Abstract

The purpose of this study was to compare the physiological and the physical characteristics of elite and sub-elite Italian male field hockey players.

Twenty-two players: twelve elite (age: 25.1±3.8 years, height: 1.74±5.2m, body mass: 70.3±2.6kg) and ten sub-elite (age: 22.2±4.0 years, height: 1.72±1.8m, body mass: 66.7±5.6kg) participated to the study. Six matches, three performed at international and three at national level were analyzed by the means of a GPS device and heart rate monitoring.

The mean total distance covered by each player was 7062±1363m (elite) and 6186±1615m (sub-elite); the estimated mean total distance covered in 70 min was 8553±705m and 8067±1081m respectively. The acceleration (n=256±35 elite and n=231±51 sub-elite) and deceleration events (n=256±35 elite and n=233±51 sub-elite) were also computed. Mean heart rate was 84.5±3.7% and 85.77±2.8% of the maximal heart rate, in elite and sub-elite respectively. Blood lactate concentrations sampled at the end of the first half and at the end of the matches were collected and processed. No significant differences between elite and sub-elite Italian hockey players were found both in distance covered measured, even at different speed intensities, and in heart rates. Significant differences with Effect Sizes ranging from small to very large, were found in accelerations.

Key words: Match analysis; heart rate; team sports, acceleration, GPS
1. Introduction

Field Hockey is a team sport, similar to the majority of field invasive sports (Reilly and Borrie, 1992). For this reason in recent years many studies have been carried out using similar researching approaches (Aughey, 2011; Coutts and Duffi, 2010). Match analysis in various field team sports has been increasingly performed using new technologies, including the global positioning system (GPS) devices (Gabbett et al., 2012; Spencer et al., 2004; Wisbey et al., 2010; Granatelli et al. 2013).

In the last years, different GPS devices, sampling at different rates (Hz), have been validated both in term of precision and in reliability when measuring the steady-state and the running movements in a range of velocities, in many field sports (Coutts and Duffi, 2010; Jennings et al., 2010; MacLeod et al., 2009). The GPS technology has been already used to objectively quantify the movements (distance and speeds) in hockey players (Gabbett, 2010; Lythe and Kilding, 2011; Spencer et al., 2005).

Most of the information provided by these researches referred to the description of the physical demands of the game, investigating the different intensities of the performances, described quantitatively through the “speed intensities” approach (Di Salvo et al., 2007; Di Salvo et al., 2013; Lythe and Kilding, 2011) and the physiological responses to the game, measured through the heart rates (Di Salvo et al., 2007; Lythe and Kilding, 2011) and the lactate blood concentration (Ghosh et al., 1991).

However, to the best of our knowledge, there are no studies that compare the distance covered, speed intensities and heart rates between male field hockey players, competing at different level of qualification.

The practical question we made ourselves was to understand whether and how much of these physical and physiological parameters might explain these different levels of qualification, beside the obvious different technical and tactical level of mastery in this game.

Thus the primary purpose of our study was to verify the hypothesis that possible differences exist in physical and physiological performance between Italian male field hockey players competing at the international level (Elite) and at the domestic level (sub Elite).

Secondly we aimed at comparing the obtained results with the ones available in scientific literature and regarding other elite field hockey players, placed in a higher world ranking.

2. Methods

2.1. Experimental Approach to the Problem

To verify the hypothesis we formulated, we measured during six matches some physical and physiological parameters (set as independent variables) in Elite and Sub Elite field hockey players, setting the different level of qualification as the dependent variable.
Three international matches were analyzed during the participation of the Italian national team to the EuroHockey Challenge 2011, held in Catania (Italy) in July 2011. Three domestic matches were analyzed in Cagliari (Italy), in a local club team, involved in the first division of the national league (Serie A), in June 2011.

All the matches were performed on synthetic surface water filled pitches, approved for international competitions. The weather conditions were fine, with temperatures averaging from 25 to 29°. All the matches were scheduled in the afternoon, starting from 5 p.m.

All the participants were experienced players and advised to maintain a regular diet and used to eat, at least 3 hours before the commencement of the match, according to specific guidelines (i.e., 60, 25, and 15% of carbohydrates, fat, and protein, respectively). To avoid hypohydration, players were allowed to drink fluids according to their personal needs.

2.2. Subjects
Twenty-two male hockey players of different qualification (elite and sub-elite) volunteered to participate in the study: elite players belong to the Italian senior national team (n=12; Height: 1.74±5.2 m; Body Mass: 70.30±2.58 kg; BMI: 23.12±1.62 Kg·m⁻²; Age: 25.09±3.81 years; HR_max: 194±9 bpm; estimated VO₂_max: 55.79±2.76 mL·kg⁻¹·min⁻¹); sub-elite players belong to a senior club team, playing at domestic level, in the Italian first division “Serie A” (n=10; Height: 1.72±1.81 m; Body Mass: 66.67±6.15 kg; BMI: 22.29±1.71 Kg·m⁻²; Age: 22.2±3.97 years; HR_max: 192±9 bpm; measured VO₂_max: 52.03±2.45 mL·kg⁻¹·min⁻¹).

The elite and sub elite players had a minimum field hockey training experience of 12±2 and 9±2 years respectively. The typical weekly training volume for the elite and sub elite players was 13-15 hours and 8-10 hours respectively, which included four-five technical training sessions (8-10 hours) and two sessions of specific physical preparation (3-4 hours, elite players) and three-four technical training sessions (6-8 hours) and two sessions of specific physical preparation (3-4 hours) for sub elite players.

Each player was informed about the study, including the risks and benefits and provided written informed consent, in conformity with the Ethical Code of the World Medical Association (Declaration of Helsinki). The Tournament Director and the Italian Hockey Federation also provided clearance before the commencement of the study. All experimental procedures were approved by the institutional human ethics committee.

2.3. Instrumentation
The data referring to the physical demands of the matches were recorded by the means of GPS devices (SPI Elite units, GPSports, Fyshwick, Australia), sampling at 1Hz. In order to track the position of players during matches, we recorded the effective distances (m) and the effective time (s) of performances involving each participant player. In order to evaluate the different loading intensities as a function of the speed performed by the players during the matches, we adopted the intensity zones proposed by other authors in hockey (Lythe and Kilding, 2011) and in soccer (Di Salvo et al., 2007).
(see table 1) and we also computed the acceleration events occurring during the games (Osgnach et al., 2010).

Considering the possibility of continuous interchanging of players allowed by the Game Regulations, we made the appropriate calculations to obtain a reliable estimate of the measure of the total distance covered, if related to seventy minutes of play (Estimate Total Distance covered = ETD70). This measure is obtained from the one actually covered by the player in the sections of the match effectively played and takes into account the measurements made for each of the six intensity zones.

We then estimated the ETD70 as the sum of measurements obtained in the two halves of the game (ETD35\textsubscript{1h}+ ETD35\textsubscript{2h} = estimated total distance in \textsuperscript{1}st and \textsuperscript{2}nd half).

To obtain the ETD70 we used the following formulas (1a, 1b):

\[
ETD35xh = \sum_{n=1}^{6}[(EDC/E TP) \cdot (TSZ \cdot 2100)] \\
ETD70= (ETD35\textsubscript{1h}+ ETD35\textsubscript{2h})
\]

Where ETD35\textsubscript{xh}=estimate of the total distance covered in 35 minutes (ETD35\textsubscript{xh}) for each speed zone (sum 1 to 6 speed zone); EDC=effective distance covered in the considered speed zone (m); ETP = Effective time of performance in the considered speed zone (s); TSZ= Percentage of time spent in the considered speed zone; 2100 = time in seconds for each half (s).

This calculation was performed for each of the six intensity zones and ETD35xh was then computed as the sum of the six different values obtained (\sum_{n=1}^{6} speed zone ).

**2.4. Heart Rates and Blood Lactate concentration**

The physiological demands of the game were also considered and measured through the heart rates (HR) and the blood lactate (Bla) concentrations; the latter were sampled during official matches only, at international level. Each player wore a HR monitor chest belt (Polar, Electro Oy, Kempete, Finland), sampling every five seconds, during all matches. In order to collect the Bla data, the Lactate Pro LT 1710 analyzers (Arkray, Japan) were used.

**2.5 Collected Data**

Distance covered (m), intensity zones (m·s\textsuperscript{-1}) and the number (n) of accelerations and decelerations, greater than \(\pm 1\) m·s\textsuperscript{-2}, were computed by the GPS device SPI Elite and processed by the GPSports Team AMS V1.2.1.0 software. The HR data refer to the mean heart rate during the match and the different percentage of time spent in each cardiac intensity zone, adopted in this study, were collected and processed. The data of blood lactate concentrations (m/mol·L\textsuperscript{-1}) sampled at the end of the warm-up procedures, at the end of the first half and at the end of the matches were collected and processed.

Using substitution timings, distance covered, intensity zones and HR data were edited so that analysis did not include half-time data, injury breaks, or time spent off the field of play. The HR\textsubscript{max} for each elite player was obtained from a Maximal Multistage
Fitness Test (Yo-Yo Endurance Test, Lev. 1) conducted one week prior to the first match.

The maximal oxygen uptake (VO$_{2}^{\text{max}}$) for each elite player was indirectly estimated interpolating the HR data measured in two sub maximal running tests (6 minutes with running speeds equal to 2.77 m·s$^{-1}$ and 3.33 m·s$^{-1}$ respectively) with the maximum Heart Rate (HR$_{\text{max}}$) obtained through the Yo-Yo Endurance Test. We also considered the energetic cost of running over a field equal to 4.6 J·kg$^{-1}$·m$^{-1}$ (Osgnach et al., 2010; Buglione and di Prampero, 2013).

The HR$_{\text{max}}$ and VO$_{2}^{\text{max}}$ for each sub-elite player were obtained directly from an incremental running test performed on a treadmill (Technogym, Run Race, Cesena, Italy), by the means of MedGraphics VO2000 (Medical Graphics Corporation, St. Paul, Minnesota, USA). Starting speed was set at 8 km·h$^{-1}$, with an increasing speed of 1 km·h$^{-1}$ each minute, until voluntary exhaustion. In order to compare the HR data belonging to the different samples (elite, sub-elite), the match HR data were divided into 4 zones, as proposed by other authors in hockey (Lythe and Kilding, 2011): Low-Moderate Intensity < 75 %; High Intensity = 75 – 84 % ; Very High Intensity = 85 – 95 % ; Maximal Intensity > 95 %.

2.6. Statistical Analyses

Data are presented as mean ($M$) ± standard deviation (SD) and 95% confidence intervals (95% CIs). The assumption of normality was assessed using the Shapiro-Wilk test. Parametric and nonparametric statistics were used when appropriate. To identify the differences in physical and physiological parameters (distance covered, heart rates, accelerations) between first and second half, within the same group, a paired t-test was used. To identify the differences in physical and physiological parameters, as above reported, between the elite and sub elite players, an independent t-test was used. To analyze the differences between the performances recorded in Italian and New Zealand field hockey players, a One Sample t-Test and one way Anova were used. In addition to the null hypothesis testing, effect sizes (Cohen’s $d$) were reported for all normally distributed data. Absolute effect sizes of 0.20, 0.50, and 0.80 represented small, moderate, and large differences, respectively. The corresponding “P” values were provided for each analysis. Statistical significance was accepted at $p\leq0.05$. Statistical package for Social Sciences (SPSS 20.0) for Windows was used to analyze and process the collected data.

3. Results

The mean total distance covered by each individual player was 7062 ± 1015 m and 6186 ± 997 m in elite and sub-elite respectively. The mean match time for each individual player was 58.2±8.5 min. (83.1% out of 70 minutes of the total match duration) in elite and 56.0 ± 10.5 min. (80% out of 70 minutes of the total match duration) in sub-elite. Estimated mean Total Distance covered per match (ETD$_{70}$) was 8553 ± 705 m and 8067 ± 609 m, respectively (see table 1). No significant differences were found (p=ns), although a moderate to large ES (Cohen d=0.73) indicates possible practical implications.
### Table 1. Intensity zones approach (km·h⁻¹); Estimated Total Distances covered at each speed zone (m); % of distance covered and % of time spent in each speed zone; (Mean ± SD) Independent t-Test – no significant differences were found (p=ns).

<table>
<thead>
<tr>
<th>Group</th>
<th>Zone 1 (0.1-6)</th>
<th>Zone 2 (6.1-11)</th>
<th>Zone 3 (11.1-14)</th>
<th>Zone 4 (14.1-19)</th>
<th>Zone 5 (19.1-23)</th>
<th>Zone 6 (&gt; 23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Match (m)</td>
<td>Elite</td>
<td>Sub-elite</td>
<td>Elite</td>
<td>Sub-elite</td>
<td>Elite</td>
<td>Sub-elite</td>
</tr>
<tr>
<td></td>
<td>2592 ± 396</td>
<td>2555 ± 324</td>
<td>2639 ± 339</td>
<td>2349 ± 569</td>
<td>1557 ± 218</td>
<td>1439 ± 389</td>
</tr>
<tr>
<td>1st half (m)</td>
<td>1205 ± 110</td>
<td>1319 ± 192</td>
<td>1359 ± 185</td>
<td>1185 ± 253</td>
<td>825 ± 139</td>
<td>775 ± 236</td>
</tr>
<tr>
<td>2nd half (m)</td>
<td>1388 ± 378</td>
<td>1236 ± 224</td>
<td>1280 ± 217</td>
<td>1155 ± 363</td>
<td>732 ± 165</td>
<td>664 ± 238</td>
</tr>
<tr>
<td>Distance covered %</td>
<td>30.4 ± 4.4</td>
<td>32.5 ± 8.0</td>
<td>30.9 ± 3.1</td>
<td>28.8 ± 4.6</td>
<td>18.2 ± 1.89</td>
<td>17.6 ± 2.8</td>
</tr>
<tr>
<td>Time spent %</td>
<td>53.5 ± 5.8</td>
<td>56.5 ± 9.4</td>
<td>26.5 ± 3.7</td>
<td>24.2 ± 5.4</td>
<td>10.9 ± 2.0</td>
<td>10.3 ± 2.9</td>
</tr>
</tbody>
</table>
Difference in ETD15 between halves in elite was 4269 ± 339 and 4284 ± 502 m, respectively, (+ 0.35%; ES=-0.04) and in sub-elite was 4143±525 and 3925±692 m, respectively (- 5.26%; ES=0.36), but it was not statistically significant in elite and sub-elite (p=ns). The intensity zones approach is reported in Table 1.

The acceleration (a; n=256±35 and n=231±51 and deceleration events (d; n=256±35 and n=233±51) were also computed in elite and sub-elite players, respectively. These values were also sorted into different acceleration zones, as reported in Table 2, with the effect sizes values reported.

Table 2. Acceleration (a) and deceleration (d) events, computed in different acceleration zones, per half (M±SD; 95% CIs; ES as Cohen d).

<table>
<thead>
<tr>
<th></th>
<th>1st half</th>
<th>2nd half</th>
<th>Total Match</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elite</td>
<td>Sub-elite</td>
<td>Elite</td>
</tr>
<tr>
<td>1&lt;a&lt;2 m·s⁻²</td>
<td>111 ± 21</td>
<td>93 ± 20</td>
<td>98 ± 14</td>
</tr>
<tr>
<td>2&lt;a&lt;3 m·s⁻²</td>
<td>20 ± 6</td>
<td>20 ± 4</td>
<td>22 ± 3</td>
</tr>
<tr>
<td>&gt;3 m·s⁻²</td>
<td>2 ± 1</td>
<td>2 ± 1</td>
<td>3 ± 1</td>
</tr>
<tr>
<td>-1&lt;a&lt;-2 m·s⁻²</td>
<td>104 ± 16</td>
<td>95 ± 20</td>
<td>95 ± 12</td>
</tr>
<tr>
<td>-2&lt;a&lt;-3 m·s⁻²</td>
<td>27 ± 7</td>
<td>22 ± 10</td>
<td>25 ± 9</td>
</tr>
<tr>
<td>&gt;-3 m·s⁻²</td>
<td>3 ± 2</td>
<td>3 ± 2</td>
<td>3 ± 2</td>
</tr>
<tr>
<td>Sum a + d</td>
<td>267 ± 44</td>
<td>235 ± 49</td>
<td>245 ± 31</td>
</tr>
</tbody>
</table>

Heart Rate (HR) values, reported as percentages of time spent in each considered zone, are reported in Figure 1. Mean HR max was 84.5±3.7% and 85.77±2.8% HR max (ES as Cohen d= -0.40) in elite and sub-elite respectively.

The values of the lactate blood concentration (mmol·L⁻¹) found in elite players during two matches were 4.3 ± 1.7mmol·L⁻¹ (range 2.7 – 8.8) in the first half (n=12 subjects) and 5.3± 2.7 mmol·L⁻¹ (range 1.9 – 9.8) in the second half (n=13 subjects).
4. Discussion

To our knowledge, this is the first study to investigate the physical performance and physiological parameters measured in field hockey players, competing at different level of qualification (elite vs. sub elite).

The mean HR, recorded during the matches, did not show any significant differences between the Italian elite (84.45 ± 3.70% HR\(_{\text{max}}\) ), sub-elite (85.77 ± 2.80% HR\(_{\text{max}}\) ) with a small to moderate ES.

Comparing the mean HR results of the elite Italian with the New Zealand hockey players as reported by Lithe and Kilding (2011) (85.3 ± 2.90% HR\(_{\text{max}}\) ) we found no significant differences, with a small ES (d=-0.25). So did the comparison made between the Italian sub elite and New Zealand hockey players, with a small ES (d=0.15).

Mean HR decreased from 85.61 ± 3.6% of HR\(_{\text{max}}\) to 83.3 ± 3.6% of HR\(_{\text{max}}\) between 1\(^{\text{st}}\) and 2\(^{\text{nd}}\) half (ES as Cohen d=0.64) and from 86.22 ± 2.3% of HR\(_{\text{max}}\) to 85.32 ± 3.2% of HR\(_{\text{max}}\) between 1\(^{\text{st}}\) and 2\(^{\text{nd}}\) half (ES as Cohen d=0.56) in elite and sub-elite respectively. Elite players spent 60.92% of the match above 85% of the HR\(_{\text{max}}\); sub-elite players spent 62.28% of the match above 85% of the HR\(_{\text{max}}\). These differences were not statistically significant (p=ns).

The mean VO\(_2\)\(_{\text{max}}\) values in Italian elite (55.79 ± 2.76 mL\cdot kg\(^{-1}\)\cdot min\(^{-1}\) ) and sub-elite (52.03 ± 2.45 mL\cdot kg\(^{-1}\)\cdot min\(^{-1}\) ) hockey players showed a large effect size (Cohen d=1.43) indicating possible practical implications, are similar to the Indian juniors and seniors.
players (54.4 and 53.8 mL·kg\(^{-1}\)·min\(^{-1}\)), as reported by Ghosh et al. (Ghosh et al., 1991), but lower than the values of the Ireland players (61.8 ± 1.8 mL·kg\(^{-1}\)·min\(^{-1}\)), and the Australian men's field-hockey team (57.9 ± 3.0 mL·kg\(^{-1}\)·min\(^{-1}\)), as reported by Boyle et al. (Boyle et al., 1994) and Spence et al. (Spence et al., 2005), with large Effect Sizes (Cohen d= -2.53 and d= -0.74) respectively.

Although the values of the maximal aerobic power measured and estimated in Italian players fall within the range reported in scientific literature (48 to 65 mL·kg\(^{-1}\)·min\(^{-1}\)) by several authors, these values appear to be consistently lower than those required for top level hockey players (excess of 60 mL·kg\(^{-1}\)·min\(^{-1}\)), as reported by some other authors (Boyle et al., 1994; Reilly and Borrie, 1992).

Based on the HR values recorded during matches, the mean oxygen uptakes during competitions were estimated (43± 3 and 41± 2 mL·kg\(^{-1}\)·min\(^{-1}\)), corresponding to 77 ± 5% and 79 ± 4% VO\(_{2}\)max in elite and sub-elite players, respectively. According to the above, the mean estimated energy expenditures during a match were 62 ± 1 and 58± 6 kJ·min\(^{-1}\). These values are greater than the ranges (30 to 50 kJ·min\(^{-1}\)) reported by Reilly and Borrie (Reilly and Borrie, 1992), and similar to those reported by Boyle et al. (Boyle et al., 1994) (83 to 61 kJ·min\(^{-1}\)). The total estimated energy expenditures during a match were 4368 ± 436 and 4042 ± 439 kJ, lower than 5190 kJ reported by Boyle et al. (Boyle et al., 1994).

The mean lactate values recorded in Italian elite players (4.9 ± 2.1 mmol·L\(^{-1}\)) were similar to those reported by Ghosh et al. (Ghosh et al., 1991) in junior (4.2 mmol·L\(^{-1}\)) and senior (5.6 mmol·L\(^{-1}\)) Indian players, showing that the intensity of hockey competition is high level.

According to the all above reported, elite field hockey might be considered as a sport with high energy expenditure (Boyle et al., 1994; Edgecomb and Norton, 2006; Malhotra et al., 1983), although the prediction of oxygen uptake through the heart rates, is based on a procedure that takes into account the constant speed of locomotion only. This approach probably underestimates the real energy expenditure, since different types of running, changes of sense and direction, and accelerations and decelerations are not considered (Osgnach et al., 2010; Lythe and Kilding, 2011; Reilly and Borrie, 1992).

This study compared the estimated total distances covered per match (ETD\(_{70}\)), in ETD\(_{35\text{h}}\) and ETD\(_{35\text{v}}\), and the estimated distances covered in different intensity zone, by each individual elite and sub-elite Italian hockey player. No statistically significant differences between groups were found (p= n.s.) .

Using the ETD\(_{70}\) the majority of the match distance was covered in low (61.24% and 61.29%, speed zones 1-2, ranging from 0.1 to 11 Km/h), and moderate intensity activities (33.30% and 33.18%, intensity zones 3-4, ranging from 11.1 to 19 km/h) by the elite and sub-elite players, respectively. Only 5.45% and 5.53% of the total distances were covered at high intensity (intensity zones 5-6, ranging from 19 to over 23 km/h), respectively.
Comparing the Italian elite players with the New Zealand elite players (Lythe and Kilding, 2011) we found no significant differences (one sample t-test; p=ns) when referring to the distances covered both in different intensity zones and in the total distance covered.

The average distances (m) covered per minute (m·min⁻¹) in the present study in elite (122.2 m·min⁻¹) and sub-elite (115.0 m·min⁻¹) hockey players are similar to those reported by others in hockey (116.6 m·min⁻¹) and in soccer (126.5 m·min⁻¹) (Di Salvo et al., 2007; Lythe and Kilding, 2011).

Players spent most of the match time in Speed Zone 1 and 2 (elite 80.02%, sub-elite 80.67% respectively), defined as low intensity zones (Lythe and Kilding, 2011). These results, along with other authors (Lythe and Kilding, 2011) seems to suggest that hockey, like other team sports, is mostly performed at low intensity.

Nevertheless this latter consideration is in contrast with the energy expenditure estimated during the matches (Reilly and Borrie, 1992 Reilly and Borrie, 1992).

For this reason we measured the number of accelerations (both positive and negative) greater than 1 m·s⁻² (512 ± 69 vs. 464 ± 103, in elite and sub-elite, respectively, with a symmetrical distribution between positive and negative phases) in players engaged in their respective matches, finding a difference between the groups of 9.34%. In particular, we find a statistically significant difference (p <0.05) between groups in relation to the class of acceleration equal to 1-2 m·s⁻² (both positive and negative), see Table 2.

The mean of accelerations was 7.3 and 6.6 events per minute, both positive and negative, in elite and sub-elite players respectively.

From the results we obtained we can make some considerations:

1. A relevant technical difference does exist between players belonging to the Italian elite and sub-elite levels as well as between Italian elite and New Zealand elite players, the latter certified by the different world ranking achieved (Italy 28°, New Zealand 7°, respectively); in the light of the obtained results, this qualitative difference seems to be determined almost entirely by the different level of technical and tactical skills mastered by these different groups of players.
2. Possible differences in physical and physiological characteristics between these groups, that nevertheless we presume to be more than probable, are not completely detectable through a traditional match analysis, based on the intensity zones approach, using a GPS technology.

Let us consider as an example the speed zone 6.1-11.0 km/h, usually defined as a “low intensity” zone. If we consider these values as the terminal velocity of an acceleration phase starting from a stationary position and lasting 1 second, we would obtain acceleration rates averaging from 1.66 to 3.05 m·s⁻², the latter considered significant in human locomotion (Osgnach et al., 2010). The approach based on the intensity zones
would report this phase as belonging to the “low intensity” domain, not providing the correct information about the real physical cost of this event (Reilly and Borrie, 1992). In accordance with the approach proposed by Osgnach et al. (Osgnach et al., 2010), who takes into consideration the accelerations and their metabolic costs in the whole economy of soccer matches, we think that in hockey as well, a similar approach would provide the key to detect the possible differences between elite and sub-elite players or international players achieving different level of qualification in the world ranking, besides the obvious differences described as technical and tactical different levels of mastery.

This study has some limitations that need to be underlined. We referred particularly to:

1) the sampling rate used by the GPS device (1 Hz) (Aughey and Falloon, 2010; Edgecomb and Norton, 2006; Gastin and Williams 2010).
2) Due to the small sample of the investigated matches (n=6), we were not able to analyze any differences in positional play or roles.

The new technologies of GPS and accelerometers might encourage the practitioners to adopt a different approach, based on acceleration that seems to be able to provide more detailed information and to discriminate better elite and sub-elite players.

5. Conclusions

Under a practical viewpoint this paper underlines the need to carefully take into consideration the importance of acceleration, both positive and negative, suggesting the opportunity to train this performance component using a ratio about or larger than eight accelerations per minute, higher than ±1 m·s⁻² as we found in our research.

Since we noticed a symmetrical distribution of the acceleration events, measured both as positive and negative (see table 2) any forms of specific training aimed at improving these two different abilities (sprinting, braking) should use exercising tasks as closer to the real game as possible:

- Shuttle sprinting over short distances, with and off the ball.
- Sprinting over short distance with change of directions (COD), with and off the ball.
- Small Sided Games.

According to the results we have obtained, the traditional match analysis approach, based on the intensity zones analysis, might not be the most appropriate method to determine the different physical and physiological demands in differently ranked players. The probable differences in physical and physiological parameters in this sport might be found in accelerations and their metabolic costs, which the intensity zones approach does not consider.
6. Acknowledgements

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7. References


