TIME-MOTION ANALYSIS AND PHYSIOLOGICAL DEMANDS IN INTERNATIONAL WOMEN'S TEAM HANDBALL

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Summary
We analyzed the horizontal movement pattern, including the sprint acceleration profiles, of individual female handball players of the Norwegian National Team and a German First League Team and the corresponding heart rates during a match. The results indicate that a high VO_{2max} appears to be important in top-level international women's handball. Sprint and endurance training should be conducted according to the specific demands of the player's position.

Keywords
Women's handball, heart rate, aerobic capacity, run velocity, acceleration

Introduction

In women's handball, data on movement patterns in combination with physiological demands are nearly nonexistent in the literature (Lidor et al. 2011, Manchado et al., 2011). In general, for sports science and professional disciplines, it is interesting and useful to investigate the movements imposed on players in sports games. Data on the distances covered by players, the velocities of their movements and their position in two-dimensional space during a game provide an important basis for the appropriate planning and distribution of load in training sessions, thus indirectly affecting the effectiveness of training (Erculj et al. 2008). In the past few years, a computer-vision system ("Sagit") using bird's eye video positioning has been developed and validated for the exact analysis of large-scale players' movements in sports such as handball (Pers et al. 2002). To date, this system has never been used for motion analysis of female handball players.

For about 20 years, highly developed aerobic performance, determined as maximal oxygen uptake (VO_{2max}), has been considered to be a fundamental basis for team handball on the international level (Platen 1989). This statement has been summarized for team sports in general in a recent review (Stone et al. 2009). It is astonishing that the handball-specific physiological demands have not been investigated systematically. Individual heart rate (HR) is a relatively easy-to-use parameter, especially since the development of the "Polar® Team System," which allows the storage of heart rate data in a transmitter that can be worn during competition without risk of injury. Continuous measurement of heart rates allows analysis of individual physiological demands during intermittent exercise, including team sports (McInnes et al. 1995, Achten et al. 2003). Only one study has investigated heart rates in female top-level handball players during competition so far (Manchado et al. 2007). This study reported a mean heart rate of 86 % of maximum heart rate with a broad variation of 75 % to 92 % between players. However, as no time-motion analysis was carried out during that study, interactions between movement patterns and physiological demands could not be determined. Therefore, the aim of this investigation was to exactly analyze large-scale movement patterns of top-level female handball players during a match in combination with the analysis of heart rate profiles as an indicator of individual physiological demands, and to deduce the influence of maximal oxygen uptake on these parameters.

Methods

25 handball players (25.2 ± 2.8 years, 67.8 ± 4.8 kg, 175.2 ± 6.3 cm) with different positions (3 goalkeepers, 9 backs, 8 wings and 5 pivot players) from a German First League team (n=11) and the Norwegian National Team (n=14) agreed to participate. VO_{2max} and maximum heart rate

(HR_{max}) were determined during an incremental maximum intensity test on a treadmill. We investigated the Norwegian National Team during one match of an international tournament, and the German First League team during a First League match. For the time-motion analysis of player's movements, we used the Sagit computer-vision system. In short, video analysis included video calibration, automatic tracking and manual corrections (using the videos from the side of the playing field for controlling players' movements), manual annotation (optional), export of trajectory data and annotations to the file or export of graphical diagrams of trajectories, velocity and acceleration (Pers et al. 2002). Horizontal movements in the game were identified and assigned to five arbitrary velocity categories: stand (0 $m \cdot s^{-1}$), walk (0 – 1.3 $m \cdot s^{-1}$), slow run 1.4 – 3.0 $m \cdot s^{-1}$), fast run (3.1 – 5.2 $m \cdot s^{-1}$) and sprint (>5.2 $m \cdot s^{-1}$). In addition to velocity, we also analyzed horizontal sprint accelerations of the players. The values for the acceleration categories were: $A1 < -4.5\ m \cdot s^{-2}$; $A2 \geq -4.5 < -3\ m \cdot s^{-2}$; $A3 \geq -3 < -1.5\ m \cdot s^{-2}$; $A4 \geq -1.5 < 0\ m \cdot s^{-2}$; $A5 \geq 0 < 1.5\ m \cdot s^{-2}$; $A6 \geq 1.5 < 3\ m \cdot s^{-2}$; $A7 \geq 3 < 4.5\ m \cdot s^{-2}$; $A8 \geq 4.5\ m \cdot s^{-2}$. One acceleration was counted whenever the player changed from one acceleration category to another. The summarized HR measure used was the mean heart rate and its individual equivalent as percentage of HR_{max} ($\%HR_{max}$). Individual demands were categorized into five intensity zones based on $\%HR_{max}$: zone I: < 70 %; zone II: 70 – 85 %; zone III: 85 – 90 %; zone IV: 90 – 95 %, and zone V: > 95 % of HR_{max} (Helgerud et al. 2001).

Results

Players of the Norwegian National Team had a significantly higher aerobic performance (VO_{2max}) compared to the players of the German First League team (mean of both teams: 53.1 ± 4.8 $mL \cdot kg^{-1} \cdot min^{-1}$; Norwegian team: 55.5 ± 3.9 $ml \cdot kg^{-1} \cdot min^{-1}$; German team: 50.2 ± 4.3 $ml \cdot kg^{-1} \cdot min^{-1}$; $p < 0.01$). Mean HR_{max} of all players was 194.8 ± 1.0 min^{-1}. Values did not differ between both teams. There were no position specific differences concerning VO_{2max} and HR_{max}. $\%HR_{max}$ during the match was 78.4 ± 5.9 % for the goalkeepers and 86.5 ± 4.5 % for the field players. We did not find any differences between the two teams, between the two halves of the matches or between field players with different positions.
No differences concerning the time spent in the different heart rate zones were found between the two teams in any of the heart rate zones (table 1). No position-specific differences between the field players could be detected. Among the field players, time spent in heart rate zones higher than 85 % of HR_{max} (Zones III, IV, and V) accumulated to more than 65 % with about 9 % spent in the highest intensity zone.

Table 1: Percentage of total time spent in the different heart rate zones of both teams for the whole match; values are means ± standard deviation; Zone I: <70%, zone II: <85%, zone III: <90%, zone IV: <95%, zone V: ≥95% HR_{max}

Both teams		
Field players (n=22)	Field players (n=22)	Goalkeepers (n=3)
	%	%
ZoneI	5.5±7.5	15.0±12.7
ZoneII	28.9±15.9	61.5±14.8
ZoneIII	24.1±11.6	20.5±24.7
ZoneIV	32.4±16.4	2.5±3.5
ZoneV	9.2±10.4	0.0±0.0

No significant differences could be detected between mean run distances, mean run velocities during the match, absolute values of run distances and the percentage of run distances spent in each velocity category of the field players between the two teams, between the first and second halves of the match, or between the different positions of the field players. Mean run distance of the field players was 2882 ± 1506 m, and 1377 ± 293 m for the goalkeepers. Sum of run distances was 5251 ± 242 m for all field players in one position, and reached 2066 ± 513 m for the goalkeeper position during one match. Mean run velocity of the field players was relatively slow with 70 $m \cdot min^{-1}$ (4.2 $km \cdot hr^{-1}$). The field players covered 961 ± 539 m (30.8 ± 5.9 %) walking, 761 ± 420 m (29.1 ± 3.8 %) slow running, 752 ± 484 m (29.7 ± 3.9 %) fast running, and 272 ± 224 m (10.5 ± 4.1 %) sprinting. The goalkeepers covered 950 ± 290 m (68.5 ± 10.2 %) walking, 358 ± 100 m (26.6 ± 8.7 %) slow running, 67 ± 37 m (4.7 ± 2.3 %) fast running, and 3 ± 2 m (0.2 ± 0.2 %) sprinting.

We found a significant positive correlation between aerobic performance (VO_{2max}) and mean run velocity during the match in the group of the field players ($r=0.48$, $p<0.05$) (figure 1).

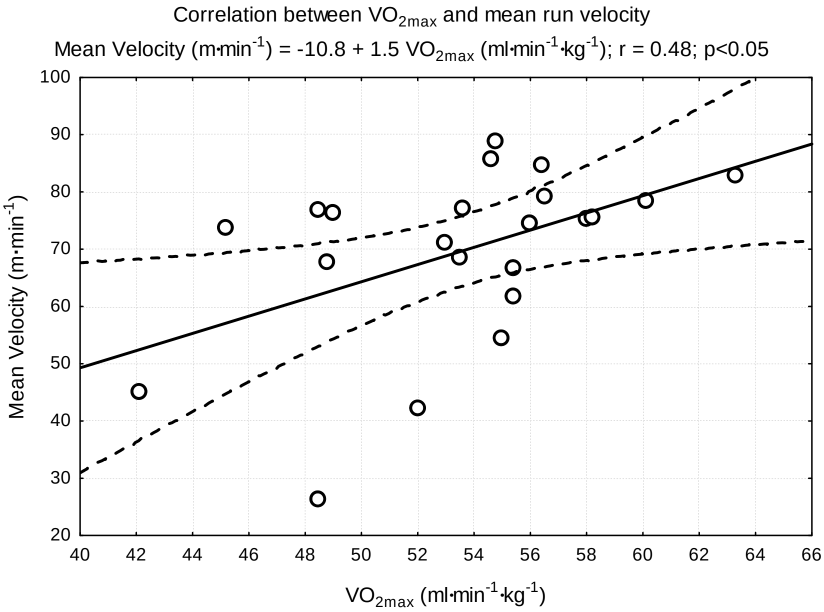

Figure 1: Correlation between maximal oxygen uptake (VO_{2max}) and mean run velocity during the match; only data of the field players are included.

Furthermore, VO_{2max} was negatively correlated with the percentage of the total distance covered walking ($r = -0.63$, $p<0.05$), while the percent values of the total distance covered for fast running and sprinting were both positively correlated with VO_{2max} (percent fast running (%): $r=0.50$, $p<0.05$, percent sprinting (%): $r=0.62$, $p<0.05$).

The division of all field players into two equal-size subgroups of either lower (< 54.0 $mL \cdot kg^{-1} \cdot min^{-1}$) or higher (> 54.0 $mL \cdot kg^{-1} \cdot min^{-1}$) VO_{2max} revealed a clear trend for a higher percentage of total distance spent sprinting in the players with a higher VO_{2max} (12.1 ± 4.8 % vs. 8.9 ± 2.4 %, $p=0.07$), while percentage of total distance spent walking tended to be lower in this subgroup (28.6 ± 4.4 % vs. 32.9 ± 6.5 %, $p = 0.08$). The two subgroups did not differ in their distances in the run categories “slow running” and “fast running”, in their mean $\%HR_{max}$, and in the percentage of time spent in the different heart rate zones.

The total number of accelerations per minute was quite high with an amount of nearly 200 as mean number of both teams. The Norwegian National Team had a significantly lower number of total accelerations as well as number of accelerations in most of the different acceleration categories as compared to the German First League team. There was no team effect on the number of accelerations in the different playing positions. There was, however, a clear position effect on the number of accelerations with the wing players showing the highest numbers of all positions, and the goalkeepers with clear trends towards a lower number in the high-acceleration

categories A1-A3 and A6-A8.
Mean duration in each acceleration category was significantly higher in the Norwegian team in nearly all categories as compared to the German First League team. There was no team effect on the duration in each acceleration category in the different groups of playing positions. The wing players of both teams had significantly lower duration values in the middle acceleration categories A3, A5 and A6 as compared to the back and pivot players, and the goalkeepers' values were similar to the duration values of the field players. Mean distance covered in each acceleration category was higher for the Norwegian National Team as compared to the German First League team in all but the fastest categories (A1 and A8), while there was no position effect on the distance in any of the eight acceleration categories beside the fact that the goalkeepers had lower distances in all eight categories.
We found significant negative correlations between individual VO_{2max} values and the number of accelerations per minute in nearly all acceleration categories, including the total number of accelerations per minute. Furthermore, we found significant positive correlations between VO_{2max} and the duration of and distance in nearly all acceleration categories, besides the highest and lowest categories (A1 and A8). Duration of the highest acceleration category A8 was negatively correlated with VO_{2max}.

Discussion

The individual run distances of the female players during the matches varied broadly between single players. This is at least partly due to remarkable differences the individual playing time. The longer a player is on the field, the more she runs. Mean run distance of the players was similar to the distance covered by male top-level players during the World Championship in 2007 (2702 ± 1497 m for the female players and 2939 ± 1404 m for the male players) (Luig et al. 2008). The men's World Championship matches were analyzed with the same motion-analysis technique (Sagit system) as in this investigation. Other studies also using the Sagit system reported a mean total distance averaging 1777 ± 264 m per game in adolescent male handball players (Chelly et al. 2011), while male adult professional players covered 4464 – 5088 m (Pers et al. 2001), and male national players 4700 – 5600 m (Sibila et al. 2004). Differences between studies are probably mainly due to differences in playing time of one single player. As no data corrected for playing time are available from these studies, no direct comparisons can be made. With an average of 5251 ± 242 m for all field players with the same position, however, the female top players of our study fit well with the run distances of elite male handball players.
The most important finding of the present study is that the running performance of elite female handball players during a match varied in close association with differences in individual aerobic physical capacity. The field players with a higher aerobic performance not only ran with a higher mean velocity during the match, but also sprinted more. Because of their higher endurance capacity, individual physiological reactions (e.g. heart rates) remained in the same range as compared to those of the players with a lower aerobic performance (about 86 % of HR_{max}).
To our knowledge, acceleration profiles during matches have never been analyzed in handball or any other team sports so far. Dividing horizontal movements into eight different acceleration categories revealed a high mean number of distinct accelerations per minute for the players of the two teams. With about 200 separate accelerations per minute, nearly three accelerations occurred per second. This finding suggests that top-level women's team handball is a game in which changes from one type of action to another are very frequent, and hence agility and speed are extraordinary important.
In our study we could demonstrate for the first time that acceleration profiles of horizontal movements in female top level handball players depend on aerobic performance. The fitter the players are, the fewer number of acceleration actions they have, but the longer they perform in all but the fastest of the different acceleration categories. This means that the fitter players are

characterized by “calmer” movements and longer-lasting constant accelerations as compared to the less fit players. Whether these acceleration characteristics are associated with better handball-specific performance has to be analyzed in further studies. We could also demonstrate that the wing players differed significantly from all other playing positions in their acceleration profile: their higher number of accelerations per minute and their lower duration in each category is also an indicator for less “calm” movement behavior. Furthermore, players in this position were characterized by a higher number of single sprints per minute, a longer duration of each sprint, and a longer distance covered during each sprint. Again, this finding has to be confirmed in further studies.

Conclusion

Our results clearly show the importance of a high aerobic performance in women’s team handball. Furthermore, wing players are characterized by remarkable differences in their acceleration and sprinting profiles as compared to other field players. This would mean that training programs should address 1) a superior level of aerobic performance and 2) the development of position-specific movement characteristics. Intermittent high-intensity endurance development must be carefully considered.

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