Original Article

Physical profile of young tennis players in the tennis match-play using global positioning systems

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Abstract

Purpose: to describe the physical profile in matches played by young tennis players using GPS technology. **Methods:** Seventeen female and twelve male young high-level tennis players (age 14.0 ±2.1 years) took part in the study. Portable GPS (10 Hz) devices (MinimaxXv.4.0, Catapult Innovations) were used to assess physical variables in the Aragon Tennis Master. Dependent variables were: maximum and average speed, total distance covered per minute and at speed zones, acceleration distance covered. Independent variables were: ranking and gender of players. **Results:** The majority of the distance were covered by players was accelerating (89.7%). High ranked players covered more distance per minute than low ranked ones (HiR=46.7 ±8.9 vs. LR=44.5 ±7.3 m; F(1, 94)= 12.96; p <0.001; η^2p =0.121) and developed a significant greater maximum speed (HiR=4.3 ±0.6 vs. LR=3.9 ±0.4 m·s⁻¹; F(1, 94)= 10.99; p <0.001; η^2p =0.104). Male players covered more distance per minute than female players at all speed zones. **Conclusions:** The GPS technology allows us to know the physical demands of tennis. Therefore, coaches must use this data to propose specific training, similar to the demands of match play.

Key words: racquet sports, GPS, physical demands, motion-analysis, performance, accelerations.

Introduction

The recent development of Position System (GPS) devices has permitted the wider application of this technology in a variety of sports, providing an additional means of describing and understanding the physical demands on players (Baiget, 2011). Player tracking describes the physical profile of the demands of each sport and it allows us to assess competition performance (Carling, Bloomfield, Nelsen, and Reilly, 2008).

In the last few years, scientists have used portable GPS units to investigate the physical demands in training and match-play in different sports (Cummins, Orr, O'Connor, and West, 2013). Accordingly to that, GPS technology has been used in soccer (Buchheit, Méndez-Villanueva, Simpson, and Bourdon, 2010; Harley et al., 2010; Njororai, 2012), Australian football (Brewer, Dawson, Heasman, Stewart, and Cormack, 2010) and cricket (Petersen, Pyne, Dawson, Portus, and Kellett, 2010). Player tracking describes the physical profile of each sport and it assesses competition performance (Carling et al., 2008).

In tennis, these physiological demands are different from the rest of intermittent sports (Smekal et al., 2001). The internal load of tennis match-play has been analysed through match duration, effective playing time, and the rest time ratio (Fernández-Fernández, Méndez-Villanueva, Pluim, Fernández-García, and Terrados, 2005). Tennis match-play involves high intensive work periods interspersed with moderately long rest periods (Comellas and López, 2001; Fernández-Fernández, Sanz-Rivas, and Méndez-Villanueva, 2009). However, these researches it seem to be not enough to describe the tennis player profile in match-play because it did not analyse other variables such as: distance covered, speed or acceleration. In relation to that, the majority of the studies applied to tennis have analysed training sessions (Reid et al., 2013), instead of match-play. One of the first research works on tennis training, which assessed the velocity and distance covered for tennis players (Reid, Duffield, Dawson, Baker, and Crespo, 2007), suggested that in the training drills proposed by coaches the movements are short and of high intensity due to the small size of the tennis court. Hoppe and colleagues (2014) analysed the velocity, accelerations and decelerations of adolescent tennis players in simulated match-play. They concluded (Hoppe et al., 2014) that the physical activity of tennis players was characterized by high accelerations and decelerations but low velocities, reaching values of almost 90% of the distance covered by players accelerating or decelerating (Galé-Ansodi, 2014). According to that, Fernández-Fernández et al. (2005), who concluded that physical demands in tennis match play are not the same in training as in small-side games in football trainings (Casamichana and Castellano, 2011; Clemente, Couceiro, Martins, and Mendes, 2012; Hodgson, Akenhead, and Thomas, 2014).

In this sense, the authors are aware of the current knowledge about physical profile in match-play of young tennis players is not enough. It is for this reason that the aim of this work is to describe the physical profile in match play of young tennis players using GPS technology in order to improve the knowledge of the physical demands of tennis, assessing variables like: distance covered, speed of movement, velocity and acceleration considering gender and ranking. The results of this research will provide further information regarding the physical demands from matches-play on young tennis players. Tennis coaches should take into account the values obtained by tennis players in order to design specific trainings.

Material & Methods

Participants

Seventeen female and twelve male young high-level tennis players (Spanish Tennis Ranking) took part in the study (age 14.0 ± 2.9 years). They were members of different age divisions (beginner: under 12 years old; youth: under 14 years old; teenager: under 15 years old; and junior: under 18 years old) of the High Level Performance Centre in the Aragon Tennis Federation. They had been playing in high-level competitions for between 2 and 5 years, and at the time this study was carried out they were among the top few in the state ranking. All the tennis players were tracked in 1 to 3 matches ($n=98$). All of them were notified of the research design and its requirements, and the potential benefits and risks, and all gave their informed consent before the start. The Ethic Committee of the University of the Basque Country (UPV/EHU) gave its institutional approval of the study.

Table I. Participants.

	Male=49		Female=49	
	HiR=27	LR=22	HiR=25	LR=24
Beginner	10	7	4	6
Teenager	8	8	4	6
Youth	5	4	10	3
Junior	4	3	7	9

Note: HiR is high ranking players and LR is low ranking players.

Variables

The independent variables used were: gender (male $n=49$ and female $n=49$ records), and ranking of players (high ranked players, HiR $n=52$ and low ranked players, LR $n=46$ records).

The dependent variables to describe the physical demands were: (a) Global indicators, including distance covered (Dc), distance covered per minute (DcM), number of rallies of match-play (N), maximum speed (MxS), average speed (AvS), player load per minute (PLmin), that is, an external load indicator of players acceleration distance covered per minute (DcMA), that is, the accelerating distance covered by player per each minute of match, percentage of acceleration distance covered (%DcA); (b) Distance covered per minute at speed zones (positioning: $0.0-0.5 \text{ m}\cdot\text{s}^{-1}$; jogging: $0.6-1.9 \text{ m}\cdot\text{s}^{-1}$, low intensity: $2.0-3.7 \text{ m}\cdot\text{s}^{-1}$ and high intensity: $3.8-5.0 \text{ m}\cdot\text{s}^{-1}$). These speed zones were supported in a previous study (Castillo-Rodríguez, Alvero-Cruz, Hernández-Mendo, and Fernández-García, 2014).

Materials

Twelve portable GPS devices (*Minimax S4*, *Catapult Innovations*) operating at a sampling frequency of 10 Hz were used. The *Minimax S4* device contains a tri-axial piezoelectric linear accelerometer (*Kionix: KXP94*) sampling at a frequency of 100 Hz. Acceleration/deceleration variables was recorded using this accelerometer. During matches, the GPS devices had connections with 13.3 ± 0.9 satellites, and the horizontal dilution of position was 0.9 ± 0.1 , indicating ideal measuring conditions (Varley, Fairweather, and Aughey, 2012).

After the recording, the data were downloaded to a computer and analysed using the software package *SPRINT v.5.1.4* (*Catapult Innovations*, 2010). With respect to velocity assessment, the reliability and accuracy of the devices used in this study in short distance exercises has been assessed in previous works (Castellano, Casamichana, Calleja-González, San Román, and Ostojic, 2011; Rampinini et al., 2015). Also the acceleration/deceleration assessment has previously reported as from moderate to high reliability and accuracy (Boyd, Ball, and Aughey, 2011) although we should be aware when assess accelerations of over $4 \text{ m}\cdot\text{s}^{-2}$ because accuracy is compromised (Akenhead et al., 2014). Moreover, Galé-Ansodi, Langarika-Rocafort, Usabiaga, and Castellano (2016) have shown the reliability of this type of GPS was adequate also in tennis tasks, specifically variables such as: maximum speed (MxS); average speed (AvS); player load per minute (PLmin); acceleration distance covered per minute (DcMA) and percentage acceleration distance covered (%DcA).

Procedures

In the weeks prior to the study, the players were familiarized with the use of these devices and they chose the size of their harness in training matches. Physical demands were assessed over 81 tennis matches-play, from which 98 recordings were obtained. Match analysis was carried out by Aragon Tennis Master in December 2014-2016. Individual matches were played on hard court in the evening from 16:00 to 20:00 in similar climatic conditions (temperature, relative humidity and wind) and at least 24 hours elapsed between each match. Thirty minutes before the beginning of the match, the players put on their harnesses and carried out standard warm-up

exercises. Just before starting the match, the relevant researcher put the GPS devices into the players' harnesses. The length of the match was noted to discover the physical demands on each player.

Statistical Analysis

All the statistical analysis was performed using SPSS 20.0 for Windows. Data is expressed as mean and standard deviation ($\pm$ SD). After validating the normality and homogeneity assumptions, Parametric Student t test was applied with significant being set at $p < 0.005$. The effect size statistic (η^2p) was used to assess the magnitude of difference between variables. The criteria for: interpreting differences in the mean was 0.2-0.5 (small), 0.5-0.8 (moderate), and > 0.8 (large) (Cohen, 1988). The coefficient of variation (%) was used to characterize the degree of variability in each physical variable (Hopkins, Marshall, Batterham, and Hanin, 2009).

Results

Table 2 shows the general values about physical demands in tennis. The distance covered by players were 3651 ± 1572 meters in a match-play. The majority of this distance covered by players were accelerating, so that, the 89.7% of the total distance covered by players was covered accelerating. In addition to that, tennis players disputed 19.4 ± 5.9 rallies to cover the distance in a tennis match-play. Furthermore, the maximum speed of players was 4.3 ± 0.5 , whereas the average speed of them was $3.0 \pm 0.4 \text{ m}\cdot\text{s}^{-1}$. On the other hand, table 2 shows the distance covered per minute at different speed zones. The most common speed zone was jogging ($0.6\text{-}1.9 \text{ m}\cdot\text{s}^{-1}$) because players covered $47.4 \pm 26.9 \text{ m}\cdot\text{min}^{-1}$ at this speed.

Table II. General variables of players

	n	Mean	SD	CV%
Dc (m)	98	3651	1572	43
DcM (m)	98	46.01	7.01	15
N (n)	98	19.43	5.97	31
MxS ($\text{m}\cdot\text{s}^{-1}$)	98	4.34	0.57	13
AvS ($\text{m}\cdot\text{s}^{-1}$)	98	3.05	0.46	14
PLmin ($\text{UA}\cdot\text{min}^{-1}$)	98	7.65	3.85	50
DcMA (m)	98	41.35	10.01	23
%DcA	98	89.75	18.10	20
Positioning ($\text{m}\cdot\text{s}^{-1}$)	98	10.02	5.24	52
Jogging ($\text{m}\cdot\text{s}^{-1}$)	98	47.49	26.98	56
Low Intensity ($\text{m}\cdot\text{s}^{-1}$)	98	7.11	4.18	58
High Intensity ($\text{m}\cdot\text{s}^{-1}$)	98	0.51	0.31	60

Note: distance covered (Dc); distance covered per minute (DcM); number of rallies (N); maximum speed (MxS); average speed (AvS); player load per minute (PLmin); acceleration distance covered per minute (DcMA); percentage acceleration distance covered (%DcA); game duration in minutes (GD), total average accelerations (TA); positioning: $0.0\text{-}0.5 \text{ m}\cdot\text{s}^{-1}$; jogging: $0.6\text{-}1.9 \text{ m}\cdot\text{s}^{-1}$, low intensity: $2.0\text{-}3.7 \text{ m}\cdot\text{s}^{-1}$ and high intensity: $3.8\text{-}5.0 \text{ m}\cdot\text{s}^{-1}$

On the other hand, players' ranking was also analysed. High ranked players covered more distance per minute than low ranked ones ($\text{HiR}=46.7 \pm 8.9$ vs. $\text{LR}=44.5 \pm 7.3 \text{ m}$; $F(1, 94)=12.96$; $p<0.001$; $\eta^2p=0.121$) although low ranked players needed to play more rallies to win the matches-play ($\text{HiR}=18.5 \pm 6.2$ vs. $\text{LR}=21.8 \pm 5.0$ rallies; $F(1, 94)=3.70$; $p=0.200$; $\eta^2p=0.013$). However, high ranked players developed a significant greater maximum speed ($\text{HiR}=4.3 \pm 0.6$ vs. $\text{LR}=3.9 \pm 0.4 \text{ m}\cdot\text{s}^{-1}$; $F(1, 94)=10.99$; $p<0.001$; $\eta^2p=0.104$). Besides that, high ranked players covered more acceleration distance per minute than low ranked players ($\text{HiR}=43.8 \pm 11.8$ vs. $\text{LR}=38.6 \pm 6.0 \text{ m}\cdot\text{min}^{-1}$; $F(1, 94)=7.12$; $p=0.009$; $\eta^2p=0.070$). Although, low ranked players developed a greater player load per minute than high ranked players ($\text{HiR}=7.7 \pm 4.3$ vs. $\text{LR}=8.7 \pm 4.9$ arbitrary units; $F(1, 94)=1.32$; $p=0.140$; $\eta^2p=0.070$). Furthermore, table3 shows the distance covered at different speed zones. High ranked players covered more metres per minute at all speed zones than low ranked players, above all at low ($\text{HiR}=8.2 \pm 5.4$ vs. $\text{LR}=5.8 \pm 4.7 \text{ m}\cdot\text{min}^{-1}$; $F(1, 94)=4.88$; $p=0.030$; $\eta^2p=0.049$) and high intensity ($\text{HiR}=0.6 \pm 0.3$ vs. $\text{LR}=0.3 \pm 0.2 \text{ m}\cdot\text{min}^{-1}$; $F(1, 94)=2.95$; $p=0.089$; $\eta^2p=0.031$).

Table III. General variables of players' ranking.

	HiR			LR			F	p	η^2p
	Mean	SD	CV%	Mean	SD	CV%			
Dc (m)	3465	1458	42	3603	1518	42	1.415	0.237	0.015
DcM (m)	46.69	8.89	19	44.54	7.35	17	12.962	<0.001	0.121
N (n)	18.57	6.27	34	21.82	8.01	37	1.215	0.207	0.013
MxS ($\text{m}\cdot\text{s}^{-1}$)	4.28	0.61	14	3.96	0.52	13	10.908	<0.001	0.104
AvS ($\text{m}\cdot\text{s}^{-1}$)	2.92	0.48	16	2.96	0.41	14	0.360	0.550	0.004
PLmin ($\text{UA}\cdot\text{min}^{-1}$)	7.75	4.30	55	8.69	4.92	57	1.325	0.253	0.014
DcMA (m)	43.78	11.84	27	38.60	5.45	14	7.122	0.009	0.070

%DcA	91.26	24.51	27	88.03	44.02	50	0.808	0.371	0.009
Positioning (m·s ⁻¹)	10.76	5.57	52	10.40	3.99	38	0.135	0.715	0.001
Jogging (m·s ⁻¹)	50.90	27.54	54	43.63	26.08	60	1.487	0.226	0.016
Low Intensity (m·s ⁻¹)	8.20	5.40	66	5.88	4.69	80	4.886	0.030	0.049
High Intensity (m·s ⁻¹)	0.62	0.31	51	0.38	0.21	54	2.959	0.089	0.031

Note: distance covered (Dc); distance covered per minute (DcM); number of rallies (N); maximum speed (MxS); average speed (AvS); player load per minute (PLmin); acceleration distance covered per minute (DcMA); percentage acceleration distance covered (%DcA); game duration in minutes (GD), total average accelerations (TA); positioning: 0.0-0.5 m·s⁻¹; jogging: 0.6-1.9 m·s⁻¹, low intensity: 2.0-3.7 m·s⁻¹ and high intensity: 3.8-5.0 m·s⁻¹

Besides that, players' gender was analysed too. Table 3 shows significant differences between gender of players, analysing the distance covered by them (Male=4172± 1660 vs. Female=3129 ±1269 m·min⁻¹; F(1, 94)=13.15; p<0.001; η^2 p=0.123). In relation to that, male players disputed a higher number of rallies than female player (Male=21.3± 5.9 vs. Female=17.5 ±5.5 m·min⁻¹; F(1, 94)=9.19; p=0.003; η^2 p=0.089). Taking into account the players' speed, there were significant differences in maximum speed (Male=4.6± 0.5 vs. Female=2.9±0.4 m·min⁻¹; F(1, 94)=24.98; p<0.001; η^2 p=0.210) and average speed (Male=3.2± 0.5 vs. Female=4.1±0.5 m·min⁻¹; F(1, 94)=13.63; p<0.001; η^2 p=0.127), which were higher in male players than female players. However, there were not hardly differences in terms of acceleration between male and female players, finding the female players covered more distance accelerating than female players (Male=41.8± 5.6 vs. Female=40.8± 12.6m·min⁻¹; F(1, 94)=0.13; p=0.719; η^2 p=0.001). Finally, male players covered more distance per minute than female players at all speed zones. In this line, there were significant differences at jogging: 0.6-1.9 m·s⁻¹ (Male=56.0± 28.3 vs. Female=38.9± 22.7 m·min⁻¹; F(1, 94)=9.88; p=0.002; η^2 p=0.095), and at high intensity: 3.8-5.0 m·s⁻¹ (Male=0.7± 0.5 vs. Female=0.3± 0.2 m·min⁻¹; F(1, 94)=8.47; p=0.005; η^2 p=0.083).

Table IV. General variables of players' gender.

	Male			Female			F	p	η^2 p
	Mean	SD	CV%	Mean	SD	CV%			
Dc (m)	4172	1660	40	3129	1296	41	13.153	< 0.001	0.123
DcM (m)	47.29	5.03	11	44.72	7.94	18	3.199	0.077	0.033
N (n)	21.27	5.92	28	17.59	5.46	31	9.194	0.003	0.089
MxS (m·s ⁻¹)	4.57	0.55	12	4.11	0.49	12	24.981	< 0.001	0.210
AvS (m·s ⁻¹)	3.20	0.461	14	2.91	0.40	14	13.636	< 0.001	0.127
PLmin (UA·min ⁻¹)	6.63	1.73	26	8.65	4.99	58	7.110	0.009	0.070
DcMA (m)	41.84	5.65	14	40.85	12.57	31	0.130	0.719	0.001
%DcA	88.22	7.14	8	91.27	24.62	27	0.622	0.432	0.007
Positioning (m·s ⁻¹)	10.31	5.21	50	9.72	5.32	55	0.045	0.833	0.000
Jogging (m·s ⁻¹)	56.03	28.35	51	38.94	22.75	58	9.880	0.002	0.095
Low Intensity (m·s ⁻¹)	8.36	4.73	57	5.85	3.36	57	4.715	0.032	0.048
High Intensity (m·s ⁻¹)	0.70	0.55	79	0.32	0.23	72	8.471	0.005	0.083

Note: distance covered (Dc); distance covered per minute (DcM); number of rallies (N); maximum speed (MxS); average speed (AvS); player load per minute (PL); acceleration distance covered per minute (DcMA); percentage acceleration distance covered (%DcA); game duration in minutes (GD), total average accelerations (TA); positioning: 0.0-0.5 m·s⁻¹; jogging: 0.6-1.9 m·s⁻¹, low intensity: 2.0-3.7 m·s⁻¹ and high intensity: 3.8-5.0 m·s⁻¹

Discussion

The main aim of this study was to describe the physical demands of young tennis players in official match tournaments. Until now, all researches about physical demands in tennis have analyzed tennis training or simulated match-play. As far as we know, this is the first study that describes the physical demands of tennis players using GPS in match-play. The results showed that players experienced different physical demands depending on the variables like: gender or ranking.

Nowadays, micro technology applied to different sports (Cummins et al., 2013) allows us to know the physical demands on players, such as distances covered, motion velocities or acceleration/deceleration movements. In tennis, the physical demands had been analysed in training sessions using GPS devices operating at 5Hz (Duffield, Reid, Baker, and Spratford, 2010; Reid et al., 2007) in simulated matches-play (Hoppe et al., 2014; Pereira et al., 2016) and in match-play (Galé-Ansodi, Castellano, and Usabiaga, 2016; Galé-Ansodi, Castellano, Usabiaga, and Casamichana, 2014), in order to optimize and individualize player training drills or assess physical performance in competitions or tournaments. However, these researches have analysed the physical demands of tennis players attending to variables like: winners or losers, qualifying

round or different kind of surface. None of them, addressed variables like gender or ranking in order to know the physical profile of young tennis players.

The general values of tennis match-play, were similar to the study carried out by Comellas and López (2001), who found that the distance covered in a tennis match-play depends on the number of rallies disputed. In five set matches, the distance covered by players was less than in three set matches because the length of the rallies affected fatigue and, obviously, distance covered. In terms of the total distance, our results agreeing to revision of Fernández-Fernández et al. (2009) in tennis. On the other hand, all players covered the greatest distance accelerating according to the results of Galé-Ansodi (2014). As it has been suggested in other activities practiced on small sided fields, where demands associated with accelerations and decelerations are very important and consequently, must be taken into account (Castellano and Casamichana, 2014; Gaudino et al., 2013). This is substantial for tennis and can be a good indicator to propose specific training, because it shows what the usual intensity in tennis players is. The most common speed zone in tennis match-play was jogging. This fact was similar to other researches in simulated match-play tennis (Hoppe et al., 2014) and paddle-tennis (Castillo-Rodríguez et al., 2014).

In relation to players' ranking, the results were contrasted with other racquet sports such as squash (Hughes and Franks, 1994), paddle-tennis (Castillo-Rodríguez et al., 2014) and badminton (Leong and Krasilshchikov, 2016). The average speed in tennis was higher in low ranked players than in high ranked players, what was similar to what was observed in studies of paddle-tennis using GPS devices in match-play. Perhaps low ranked players were less efficient than higher ranked players (Del Villar, García González, Iglesias, Perla Moreno, and Cervelló, 2007) and consequently they had to cover more distance more quickly. The number of rallies was less in high ranked players than in low ranked players, because the best players needed fewer rallies to win in match-play. In paddle-tennis (Castillo-Rodríguez et al., 2014) low ranked players covered more distance at high intensity ($3.8\text{--}5.0\text{ m}\cdot\text{s}^{-1}$) than high ranked players. Besides that, in the research by Fernández-Fernández, Sanz-Rivas, Sanchez-Muñoz, Pluim, and Tiemessen (2009) it was showed that low ranked players covered more distance at higher intensities ($1.2\text{--}3.3$; $3.3\text{--}5.0$; $5.0\text{--}6.7$; $>6.7\text{ m}\cdot\text{s}^{-1}$) than high ranked ones in simulated tennis match-play. These results were different from the results reported in our research. It could be due to high ranked players being able to run quickly from side to side on a tennis court to win matches, while low ranked players were not able to run quickly during matches. In this line, high ranked players moved faster than low ranked players in all different directions, according to research done by Hughes and Franks (1994) who analysed the movements of the top 6 international ranked squash players. They demonstrated that the top ranked player accelerated 50% more quickly than the rest of the players. Perhaps the acceleration capacity of high ranked players could be a good indicator of their performance. Regarding technical tennis skill, Downey (1973), Hughes (1985) and Sanderson and Way (1977) used notational analysis to describe tennis patterns and they concluded that the technical and tactical skills of tennis players affect match-play. Hughes, Wells, and Matthews (2000) showed through notational analysis that elite female squash players had a determinate play pattern, while recreational squash players did not, similar to that reported in male squash players (Hughes, 1986). Therefore, it seems to be the tactical and technical tennis skills are the most important abilities in tennis, although the physical demands of tennis should not be underestimated.

The results were similar in tennis and paddle-tennis in terms of gender. Castillo-Rodríguez et al. (2014) showed that male paddle-tennis players were faster than female paddle-tennis players, which is similar to observations made regarding in tennis. In addition to that, the distance covered per minute was higher in male tennis players in both sports. Regarding to the distance covered in different speed zones, the results were similar in both sports, with male players covering more distance at all intensities: positioning ($0.0\text{--}0.5\text{ m}\cdot\text{s}^{-1}$) jogging ($0.6\text{--}1.9\text{ m}\cdot\text{s}^{-1}$), low intensity ($2.0\text{--}3.7\text{ m}\cdot\text{s}^{-1}$) and high intensity ($3.8\text{--}5.0\text{ m}\cdot\text{s}^{-1}$) than female players. The results obtained are due to physiological and physical differences determined by gender, where men are able to move faster than women.

Conclusions

The results of this study show that GPS devices are a useful tool to quantify the strain on players both in training and match-play. In addition, GPS devices would improve tennis players' performance, through adapting specific training to individual physical demands. Therefore, coaches must use this data to propose specific training, similar to the demands of match-play. Consequently, tennis players would improve their performance. It would be interesting to compare the physical demands between match-play and training to know the relationship between: intensity, acceleration distance covered, average acceleration and distance covered per time. However, it should be taken into account that results which exceed $4\text{ m}\cdot\text{s}^{-2}$ could be underestimating the situation (Vickery et al., 2013). It should be considered that there was no differentiation between work time and rest time. Besides this fact, the distance covered during changes of field is a factor which should have been taken into consideration in our research.

Practical Applications

- The physical demands of young tennis players will be determined in accordance with the following variables: distance covered per minute, average speed, accelerating distance covered per minute, player load per minute, distance covered at speed zones.

- All tennis players covered the majority of the distance, around 90%, accelerating without continuous intensity. Therefore, it would be interesting to involve a large amount of accelerations in tennis trainings.
- Tennis training should be design attending to gender and ranking of players due to depending on these variables, the physical demands could be different for tennis players.

References

- Akenhead, R., French, D., Thompson, K. G., & Hayes, P. R. (2014). The acceleration dependent validity and reliability of 10 Hz GPS. *Journal of Science and Medicine in Sport*, 17(5), 562-566.
- Baiget-Vidal, E. (2011). Metodología del entrenamiento de la resistencia específica en el tenis de competición. Revisión y propuesta. Training methods for specific endurance in competitive tennis. Review and proposal. *Cultura, Ciencia y Deporte*, 6 (16), 45-54.
- Boyd, L. J., Ball, K., & Aughey, R. J. (2011). The Reliability of MinimaxX Accelerometers for Measuring Physical Activity in Australian Football. *International Journal of Sports Physiology and Performance*, 6, 311-321.
- Brewer, C., Dawson, B., Heasman, J., Stewart, G., & Cormack, S. (2010). Movement pattern comparisons in elite (AFL) and sub-elite (WAFL) Australian football games using GPS. *Journal of science and medicine in sport / Sports Medicine Australia*, 13(6), 618-623.
- Buchheit, M., Mendez-Villanueva, A., Simpson, B. M., & Bourdon, P. C. (2010). Match running performance and fitness in youth soccer. *International Journal of Sports Medicine*, 31(11), 818-825.
- Carling, C., Bloomfield, J., Nelsen, L., & Reilly, T. (2008). The Role of Motion Analysis in Elite Soccer: Contemporary Performance Measurement Techniques and Work Rate. *Sports Medicine*, 38(10), 839-862.
- Casamichana, D., & Castellano, J. (2011). Demandas físicas en jugadores semiprofesionales de fútbol: ¿se entrena igual que se compete?. Physical Demands in Semi-Professional Football Players: Is Training Carried out the Same as Competition? *Cultura, Ciencia y Deporte*, 6(17), 121-127.
- Castellano, J., & Casamichana, D. (2014). Deporte con dispositivos de posicionamiento global (GPS): aplicaciones y limitaciones. Sport with global positioning devices (GPS) : applications and limitations. *Revista de Psicología del Deporte*, 23(2), 355-364.
- Castellano, J., Casamichana, D., Calleja-González, J., San Román, J., & Ostojic, S. (2011). Reliability and accuracy of 10 Hz GPS devices for short-distance exercise. *Journal of Sports Science and Medicine*, 63, 233-234.
- Castillo-Rodríguez, A., Alvero-Cruz, J. R., Hernández-Mendo, A., & Fernández-García, J. (2014). Physical and physiological responses in Paddle Tennis competition. *International Journal of Performance Analysis in Sport*, 14, 524-534.
- Clemente, F., Couceiro, M., Martins, F., & Mendes, R. (2012). The usefulness of small-sided games on soccer training. *Journal of Physical Education and Sport*, 12(1), 93-102.
- Comellas, J., & López, P. (2001). Análisis de los requerimientos metabólicos del tenis. Analysis of the metabolic requirements of tennis. *Apunts: Educación física y Deportes*, 65, 60-63.
- Cohen, J. Statistical Power Analysis for the Behavioral Sciences. New York, NY: Routledge Academic. 1988.
- Cummins, C., Orr, R., O'Connor, H., & West, C. (2013). Global Positioning Systems (GPS) and Microtechnology Sensors in Team Sports: A Systematic Review. *Sports Medicine*, 43, 1025-1042.
- Del Villar, F., García-González, L., Iglesias, D., Perla Moreno, M., & Cervelló, E. M. (2007). Expert-novice differences in cognitive and execution skills during tennis competition. *Perceptual and Motor Skills*: 104, 355-365.
- Downey, J. C. (1973). The Singles Game. (E. P. Publ.). London.
- Duffield, R., Reid, M., Baker, J., & Spratford, W. (2010). Accuracy and reliability of GPS devices for measurement of movement patterns in confined spaces for court-based sports. *Science and Medicine in Sport*, 13(5), 523-525.
- Fernández-Fernández, J., Fernández-García, B., Méndez-Villanueva, A., & Terrados, N. (2005). La intensidad de trabajo en tenis: el entrenamiento frente a la competición. Exercise intensity in single tennis: training drills vs simulated match play. *Archivos de medicina del deporte*, 22(107), 187-192.
- Fernández-Fernández, J., Sanz-Rivas, D., & Mendez-Villanueva, A. (2009). A review of the activity profile and physiological demands of tennis match play. *Strength and Conditioning Journal*, 31(4), 15-26.
- Fernandez-Fernandez J., Sanz-Rivas D., Sanchez-Muñoz C., Pluim B.M., Tiemessen I., & Méndez-Villanueva, A. (2009). A comparison of the activity profile and physiological demands between advanced and recreational veteran tennis players. *Journal Strength Condition Research*, 23(2), 604-610.
- Galé-Ansodi, C., Usabiaga, O., & Castellano, J. (2016). Effects of different surfaces in time-motion characteristics in youth elite tennis players. *International Journal of Performance Analysis in Sport*, 16, 860-870.
- Galé-Ansodi, C., Langarika-Rocafort, A., Usabiaga, O., & Castellano, J. (2016). New variables and new agreements between 10 Hz global positioning system devices in tennis drills. *Journal of Sports Engineering and Technology*, 1-3.

- Galé-Ansodi, C. (2014). Youths Tennis Players' Velocity and Acceleration in matchplay. *Revista Internacional de Deportes Colectivos*, 18, 50-57.
- Galé-Ansodi, C., Castellano, J., Usabiaga, O., & Casamichana, D. (2014). Metabolic Power in Tennis: New Approach to understand the Physical Demands. *Journal of Strength and Conditioning Research. IV International Conference*, 9 (25), 44.
- Gaudino, P., Iaia, F. M., Alberti, G., Strudwick, A. J., Atkinson, G., & Gregson, W. (2013). Monitoring Training in Elite Soccer Players: Systematic Bias between Running Speed and Metabolic Power Data. *International Journal of Sports Medicine*, 34(11) 963-968.
- Harley, J. A., Barnes, C. A., Portas, M., Lovell, R., Barrett, S., Paul, D., & Weston, M. (2010). Motion analysis of match-play in elite U12 to U16 age-group soccer players. *Journal of Sports Science*, 28 (13), 1391-1397.
- Hodgson, C., Akenhead, R., & Thomas, K. (2014). Time-motion analysis of acceleration demands of 4v4 small-sided soccer games played on different pitch sizes. *Human Movement Science*, 33, 25-32.
- Hoppe, M. W., Baumgart, C., Bornefeld, J., Sperlich, B., Freiwald, J., & Holmberg, H. C. (2014). Running activity profile of adolescent tennis players during match play. *Pediatric Exercise Science*, 26(3), 281-290.
- Hopkins, W.G., Batterham, A.M., Marshall, S.W., & Hanin, J. (2009). Progressive Statistics. *Sport Science*, (13), 55-70.
- Hughes, M. D. (1985). A comparison of patterns of play in squash. In K. C. and M. A. S. Brown, R. Goldsmith (Ed.), *International Ergonomics* (pp. 139-141). London.
- Hughes, M. D. (1986). A review of patterns of play in squash at different competitive levels. *Sport Science*, 363-368.
- Hughes, M. D., & Franks, I. M. (1994AD). A time-motion analysis of squash players using a mixed-image video tracking system. *Ergonomics*, 37(1), 23.
- Hughes, M. D., Wells J., & Matthews, K. (2000). Performance profiles at recreational and elite levels of women's squash. *Journal of Human Movement Studies*, 39, 85-104.
- Leong, K.L. & Krasilshchikov, O.(2016). Match and game performance structure variables in elite and youth international badminton players. *Journal of Physical Education and Sport*, 16(2), 330-334.
- Njororai, W.W.S. (2012). Physical demands of soccer: lessons from team USA and Ghana matches in the 2010 FIFA WORLD CUP. *Journal of Physical Education and Sport*, 12(4), 407 - 412.
- Pereira, L. A., Freitas, V., Moura F. A., Aoki, M. S., Loturco, I., & Nakamura, F. Y. (2016). The activity profile of young tennis athletes playing on clay and hard courts: Preliminary data. *Journal of Human Kinetics*, (50), 211-222.
- Petersen, C. J., Pyne, D., Dawson, B., Portus, M., & Kellett, A. (2010). Movement patterns in cricket vary by both position and game format. *Journal of Sports Sciences*, 28(1), 45-52.
- Rampinini, E., Alberti, G., Fiorenza, M., Riggio, M., Sassi, R., Borges, T. O., & Coutts, A. J. (2015). Accuracy of gps devices for measuring high-intensity running in field-based team sports. *International Journal of Sports Medicine*, 36, 49-53.
- Reid, M., Duffield, R., Dawson, B., Baker, J., & Crespo, M. (2007). Quantification of the physiological and performance characteristics of on-court tennis drills. *British Journal of Sports Medicine*, 42(2), 146-151.
- Reid, M., Duffield, R., Minett, G. M., Sibte, N., Murphy, A. P., & Baker, J. (2013). Physiological, perceptual, and technical responses to on-court tennis training on hard and clay courts. *Journal of Strength and Conditioning*, 27(6), 1487-1495.
- Sanderson, F. H., & Way, K. I. M. (1977). The development of an objective method of game analysis in squash rackets. *British Journal of Sports Medecine*, 11, 118.
- Smekal, G., VonDuvillard, S.P., Rihacek, C., Pokan, R., Hofmann, P., Baron, R., Tschan, H., & Bachil, N. (2001). A physiological profile of tennis match play. *Medicine and Science in Sports and Exercise*, 33(6), 999-1005.
- Varley, M. C., Fairweather, I. H., & Aughey, R. J. (2012). Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. *Journal of Sports Sciences*, 30(2), 121-127.
- Vickery, W. M., Dascombe, B. J., Baker, J. D., Higham, D. G., Spratford, W. A., & Duffield, R. (2013). Accuracy and reliability of GPS devices for measurement of sports-specific movement patterns related to cricket, tennis and field-based team sports. *Journal Strength Conditional Research*, 28(6), 1697-1705.