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A multivariate assessment of offensive performance indicators in Men's Handball: Trends and differences in the World Championships

Meletakos, P. [1], Vagenas, G. [2], & Bayios, I. [1]

[1] Division of Team Sports, Department of Physical Education and Sports Science, University of Athens, Greece.

[2] Quantitative Analysis, Division of Theoretical Sciences, Department of Physical Education and Sports Science, University of Athens, Greece.

Abstract

The purpose of the present study was to assess the relative importance of selected performance indicators in modern top-level handball through the analysis of offensive actions in three consecutive men's world championships (2005, 2007 and 2009). A total of 288 matches were examined, which included 29,439 throw attempts resulting in 16,240 goals. The results demonstrated the strong relationship between the six-meter and nine-meter offensive actions, as evidenced by their very high negative correlation coefficients in both the throw attempts and goals scored. The significant decrease of the throw attempts and goals scored from the six-meter position, evidenced in the 2007 and 2009 championships, is associated with the collateral significant increase of the nine-meter throws and goals. Interestingly, the nine-meter efficacy remained relatively constant throughout the three competition years, while the six-meter efficacy depicted a significant increase in competition years 2007 and 2009 compared to 2005, as a result of the appearance of highly qualified top ranking players in the pivot position. The high performance efficiency of these players resulted in adaptive defensive tactics to prevent the ball from reaching this key position. The present findings provide valuable information to handball coaches, in the design of their strategic and tactical plans.

Keywords: Men's Handball, offensive performance, World Championships

1. Introduction

Contemporary technological progress provides athletic coaches and researchers with the means of real-time recording and processing of sport games. Advanced analysis programs compute accurate and detailed spatiotemporal information regarding critical aspects (performance indicators) of the game (Hill, 1999). The results of these analyses can reveal critical information about the strong and weak points of sport teams (Alford, 1998; Bliss, 1998). The need for objective tools of assessing athletic performance at the individual and team level led to the increase of recording and analyzing sport games and events (Cooper and Siesentop, 1975; Mac Donald, 1985). Observing players and teams

during performance is essential for the design, organization, teaching, and training in team sports (Hughes and Franks, 1997; Hughes and Bartlett, 2002). The majority of the research in this area focus on those aspects of performance that substantially determine athletic success (Hughes and Barlett, 2002; O'Shaughnessy, 2006).

A number of published studies have examined performance indicators in team sports such as basketball (Akers et al., 1991; Kozar et al., 1994; Karipidis et al., 2001; Taxildaris et al., 2001; Ibanez et al., 2003; Trinic et al., 2002; Sampaio and Janeira, 2003; Sampaio et al., 2004; Sampaio et al., 2006), football (Hunges et al., 1988; Olsen, 1988; Hill and Hughes, 2001; Petit, 2001), volleyball (Palao, et al., 2004; Drikos, et al., 2009;) and rugby (Prim, et al., 2006). Differences between successful and non-successful teams or between national championships and higher level competitions are determined and relevant data are collected regarding the development of the sport, the choice of tactics, and the game profile of the competing teams.

In handball the relevant data are sparse, as only a few studies have employed performance indicators in determining changes, trends, and differences between winning and losing teams. Jadach (2005) examined a sample of 30 female handball matches, analyzed 41 variables of play, and established defense efficiency, offence and defense index of efficiency, and number of frontal attacks as the most significant of them. Rogulj (2004) studied 132 first league men's games and particularly differences in the prevalence of 19 elements of collective tactics between score efficient and inefficient teams. These elements were related to the duration, continuity, system, organization, and spatial direction of the attacks. His results showed that score the efficient teams were characterized by short continuous and position attacks of not more than 25 seconds. Two other studies set out to determine and analyse the factors of performance or situational efficiency in top level World Handball Championships (men and woman 2003) and their sample of predictor variables encompassed the shooting efficiency parameters across playing positions, the 7m-throws won, the technical errors committed, and the assist passes (Gruic et al., 2006; Ohnjec et al., 2008). Apparently, the existing database regarding handball performance is insufficient in permitting coaches and analysts of the game to establish definite criteria of performance optimization. In addition, the last three world championships have not yeat been analyzed in this resepct. Handball is in continuous evolution. Its rules have been drastically reformed over the last years to make the game faster (International Handball Federation, Playing Rules & Referees Commission, 2001 & 2005). This reform made the dynamics of play very demanding and as a general trend the game is characterized by fast play with increased number of goals scored per match (Taborsky, 2003; Meletakos and Bayios, 2010) as a result of a significant increase in the number of attacks per game due to significantly faster attacks (Spate, 2005). In turn these changes in modern handball rapidly led to a corresponding improvement in the development of the athletes' profile in terms of technical, tactical, and physical preparation abilities. The present study aimed at statistically investigating result related trends in international level handball. Specifically, proper multivariate methods were applied for the purpose of detecting potential differences and trends in selected performance indicators across the last three World Championships.

2. Methods

2.1. Sample

The sample consisted of the 288 matches played in the last three World Men's Handball Championships: Tunisia 2005 (86 games), Germany 2007 (92 games), and Croatia 2009 (110 games). Twenty four national teams participated in each competition. A total of 29439 throws were attempted in these matches and 16240 goals were scored (efficacy of 55.2%). The final sample consisted of 72 rows of data gathered from the 24 teams in each of the three competitions.

2.2. Procedure and Data

The raw data were the official box scores of the International Handball Federation (IHF), which employs a group of trained statisticians who use standard procedures for the in situ notational analysis of the matches that produces standard measures of the statistics of each match and each team. Reliability of the data from the official box scores was checked by an independent observer by means of re-analysis of the video-recordings of fifteen random games (five from each Championship), which included 1541 (5.23% of the total) throws. There was a perfect match between the number of throws and goals scored per game, while with regards to the category of the throws Cohen's kappa coefficient, which is completely equivalent to the intraclass correlation coefficient was 0.991. This result was expected, as it is highly improbable not to differentiate the category of the throw, consequently the very few discrepancies are probably due to incorrect data entries during the in situ recordings.

In handball, the throws attempted are characterized by the *position* and/or the *situation* under which the shot was executed. Thus, there are six different categories of throws, three positional and three situational. The categories that define the position from where the throw was made are the *six-meters*, *wing*, and *nine-meters*, while those that define the circumstances under which the throw was made are *penalty*, *fast break*, and *breakthrough*.

The full description of these six categories of throws is as follows:

1. *Six-meter*: throws from the pivot, from a zone outside the 45^0 angle from the left and right;
2. *Wing*: throws from within an angle of 45^0 left and right without a defense player in front;
3. *Nine-meter*: throws from a backcourt player either (a) over or through the defense, and (b) after a breakthrough but with another defense player in front;
4. *Penalty*: throws from the seven-meters line (penalty);
5. *Fast break*: throws attempted in fast breaks (until defense is organized);
6. *Breakthrough*: throws (a) from the backcourt players after breakthrough in the 9 m zone without a defense player in front, (b) of the pivot after 1:1 situation, (c) from the left or right back after breaking through 1:1 situations). For each team the following data were extracted and shaved: a) Total throws attempted (TTA), b) Total goals scored (TGS), c) Number of throws attempted for each of the six categories (TTA_i, where i is number of the throw category and ranges

from TTA_1 to TTA_6), and d) Number of goals scored for each of the six categories (TGS_i).

Based on these data three groups of six variables were computed:

a) Throws: percent (%) throws attempted (PTA_i) = (TTA_i / TTA)*100,
b) Goals: percent (%) goals (PGS_i) = (TGS_i / TGS)*100, and
c) Efficacy: percent (%) efficiency (E_i) = (TGS_i / TTA_i)*100.

It is evident from the above that $\sum_{i=1}^{i=6} PTAi = 100\%$ and $\sum_{i=1}^{i=6} PGSi = 100\%$.

2.3. Statistical Analysis

The 18 variables were initially subjected to full descriptive statistical analysis, including measures of central location and variation. No outliers were identified and the inspection of the respective histograms and box-plots revealed satisfactory compliance to distributional symmetry. This was verified by the Kolmogorov-Smirnov tests, which showed that deviations from normality were not statistically significant, as the respective z values ranged from z=0.411 (p=0.996) to z=0.877 (p=0.425).

The variables were also tested for multicollinearity. The inter-correlations among the six variables in each of the three groups were computed and assessed. The results showed that from the 45 correlations only one, that between PTA_1 and PTA_3 (-0.722), slightly exceeds the value of 0.70, which has been suggested as an indication for the presence of serious collinearity (Tabacknick and Fidell, 1989, Pallant, 2007). In addition, based on the estimated lowest tolerance (.43) and highest variance inflation factor (2.11) multicollinearity was assessed to be at acceptable levels according to empirical criteria (Aczel and Sounderpandian, 2002; O' Brien, 2007).

Each group of six variables (PTAs, PGSs, Es) was subjected to multivariate analysis of variance (MANOVA) with year of competition (three levels) as the independent variable (factor). For descriptive purposes, each significant MANOVA was followed by univariate F-tests for each of the six variables and post-hoc pairwise comparisons with Bonferroni corrections to detect significant pairs of differences between competitions. Statistical significance was tested at the α=0.05 probability of type I error rate. All analyses were conducted in PASW v.18.

3. Results

The ANOVA results for the overall team statistics (means and standard deviations of throws and goals per game and of total efficacy) for the three competitions are shown in Table 1. The F-tests for goals per game and for total efficacy were not significant ($p>0.05$), while that for the throws per game was significant ($p<0.05$). This difference was due to the difference between the 2007 and the 2009 competition, as confirmed by a post-hoc pairwise comparison ($p<0.05$).

Table 1. Comparison of team statistics between the 2005, 2007, and 2009 Men's World Handball Championships (N=72).

Total performance indices	Championship			Statistics	
	2005	2007	2009	$F_{2,68}$	p-value
Throws per game	50.6±2.5[ab]	52.5±3.1[b]	50.3±3.2[a]	3.90	0.026
Goals per game	27.2±4.7[a]	28.5±3.1[a]	27.6±3.9[a]	0.70	0.507
Total efficacy (%)	53.5±8.3[a]	54.4±6.3[a]	54.8±6.1[a]	0.20	0.819

Superscripts a & b: if different show a significant difference.

The results of the multivariate analysis of variance (MANOVA) with the six PTA variables (PTA_1 to PTA_6) as dependent (Table 2) revealed a significant multivariate effect for competition year (Wilk's $\Lambda = 0.488$, $F_{10,130} = 5.522$, $p < 0.001$.). Subsequent univariate analysis showed that the effect was significant ($p<0.05$) for variables PTA_1, PTA_3, PTA_4, and PTA_6. Specifically, there was a significant drop in the percentage of six-meter and penalty throws already at competition year 2007 in comparison to 2005, while the breakthrough throws were significantly reduced in the 2009 competition. All these significant reductions were counterbalanced by a significant increase in the percentage of nine-meter throws.

As the corresponding F-values show, most significant was the decrease in the six-meter throws ($F_{2,68}$=18.40, $p<0.001$), followed by the increase in the nine-meter throws and a corresponding decrease in the penalty throws ($F_{2,68}$=5.00, $p<0.01$). These results indicate the existence of a multivariate difference among the three championships when all six performance indicators were analyzed simultaneously, with only three of them, however, substantially contributing to this effect.

Table 2. Comparison of the six percentages of throws attempts (PTA's) between the 2005, 2007, and 2009 Men's World Handball Championship (N=72).

Performance Indicators	Championship			Statistics	
	2005	2007	2009	$F_{2,68}$	p-value
Six-meter throws (PTA_1)	27.1±9.8[a]	16.4±3.5[b]	17.5±3.7[b]	18.40	0.001*
Wing throws (PTA_2)	12.8±2.9[a]	12.4±3.2[a]	14.2±3.1[a]	2.20	0.114
Nine-meter throws (PTA_3)	33.2±8.7[a]	44.2±5.6[b]	43.6±6.3[b]	17.00	0.001*
Penalty throws (PTA_4)	8.7±1.8[a]	7.3±1.7[b]	7.1±1.3[b]	5.00	0.009*
Fast break throws (PTA_5)	12.4±3.9[a]	13.2±3.5[a]	13.2±3.2[a]	0.50	0.633
Breakthrough throws (PTA_6)	6.1±4.1[a]	6.3±1.8[a]	4.2±1.6[b]	4.40	0.015

Superscripts a & b: if different show a significant difference.

The results of the multivariate analysis of variance (MANOVA) with the six PGS variables (PGS_1 to PGS_6) as dependent (Table 3) revealed a significant effect for competition year (Wilk's $\Lambda = 0.482$, $F_{10,130} = 5.731$, $p < 0.001$). Subsequent univariate analysis showed that the effect was significant ($p<0.05$) for variables PGS_1, PGS_2, PGS_3, PGS_4, and PGS_6. As the corresponding F-values show, most significant was the increase in the nine-meter goals ($F_{2,68}$=21.00, $p<0.001$), followed by the decrease in the six-meter goals ($F_{2,68}$=11.50, $p<0.001$) and the decrease in the penalty goals ($F_{2,68}$=6.90,

p<0.01). Significance was also found at lower levels, for wing goals (F=3.40, p<0.05) and breakthrough goals ($F_{2,68}$=3.40, p<0.05), while no significance was found for fast break throws ($F_{2,68}$=0.30, p>0.05).

Table 3. Comparison of the six percentages of goals scored (PGS's) between the 2005, 2007, and 2009 Men's World Handball Championship (N=72).

Performance Indicators (DV's)	Championship			Statistics	
	2005	2007	2009	$F_{2,68}$	p-value
Six-meter goals (PGS_1)	27.8±8.5[a]	19.8±4.3[b]	21.1±4.8[b]	11.50	0.001*
Wing goals (PGS_2)	12.3±3.2[a]	11.8±3.6[a]	14.2±3.2[a]	3.40	0.040
Nine-meter goals (PGS_3)	22.8±5.9[a]	31.9±5.7[b]	31.5±4.1[b]	21.00	0.001*
Penalty goals (PGS_4)	11.8±2.3[a]	9.9±2.7[b]	9.3±1.1[b]	6.90	0.002*
Fast break goals (PGS_5)	16.9±4.8[a]	17.8±5.0[a]	17.7±3.7[a]	0.30	0.746
Breakthrough goals (PGS_6)	8.5±6.0[a]	8.6±2.8[a]	6.0±2.1[a]	3.40	0.041

Superscripts a & b: if different show a significant difference.

The trends in the percentages of goals scored apparently follow the pattern found in the percentages of throws. Actually, as Tables 2 and 3 show, the main differences are those observed in the six-meter and nine-meter throws and goals. An increase in the percentage of throws and goals scored from the nine-meter area is associated with a comparable decrease of throw attempts and goals scored from the nine-meter area. This observation is corroborated by the significant negative correlation coefficients between the six and nine-meter percentages of throw attempts (r=-0.722), as well as between the six and nine-meter percentages of goals scored (r=-0.576).

The multivariate analysis of variance (MANOVA) with the six efficacies (E_1 to E_6) as dependent variables (Table 4) revealed a significant effect for competition year (Wilk's $\Lambda = 0.629$, $F_{12,126} = 2.744$, $p < 0.001$). Subsequent univariate analysis showed that the effect of competition year was significant only for the six-meter efficacy ($F_{2,68}$=9.30, p<0.001). This efficacy was increased by 10% in competition year 2007 in comparison to 2005, and remained high in 2009.

Table 4. Comparison of the six efficacies (E) between the 2005, 2007, and 2009 Men's World Handball Championship (N=72).

Performance Indicators (DV's)	Championship			Statistics	
	2005	2007	2009	$F_{2,68}$	p-value
Six-meters (E_1)	55.9±9.8[a]	65.9±10.7[b]	66.1±6.2[b]	9.30	0.001*
Wing (E_2)	51.7±9.7[a]	51.5±9.6[a]	54.7±7.1[a]	1.00	0.383
Nine-meters (E_3)	37.0±7.8[a]	39.3±6.7[a]	39.9±6.8[a]	1.50	0.238
Penalty (E_4)	72.0±9.3[a]	73.0±8.9[a]	71.2±8.6[a]	0.30	0.752
Fast break (E_5)	73.5±9.3[a]	72.7±8.0[a]	74.1±7.4[a]	0.20	0.840
Breakthrough (E_6)	80.5±12.4[a]	74.6±10.0[a]	79.7±9.6[a]	2.10	0.131

Superscripts a & b: if different show a significant difference.

An overall picture of the changes of the percentages of throw attempts, goals scored and efficacies from the six and nine meter positions at the three World Championships is shown in figure 1.

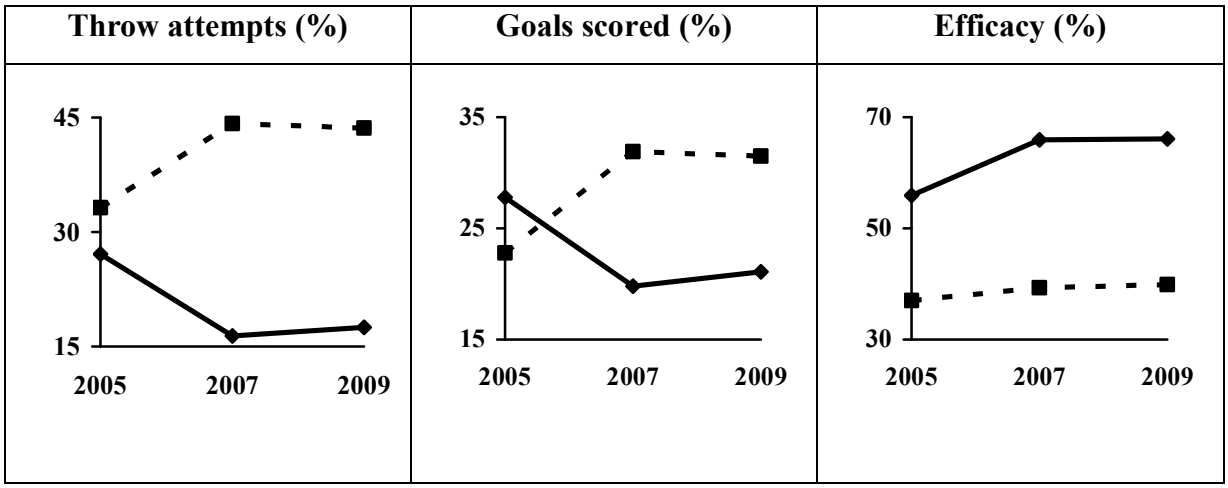

Figure 1. Mean values of the percentages of throw attempts, goals scored and efficacies from the six (continuous lines) and nine (dotted lines) meter positions at the three World Championships.

4. Discussion

The three groups of performance indicators examined in the present study represent a comprehensive set of properties that reflect recent developments and trends in the offensive profile of world level handball. The throws attempted, the goals scored, and the efficacies of the teams that participated in the last three World Championships constitute a rich database for future comparisons. For the present is clear that these three Championships are the best available sample so far for identifying and testing critical changes in men's world level handball. This sample of games is undoughtedly valid in this aspect. However, due to lack of previous relevant data, its validation in terms of the descriptive statistics is at risk. From the few existing relevant studies our percent estimates grossly agree with those of Gruic (2006). In this study a sample included all the teams that participated in the 2003 World Championship, and an average of 51 throws per game and per team was found, with efficacy being at 53.2%.

The multivariate inferential findings indicate the definite importance of the offensive actions taken from the six- and nine-meter positions. This was evidenced in both the throw attempts and the goals scored that expressed a significant drop in the six-meter throw attempts along with a corresponding rise in the nine-meter throw attempts. Grossly, the same trend of relative importance was observed for the six- and nine-meter goals scored. On the other hand, while the nine-meter efficacy remained relatively constant, the six-meter efficacy presented a significant increase over the three championships (2005 to 2009).

This finding must have at least partially to do with the progressive appearance of highly qualified top ranking players in the pivot position, which is the most critical for the final outcome of the game. In this respect, Spate (2005) analyzed a sample of teams from the 2003 World Championship and the 2004 Olympic Games and concluded that playing via the pivot position is the most successful form of attack. Similarly, Gruic et al. (2005) found that the pivot and wing positions in women's top level games play a significant role in the team's success, which is in partial accordance with our results. Thus, it appears that world level competitions are characterized by the key role played by the pivot in handball, as evidenced by high effectiveness not only in the throws attempted but also in the goals scored under various playing situations. This is because "*pivot actions like blocking, running behind, and pulling across give rise to scoring opportunities for other players or help the team to achieve numerical superiority*" (Spate, 2005).

The high performance efficiency of these players usually results in adaptive defensive tactics to prevent the ball from reaching this key position. With reference to the tactical profile of men's teams competed at the 2004 Olympic Games, the 6-0 and 5-1 are currently the most adopted defense systems (Johansson and Spate, 2004). The application of defensive tactics at the six-meter line forces the attacking team to make more throw attempts from the nine-meter positions. A high percentage of goals are scored by back court players (nine-meter positions) and a relatively low percentage of goals are scored from other positions (six-metre and wing) or situations (penalty, fast break and breakthrough). Thus, the existence of players capable in scoring, with a wide choice in shooting, excellent technical and tactical skills when confronting the opposing team's defence and goalkeeper, and a high ability to collaborate with the pivot are important characteristics of contemporary handball.

Defensive tactics near the six-meter line are also important for the teams' effectiveness during the game. This is supported by the significant drop in the throw attempts and goals scored found in the present study for breakthrough situations. Moreover, since penalties are more often committed against offensive actions near the six-meters, and given that these offensive actions have decreased significantly, the significant decrease in the committed penalties must also be a consequence of the choice in the defensive tactics. On the other hand, a tendency for a fast pace and the increasing use of the element of fast breaks as a tactical choice by teams, is also equally important (Johansson, 2004; Spate, 2005). Our results show that there are no significant differences in fast break situations for percent throws, percent goals, and efficacy. In a similar study Spate (2004) analyzed a sample of teams from the 2004 Olympic Games (men's tournament) and estimated the goals scored at 18.5% and the relative efficacy at 76.5%, which are close to our results. The fact that there were no significant differences in the percentage of throw attempts and goals scored under fast break situations in the three World Championships analyzed in our study shows that fast breaks are not that effective in reality as believed by coaches, at least in world class handball. There is a possible explanation for this finding, as the opportunity for a fast break depends on both teams. Usually a fast break is possible when the team in offense commits a technical fault or has an ineffective shot and displays an delayed return to defensive positions. The fast break situations (PGS & PTA) have remained relatively constant in our study. Thus, even though ball acquisition is the aim of defensive systems (Spate, 2005), this

finding may be a sign that today's world level teams are of a high standard, both technically and tactically. Overall, it appears that the changes witnessed in the game over the last years should be viewed with respect to other factors, which may influence the performance of the players and teams. Milanovic (1997) has stressed the potential importance of anthropometric and specific physical fitness features, as well as of the level of technical and tactical proficiency of the players. In this respect, future studies should focus on these factors along with the athletes' professionalism, the degree of competiveness during the championships, and the potential impact of refereeing on the progress and development of mens' Handball.

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