due to the fact that it probably does not separate successful players or teams from each other [15–17].

More relevant than total distance would be the distance covered above certain velocity thresholds. As an example, English Premier League football players who were non-starters accumulated on average 37%, 46% and 73% less distance at high intensity, very high intensity, and sprint velocities, respectively over the course of the season as compared to the players who belonged to the starting line-up [23]. The difference was only noticeable above the thresholds, and not in the total distance. Moreover, the difference was specifically due to the games as similar difference was not observed during training.

Polar Team Pro separates velocities to five user adjustable categories, which helps the coach to simulate the velocity requirements of a game already in the training.

Related to the speed is the change of speed, i.e., acceleration (increasing speed) and deceleration

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(decreasing speed). Polar Team Pro system provides the number of accelerations with following thresholds: less than -3 m/s^2 , $-3-(-2) \text{ m/s}^2$, $-2-(-1) \text{ m/s}^2$, $-1-(-0.5) \text{ m/s}^2$, $+0.5-(+1.0) \text{ m/s}^2$, $+1-(+2) \text{ m/s}^2$, $+2-(+3) \text{ m/s}^2$, greater than $+3 \text{ m/s}^2$. Negative sign means decrease in velocity and positive sign means increase in velocity.

High accelerations and decelerations of a player may be beneficial to the outcome of the game but their drawback is that they are very strenuous to energy metabolism and may cause short term damage to muscles. With information from Polar Team Pro the coach will be well-informed and can react accordingly.

6. Summary

Polar Team Pro is an easy-to-use system that provides the team coach and the team members a versatile and extensive set of information about both training sessions and games. The information ranges from the physiological data of an individual player to information on the movement and playing tactics of the whole team. In the hands of a wise coach Team Pro can help in injury prevention as well as in targeting training specifically to improving game performance.

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