Validation of Prozone ®: A new video-based performance analysis system

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Abstract

Prozone® is a new computerised video system that allows the tracking of many individuals performing a sporting activity. The aim of this study was to validate the Prozone® measurement system when measuring displacement velocities on a football pitch.Six male, recreationally active, subjects participated in the study. The subjects performed a series of runs in a straight line and different directions. The following runs were performed and tracked with the Prozone® system: 60m runs, 50m curved runs (30m straight, 20m angled) at different speeds (7 km/h, 11 km/h, 14 km/h, 19 km/h, and 23 km/h), one maximal sprint of 15m and a 20m sprint with a 90 degree turn (10m straight, 10 m left or right) in different zones of the Old Trafford and Reebook Stadiums.

The subjects performed the 60m and 50m curved runs at a pre-determined pace with an audio velocity control. For the short distances, the subjects were asked to run as fast as possible. For all runs, timing gates data were compared to tracking data measured with Prozone ®.

The average velocity recorded by the Prozone ® system during the paced runs of 60m and 50m showed an excellent correlation (r = 0.999; Total error 0.05, Limits of agreement 0.12) with the average velocity measured by timing gates. Similar correlation (r = 0.970; Total error 0.23, Limits of agreement 0.85) was recorded during the maximal 15m sprint and during the maximal 20m sprint with right or left turns (r = 0.960; Total error 0.05, Limits of agreement 0.12). The results of this study show that Prozone® represents a valid motion analysis system for analysing movement patterns of footballers on a football pitch.

Keywords: Prozone, reliability, video, analysis systems

1. Introduction

Team games players perform complex movements and intermittent type of activities dictated by technical and tactical situations arising during the game (Appleby & Dawson, 2002; Dawson et al., 2004; Duthie et al., 2005; Rosch et al., 2000). Due to the unpredictability of team games performance, many attempts have been made to quantify the workload of team games players in both indoor (Alexander & Boreskie, 1989; Pers et al., 2002; Alexander et al., 1989) and outdoor sports (Bangsbo et al., 1991). Video analysis has been the most popular choice. However, many observational tools so far employed have relied mostly on the skills of the observers and required long period of time to obtain and analyse the data.

Global positioning systems are nowadays being introduced in sport to analyse movement patterns and workloads in team sports (Schutz et al., 2000; Witte et al., 2004). However, the problem is that they remain quite bulky and require the athlete to carry them during the course of the performance analysed. This limits their use because when official games are played, regulations do not allow players to wear anything other than the standard clothing needed in each specific sport. Due to the restraints on the equipment that can be carried by the players, video analysis still represents the most viable alternative since it allows the measurement of movement patterns on the field of all participants in the game, referees included (Castagna et al., 2004; D'Ottavio et al., 2001; Krustrup et al., 2002). Recently, PROZONE® has introduced a novel computerised tracking system able to analyse movement patterns in many sports and has focused most of its activity on quantifying not only motion characteristics but also work rate ratios of professional football players during actual games. This technique provides the advantage of being applicable in official competitions and could help in the analysis of elite performance in football. Most of the literature so far published on football performance has presented data coming from low level games, unofficial games and/or simulated games (for a review see (Stolen et al., 2005) and was also limited to small sample sizes. The possibility of using a computerised tracking system could provide sports scientists with a new tool to analyse what actually happens in elite performers with minimal time required to obtain the necessary data.

Motion measurement is a concept used in biomechanics to describe the compilation and analysis of any kind of 2D and 3D movement. These data are obtained from video cameras and are processed in order to quantify the kinematics movement patterns. To date no study has been conducted to validate the movement patterns measurements obtained with Prozone®.

We therefore designed this study to validate the Prozone® measurement system against timing gates measurements.

2. Methods

Subjects

Six male recreationally active subjects aged between 18 and 34 (average age: 27yrs, height: 177cm, Weight: 79.5Kg), voluntarily participated in the study. They were informed about the course of the experiment according to institutional guidelines.

Procedure

The subjects were asked to perform a series of runs at different speeds in different parts of the Old Trafford and Reebok Stadiums.

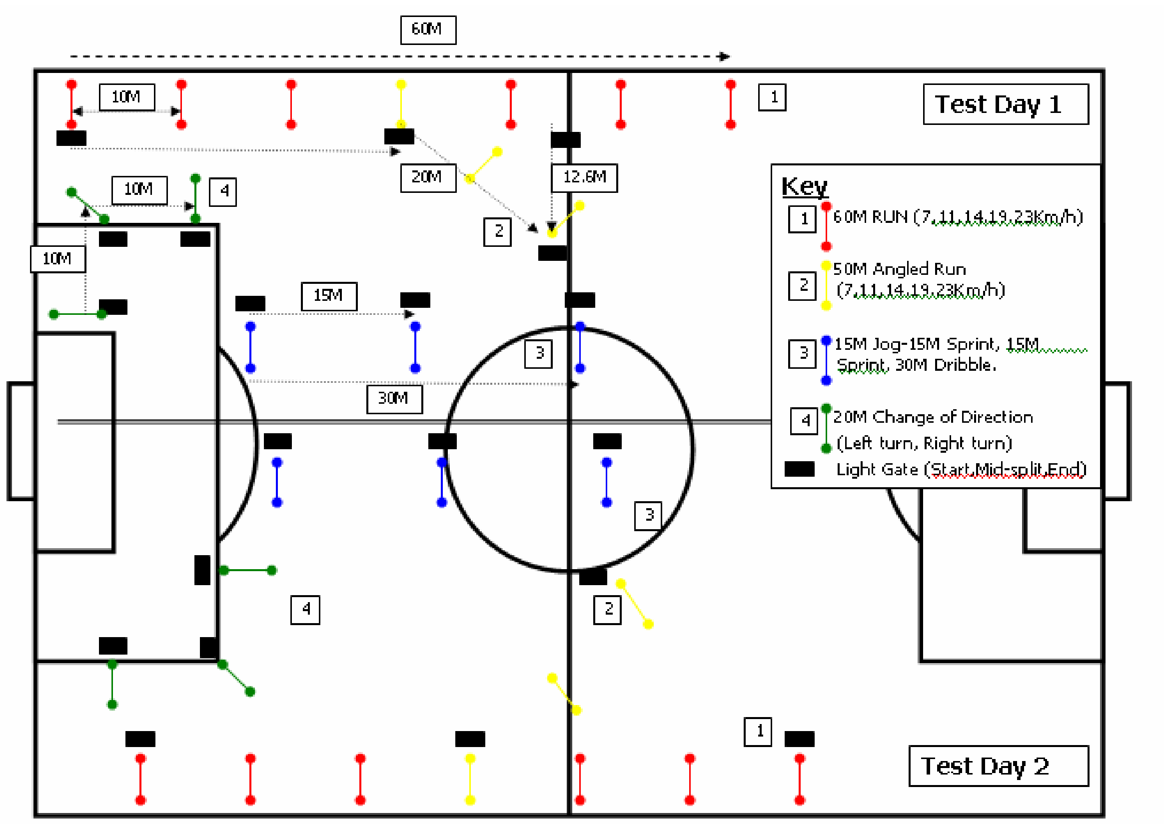

Figure1. Schematic Diagram of Test runs performed

An audio velocity control device (Ergo Tester, by Globus) was used to provide audio feedback while running and to provide a steady pace for the subjects during the run.
The subjects performed the following runs at a pre-determined pace:
1) 60m runs in a straight line, 2) 50m curved runs (30m straight, 20m angled). Both runs were performed at each of the following target velocities; 7 km/h, 11 km/h, 14 km/h, 19 km/h, and 23 km/h. These velocities were chosen since they represent the speed classification thresholds used by Prozone® to analyse movement patterns of footballers. Previous studies have subdivided football players' motion with similar velocities representing slow jog, jog, run, high speed run and sprinting actions (i.e. Bangsbo et al., 1991).

The subjects were also asked to perform: 1) one maximal sprint over a 15m course and 2) a 20m sprint with a 90 degree turn (10 m straight, 10 m left or right) to assess acceleration and deceleration actions.

A schematic diagram of the runs and the location on the pitch is presented in Figure 1. Timing-gates (Newtest 300 Series Power Timer) were placed at the beginning and the end of the distance covered and were used to measure time and speed for each run. For all runs, timing gates data were compared to tracking data measured with Prozone ®. Three subjects completed the paced runs, all the subjects completed the 20m runs with left and right turn and five subjects completed the 15m runs.

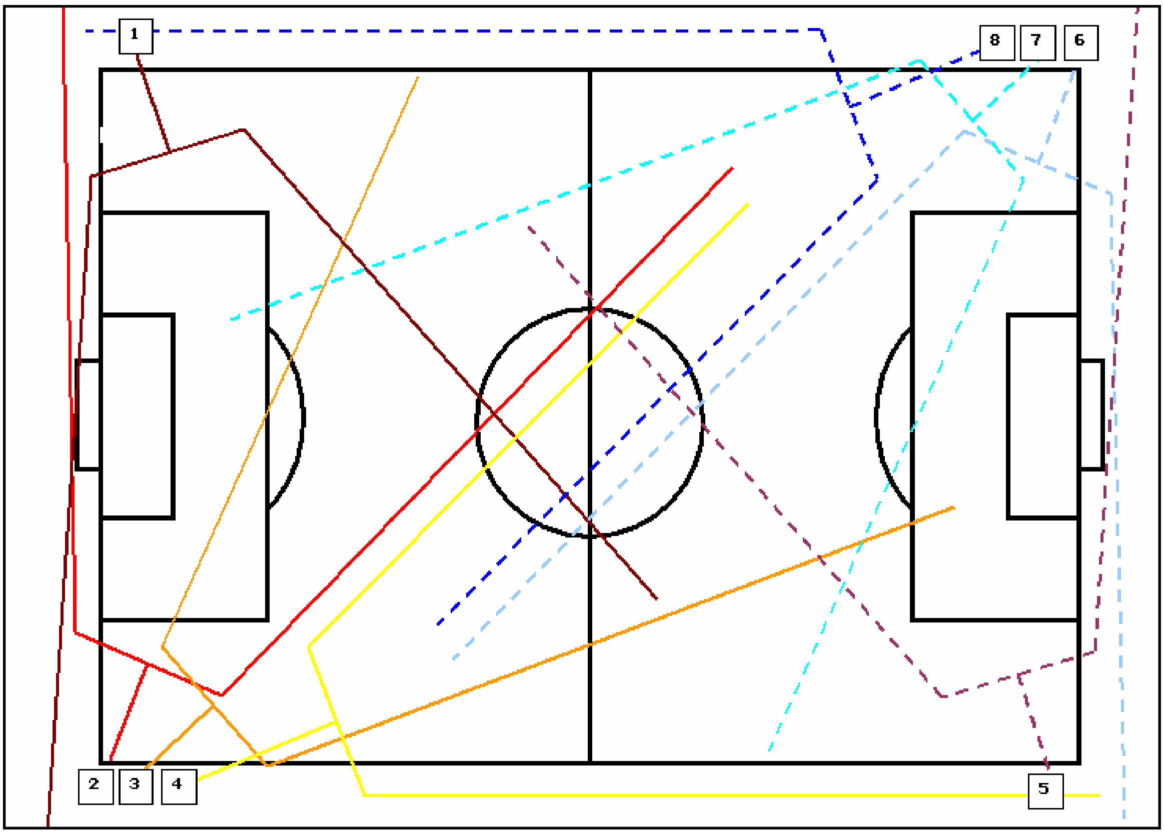

Figure 2. Camera Placement at Old Trafford's and Reebook Stadiums

Camera tracking method

The video capture was performed at Manchester United's Old Trafford football stadium and at the Reebook Stadium (Bolton), where 8 colour cameras are installed (Prozone®). The camera's parameters: (position, orientation, zoom and field of vision) were determined and fixed when installed (Vicon surveyor 23xcameras dome/SVFT-W23). The 8 cameras were positioned in order to produce a whole vision of the pitch. Furthermore every area of the pitch is covered by at least 2 cameras for accuracy, occlusion, resolution and resilience (see Figure 2).

All cameras are cabled back to a central point and connected within a video distribution box. The distribution box splits each video 3 ways: 1) to the primary capture equipment, 2) to the backup capture equipment and 3) to a telemetry unit. An outside broadcast (OB) feed is also cabled to this point, but this does not form part of the production of the players' co-ordinates and therefore does not affect data.

The primary capture equipment consists of a high specification server running Microsoft Windows Server 2000 (Microsoft®) and ProZone's proprietary capture software, PZ Stadium Manager®. Within the server there are 9 industrial specification frame grabbers connected to the distribution box. PZ Stadium Manager ® acquires the videos from the frame grabbers and converts them to AVI-MJPEGs with minimal compression to preserve image quality. All primary capture videos are in perfect synchronisation due to the server's internal time base being used for all 9 video sources (see Figure 3). Backup capture equipment consists of Super VHS VCR's, chosen due to tolerance of signal interruption (e.g. brief power loss in the stadium).

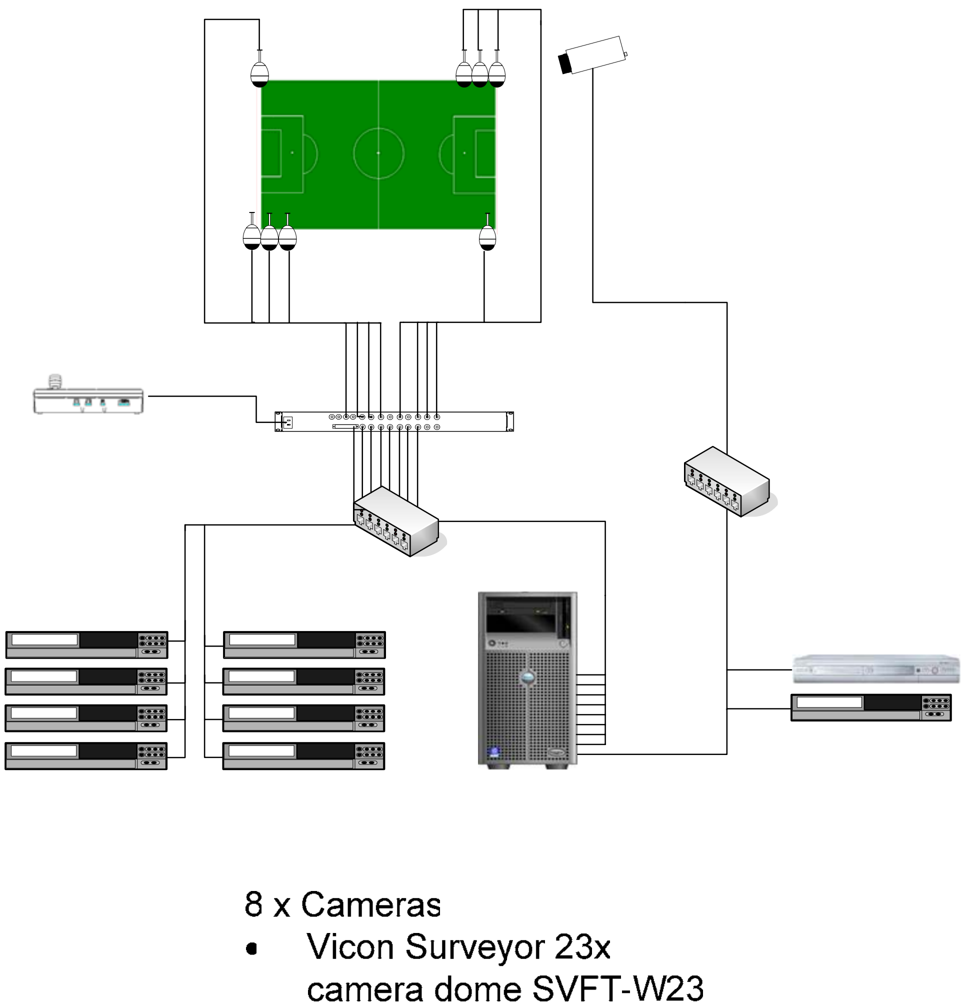

Figure 3. Schematic Diagram of Prozone® analysis system.

Capture was started and stopped manually by an onsite stadium operator recorded on removable media and then transferred to ProZone's production centre.

On receipt of video files from a stadium, the shift operator transfers the media onto dedicated file servers. The server recognises the new media and instigates the automatic tracking of the videos. Each video is tracked independently determining image co-ordinates and continuous trajectories for each player.

Once the automatic tracking has completed, the output from all 8 cameras is automatically combined to produce a single dataset. To achieve this, the combination process requires knowledge of the vision's field of view and logic around normal player behaviour, i.e. objects must qualify as being of human size with Kalman filters used to predict possible direction given current object speed (Kalman, 1960). At this point, erroneous objects (i.e. debris on the field) are filtered out of the dataset.

The video's image co-ordinates are converted into world pitch co-ordinates via a calibration process (computer vision homography). Initially, ProZone ® uses a linear 4-point transformation calibration to map the vision to the pitch co-ordinates and then refine this calibration with a proprietary 50 point algorithm that eliminates vision distortion with respect to optical errors (curvature of the lens) and non-2D playing surfaces (camber of the pitch), all these processes are described and suggested as appropriate by Hartley & Zisserman (2002). This procedure was performed during installation of the Prozone® system.

The final stage is the quality control process. Quality Control operators identify each player (by start position, position during game and correspondence with the OB feed) and verify that the trajectories identified for each player remain constant to that actual player. During periods throughout the game, the trajectory is re-identified on the computer tracking system, checking the movement of each player during the game.

To produce the results for the tests in correspondence with the field based method, the data was extracted from the central corporate database as opposed to the PZ3 application. PZ3's minimum unit for reporting time is 0.5 seconds whereas from the central corporate database any unit of time can be reported. The database contains the world pitch co-ordinates per player every 0.1 seconds. A request for data of a higher resolution than 0.1 seconds (as per the light gates - 0.001 seconds) forces the database to perform a linear interpolation of the data of the time before and after. Prozone does not store points below 0.1s, therefore to extract information below this resolution we perform the following linear interpolation:

```
SET @dt = @t2 - @t1
    SET @dx = @x2 - @x1
    SET @dy = @y2 - @y1

    SET @multiplier = (@t - @t1) / @dt

    SET @x = @x1 + ( @dx * @multiplier )
    SET @y = @y1 + ( @dy * @multiplier )
```

@x1, @y1, @t1 and @x2, @y2, @t2 are the Cartesian co-ordinates of the two points which 'surround' the requested (and therefore interpolated) @x, @y for @t1.

The start of each test was determined by visually locating the subject accelerating on any one of the visions which the subject was visible on. The split duration of the test was then calculated by a visual determination of when the subject passed through the light gates. The subjectivity of determining when the player passed the light-gate, given that between time periods the player could be before then after the gate, was a limitation of the testing procedure.

By passing the start time and required duration into a procedure (summation of Pythagoras theorem for every point of a 0.1 second internal) within the database it was possible to calculate the distance travelled for the test. The data were collected in a spreadsheet for analysis.

Statistical Analyses
Absolute and relative reliability was assessed as suggested by Atkinson and Nevill (1989) and Hopkins (2000). The Pearson product moment correlation coefficient was used to determine the relationship between the motion data obtained with photocells and the video analyses. The difference between the velocity measured by video analysis and actual velocity (as measured by the timing gates) were determined from the Bland and Altman plot. Statistical analyses were performed with Prism 4.0. Measures of Absolute reliability values (Typical Error, Total Error, Limits of Agreement, Intraclass Correlation Coefficient and Coefficient of Variation) were calculated using the spreadsheet developed by Hopkins (2000b) with a 95% level for confidence limit.

3. Results

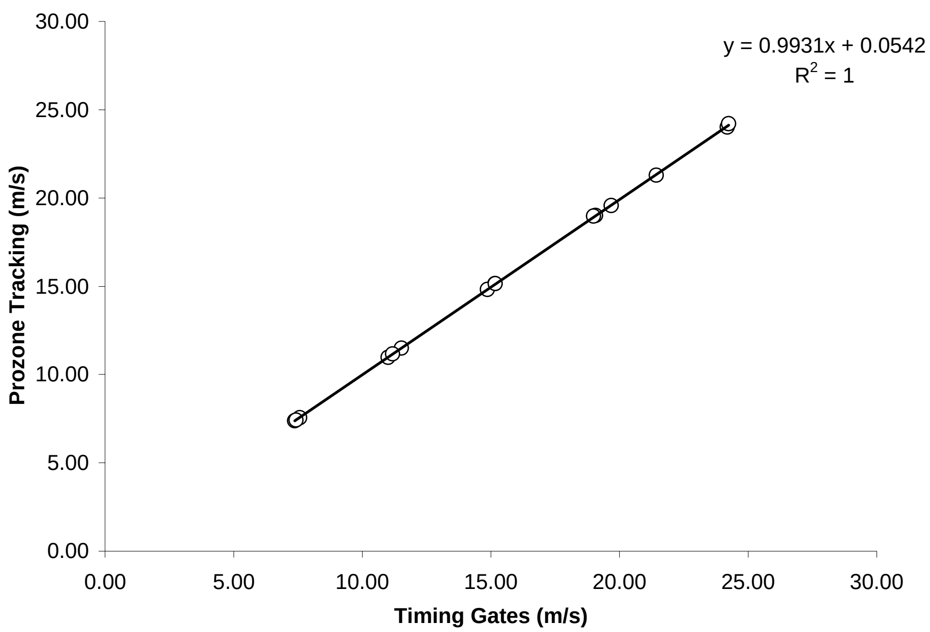

Figure 4. Relationship between the actual velocity of the subject measured by timing gates vs that calculated by Prozone® camera system during the 60m running test. (n=3, 5 different velocities measured).

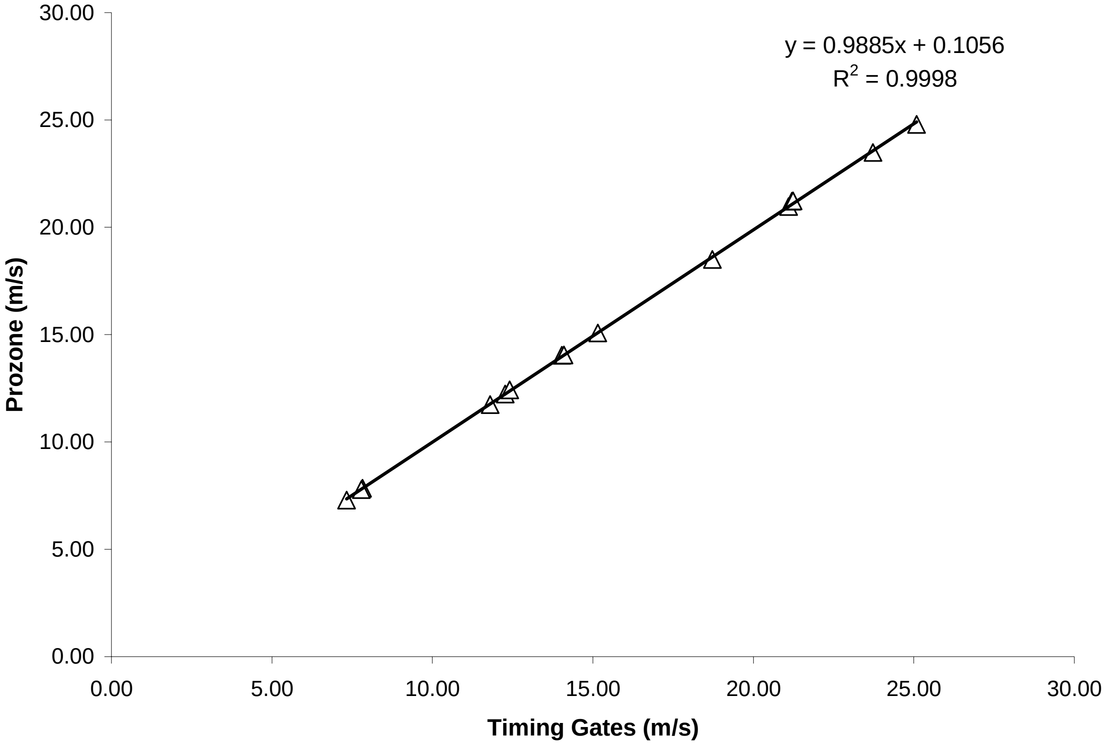

Figure 5. Relationship between the actual velocity of the subject measured by timing gates vs that calculated by Prozone® camera system during the 50m curved running test. (n=3, 5 different velocities measured).

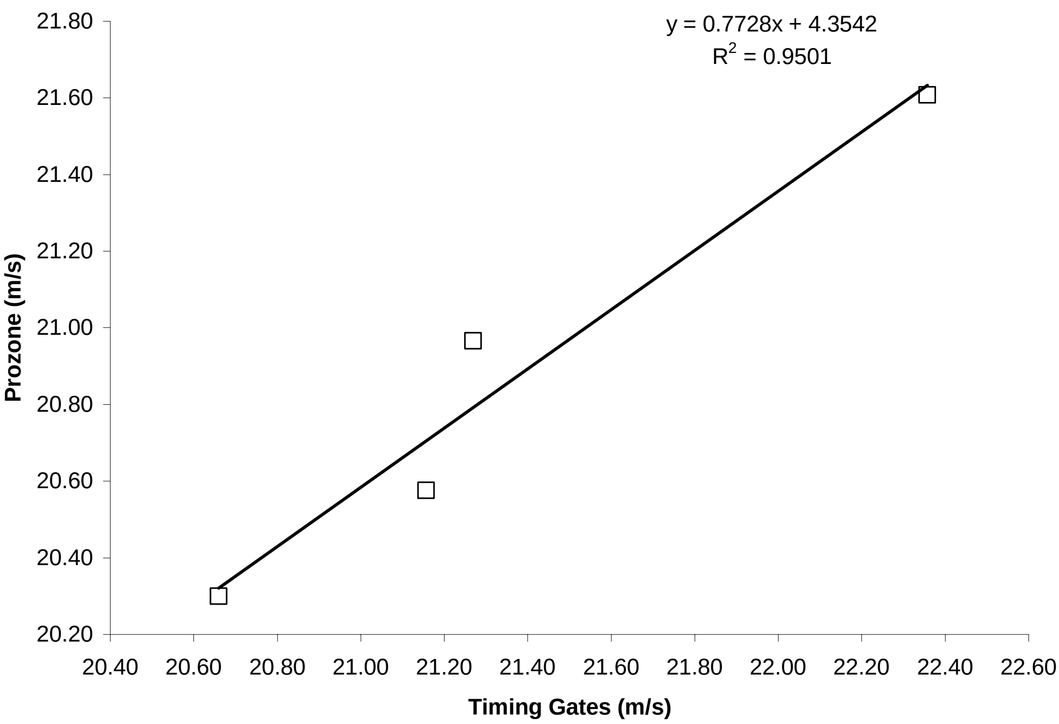

Figure 6. Relationship between the actual velocity of the subject measured by timing gates vs that calculated by Prozone® camera system during the 15m sprint test. (n=4).

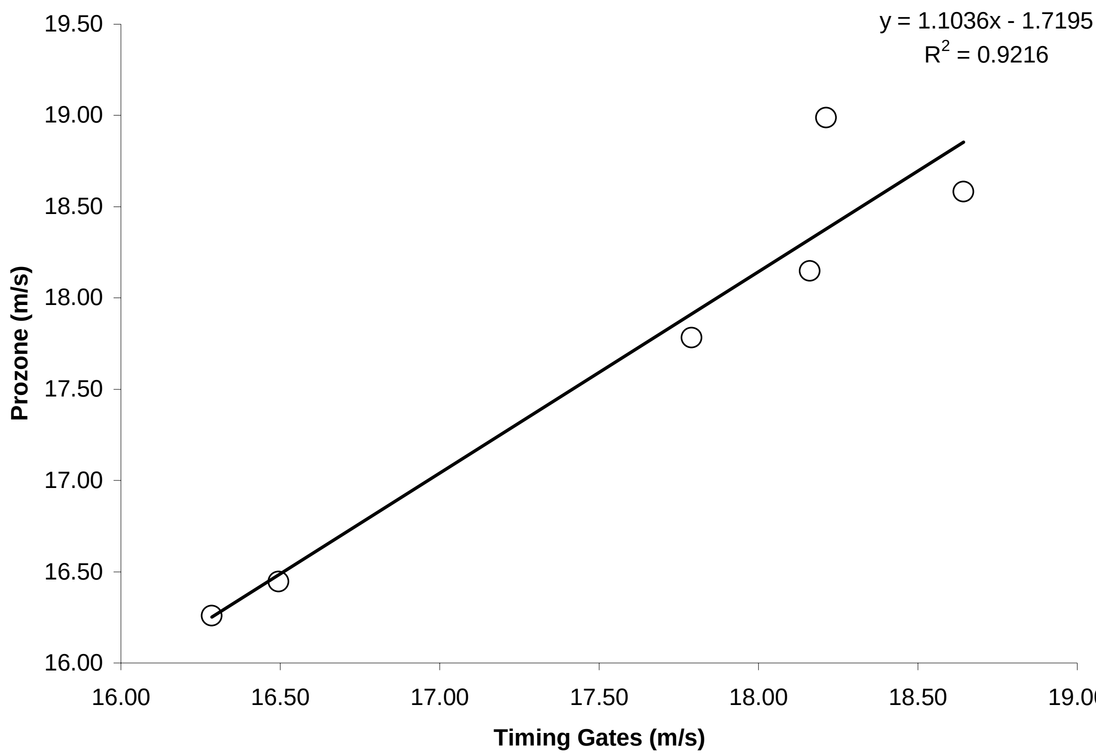

Figure 7. Relationship between the actual velocity of the subject measured by timing gates vs that calculated by Prozone® camera system during the 20m sprint and turn test. (n=6).

Table 1. Statistical measures of Absolute reliability of the parameters analysed. All data are calculated using the spreadsheet developed by Hopkins (2000b).

Test	Typical Error (Upper and Lower Confidence Limits)	Total Error (Limits of Agreement)	Intraclass Correlation Coefficient	Typical Error as CV (%)
60m running	0.04 (0.06-0.03)	0.05 (0.12)	0.999	0.2
50m curving	0.07 (0.11-0.05)	0.09 (0.22)	0.999	0.3
15m sprint	0.01 (0.04-0.01)	0.02 (0.05)	0.999	0.2
20m sprint and turn	0.23 (0.58-0.15)	0.23 (0.85)	0.950	1.3

The velocities of displacement ranged from 7.5 km/h to 25 km/h. All the data showed an almost perfect correlation with the timing gates measurement system. The mean velocity recorded by the Prozone ® system during the paced runs of 60 m showed an excellent correlation (r = 0.999) with the average velocity measured by timing gates (See Figure 4). The average velocity recorded by the Prozone ® system during the curved runs over a 50 m distance showed an excellent correlation (r = 0.999) with the average velocity measured by timing gates (See Figure 5). The average velocity recorded by the Prozone ® system during the maximal 15m sprint showed an excellent correlation (r = 0.999) with the average velocity measured by timing gates (See Figure 6). The average velocity recorded by the Prozone ® system during the maximal 20m sprint with right or left turns showed an excellent correlation (r = 0.959) with the average velocity measured by timing gates (See Figure 7). All data showed high levels of absolute and relative reliability (See Table 1).

3. Discussion

The present study has clearly demonstrated that Prozone ® allows accurate estimation of velocity on the pitch of athletes performing different types of runs at different speeds. The high correlation coefficients and the absolute reliability coefficients showed when comparing the average velocities measured with timing gates and Prozone® suggest that the human error in tracking a player’s motion is extremely limited and the multicamera approach allows perfect tracking and valid velocity of displacement data. The Bland-Altman analysis revealed an average discrepancy between the two methods of 0.127.

What is the advantage of Prozone®? Since the system allows tracking in real time of all the players on a football pitch, it is clear that this system allows the analysis of movement patterns in football during official matches with no disruption to the playing pattern. Previous camera-based systems allowed tracking of only one individual on the pitch (Castagna et al., 2004) and the cameras had to be handled by operators to follow the individual analysed during the course of the activity measured. Also, lengthy analyses were necessary due to the necessity of tracking one player at the time (Pers et al., 2002).

The advantage of this novel technology is the possibility of tracking each single individual participating in a football game (players and referees) and the ability to quantify their motion patterns. The major disadvantage, however, resides in the high costs and the necessity of installing multiple cameras and a computerised network with a dedicated operator to run the data collection and analysis.

Recently, to overcome the costs of multiple camera systems, GPS systems have been suggested as a viable alternative (Witte et al., 2004). However, it should be kept in mind that during official matches players are not allowed to wear equipment different from what is needed to play hence making impossible the use of GPS systems to measure performance during competitive games of elite players. Moreover, most of the research studies on Football movement patterns have been conducted while analysing non elite games and/or by using analysis systems strongly biased by inter and intra observer variability.

4. Conclusion

The results of this study show that Prozone® represents a valid motion analysis system for analysing movement patterns of footballers on a football pitch. Furthermore, since the Prozone ® system does not require special equipment (i.e. transmitters) or clothing (i.e. colour coded shirts) to be worn during the actual performance, it could be used to perform measurements during official matches of elite teams. For this reason, more studies are needed in order to analyse the workload of elite players in different sports using outdoor, large surface pitches (such as Football, Rugby and Hockey) while competing in official elite level games. Those studies will be helpful in defining a performance model for such sports and provide guidelines for proper training prescriptions.

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