# COMPETITIVE DEMANDS OF ELITE HANDBALL

*– Written by Claude Karcher and Martin Buchheit, France*

## INTRODUCTION

Team handball has received growing interest during the past decades[1]. Understanding the technical and physical demands of the sport is essential for talent identification, injury prevention and the design of position-specific training programmes both in developing and professional players[2–6]. To date, on-court physical and physiological demands during games have been only partially reviewed[7] and the influence of playing positions on these demands has been overlooked. In this review – a condensed summary of our previous work[8] – we attempt to present recent knowledge from both the scientific and technical literature on the various technical, tactical and physical aspects of elite team handball performance, with a special emphasis on positional demands. The data reviewed in this article are limited to elite male players (that is, those competing in the strongest leagues in Europe and/or during international championships). Playing standard, country league[9] and gender[10] are likely to modify game demands and thus deserve more specific analyses in the future.

## GAME DYNAMICS

Attack phases are split into two distinct phases: counter-attack and attack build-up. A counter-attack is the phase during which the attacking team tries to overtake the recovery phase of the opponent team, once the ball is lost (e.g. a successful defensive sequence, save from the goalkeeper or technical fault of the opponent attackers). Attack build-up phases occur when the counter-attack is unsuccessful, but the attacking team still possesses the ball.

Although not representing the greatest proportion of ball possessions (12% ±6; range 0 to 32%), counter-attacks (both their number and effectiveness) are highly determinant for game outcomes[9]. It is important to realise that the actual number of counter-attack attempts is likely to be higher than reported because counter-attacks are generally not recorded when the defending team manages to avoid a shoot with a good recovery phase. Attack build-up phases represented the largest proportion of ball possessions during the 2012 European Championship (88% ±6; range 68 to 100). The low percentage of success in this phase (47% ±4; range 39 to 60) illustrates the importance of defensive phases and goalkeeper performance for game outcomes[11]. The number of ball possessions has remained relatively stable during the past years, with 56±4 attacks per game reported in the 2008 Olympic Games[12] and 53±4 (range 44 to 67) in the 2012 European Championship. In some games (such as German professional league), more than 80 ball possessions are sometimes observed[13]. This means that, on average, defence and attack phases alternate every ~22 to ~36 seconds.

There are six different playing positions on the court (Figure 1), based on player location on the field during either offensive phases (left wing, left back, centre back, right back, right wing and pivot) or defensive phases (players are counted from the side to the centre of the field). Goalkeepers play in a dedicated zone (Figure 1), and each position has its own specificities. Pivots play in the smallest area (~12 $m^2$) and are between two defenders most of the time. Wings play in an area of ~15 $m^2$, while backs and centre backs play in wider spaces (~64 $m^2$). The technical demands for each position are described in Table 1.

PLAYING POSITION TECHNICAL ANALYSIS

Technical demands are summarised in Figure 2. Backs use their shoulders more than wings and pivots for shooting and passing (Table 1). These movements are likely to stress the shoulder joints[14], which suggests that appropriate training must be implemented for these players (such as rotator cuff training)[15].

Clasping and checking are only allowed in certain conditions and are an important part of defensive phases in handball. The tactical role of each position generates numerous body contacts and one-to-one situations. During games in the Danish first league[15], pivots were more involved in contacts than backs, while wings were the least engaged in these actions (Table 1).

The technical demands of goalkeeping have been overlooked in the scientific literature, despite goalkeeper performance being a key factor in the final results of games[16]. Interested readers are referred to coaching books[17] that highlight the specific technical requirements and strong need for flexibility and excellent hand-eye co-ordination capacity, rather than strength and/or hypertrophy for this position.

MOTION ANALYSIS

The average running pace in handball (53±7 to 89.9±9 m.minute$^{-1}$[8]) is lower than in rugby[18], basketball[19], Australian Rules football[20] or soccer[21–23]. Various factors may explain these differences, including pitch size, player number and specific tactical/technical organisation. There is a lack of homogeneity in the time-motion analyses

**OVERALL PLAYING POSITION DEMANDS**

| *Position* | | *Back* | *Pivot* | *Wing* | *Goalkeeper* |
|---|---|---|---|---|---|
| *Technical demands* | *Shoot* | •••• | •• | •• | |
| | *Pass* | •••• | • | ••• | |
| | *Contacts-duels* | ••• | •••• | •• | |
| *Motion analysis* | *Running pace* | ••• | •• | ••• | • |
| | *Low-intensity movements* | •• | ••• | •• | •••• |
| | *Moderate-intensity movements* | •••• | •• | • | •• |
| | *High-intensity movements* | ••• | •• | ••• | • |
| *High-intensity actions* | *Sprints* | ••• | •• | •••• | |
| | *Total* | ••• | ••• | • | |
| *Relative intensity distribution (physiological load)* | *Low* | • | • | •• | ••• |
| | *Moderate* | •••• | •• | ••• | •• |
| | *High* | ••• | •••• | •• | • |
| *Need for player rotations* | | •••• | •••• | •• | •• |

**Table 1:** Overall playing position demands. The magnitude of playing position demands with respect to technical activities, distance covered, high-intensity actions and physiological load variables is rated from low (•) to very high (••••) based on the data presented in the review (Table 1-2, Figure 1-4). Mod=moderate.

with respect to tracking systems in the literature (video analysis or hand notation, speed zones or the consideration of players' substitution[8]). Despite these limitations, we have merged data related to playing position with hand notation (Figure 3) to provide a basis for the understanding of on-court demands during games[24].

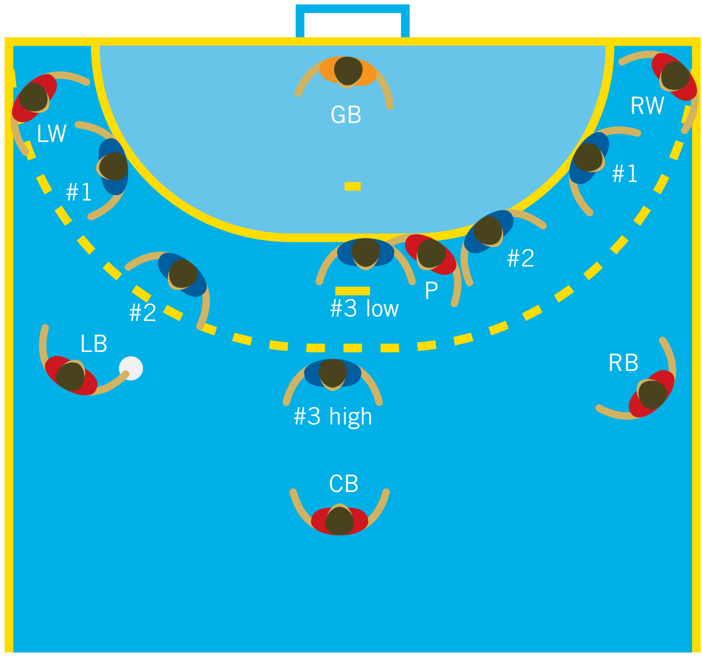



**Figure 1:** Playing positions on the court in attack build-up phases with a 5-1 defensive disposition (players are counted from the goal line to the middle). Attackers are in red and defenders in green. Defenders are numbered from the side to the centre. LW=left wing, LB=left back, CB=centre back, P=pivot, RB=right back, GB=goalkeeper.

*Position-related analysis*

Studies reporting between-position differences in running demands have shown very large disparities for wings and backs[8], with some studies demonstrating no consistency in the position classification between backs and wings[24,26–28]. These differences are likely to be related to game nature (player rotation allowed or not), playing standard, tactical systems and tracking systems[8]. Data are more consistent for pivots[24,26–29], indicating that they generally run less than all other outfield players. Goalkeepers obviously cover the least distance and have a different profile to all other players[8].

In addition to the distance covered, the occurrence of particular movement patterns and time spent in specific speed zones are useful to examine the demands of the different playing positions and eventually to adapt training contents (Table 2). When considering these criteria, the observation was made in the Portuguese league (Figure 3) that backs run moderately more than pivots and much more than wings[24]. Pivots are much more involved in very low intensity actions than the other players[24].

*High-intensity runs and actions*

In the present review, high-intensity running includes the fast running categories and sprints. These high-intensity runs are generally crucial for game outcomes (e.g. sprinting to win a ball or sprinting during counter-attacks) and have significant physiological effects. For example, they can trigger neuromuscular fatigue[30] or inflammatory responses[31] and can deplete glycogen when repeated[32]. The exact number of sprints during games and their occurrence with respect to playing positions remains unclear

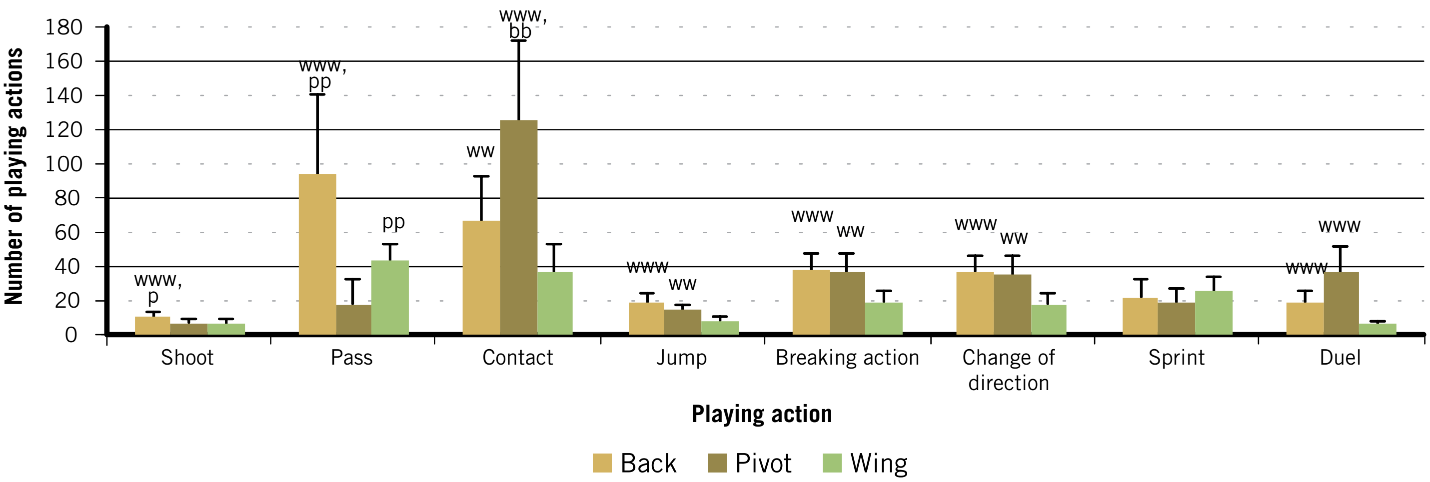



**Figure 2:** Number of high-intensity actions related to playing positions in attack and defensive phases and in high intensity motor action (group means ± SD). Standardised differences in high-intensity actions between positions are interpreted using Hopkins' categorisation criteria, where 0.2, 0.6, 1.2 and >2 are considered small, moderate, large and very large differences, respectively[55]. The letter (b) stands for substantial standardised difference vs backs, (p) vs pivot and (w) vs wings. The magnitude of these standardised differences between the different positions is indicated by the number of letters: 1 letter stands for a moderate difference, 2 for a large difference, 3 for a very large difference. Data were merged from different studies: passes from Dott[47] shoots, contacts from Michalsik et al[15] and jump, breaking action, changes of direction, sprints and duels from Povoas et al[24].

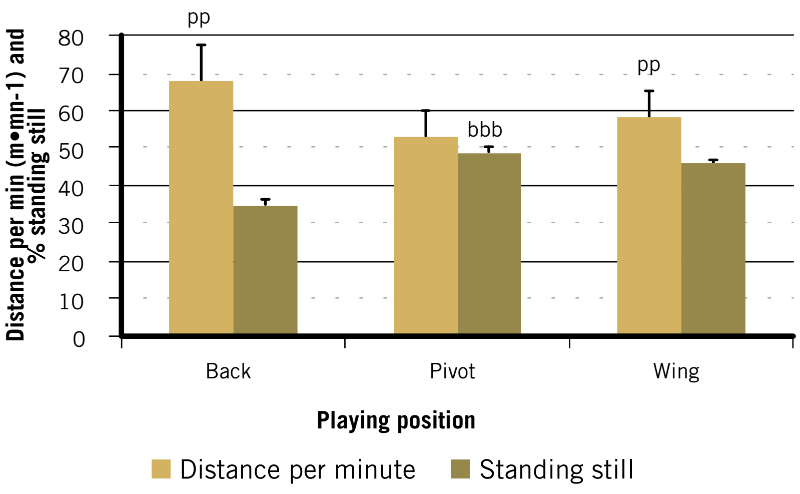
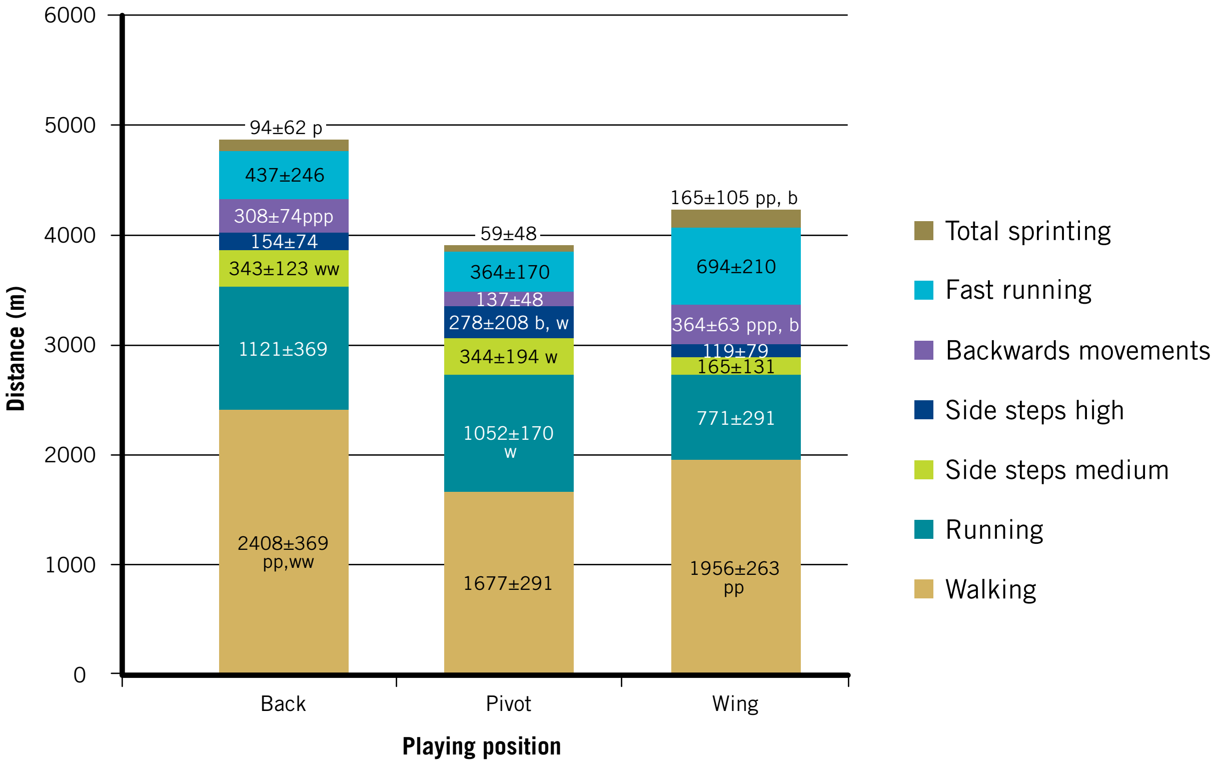



**Figure 3:** Time motion analysis for backs, pivots and wings in 10 Portuguese league games. Data retrieved from Póvoas et al[24]. Motion patterns were defined following Bangsbo's criteria[56]. Standardised differences in high-intensity actions between positions have been calculated and interpreted using Hopkins' categorisation criteria, where 0.2, 0.6, 1.2 and >2 are considered small, moderate, large and very large effects, respectively[55]. The letter (b) stands for substantial standardised difference vs backs, (p) vs pivot and (w) vs wings. The magnitude of these standardised differences between the different positions is indicated by the number of letters: 1 letter stands for a moderate difference, 2 for a large difference, 3 for a very large difference.




due to considerable differences in sprint definitions in the literature[8].

During elite Portuguese games[24], the differences between positions were small to moderate, while during the 2007 World Championships, the differences were more significant[26]. Pivots were shown to cover sprints over 5 to 7 m, backs were over 8 m and wings were over 15 to 18 m[26]. Wings sprinted more than backs and pivots, but the difference was small. These results have direct implications for the design of position-specific sprinting drills (Table 2).

In this review, high-intensity actions refer to high-intensity activities other than high-intensity running, such as jumps, stops, changes of direction and duels. Despite their very short duration, these actions are important to consider because they require high levels of strength and speed. Figure 2 shows their occurrence for each position in elite Portuguese players. Backs and pivots perform significantly more high-intensity actions than wings. Pivots perform many more duels than backs. These differences are most likely to be the result of position-specific tactical demands (Section 2) and have direct implications for position-specific training programmes (Table 2).

*Repeated high-intensity runs and actions*

Despite their importance for specific training prescription, data on the work-recovery ratio of high-intensity runs and actions during games are scarce[8]. Knowledge of the mean recovery duration alone is limited to examine effort distribution because it is likely that some repeated sprint/high-speed action sequences also occur with shorter recovery periods between efforts, as found in soccer[33-35].

Recovery time might not differ greatly between playing positions. In the study by Povoas et al[24], which is to our knowledge the only on this topic, 67±22% of the

## Table 2

| Physical quality | Main training orientation / rationale | Position | | | |
|---|---|---|---|---|---|
| | | Back | Pivot | Wing | Goalkeeper |
| Strength | Main objective | Hypertrophy - explosivity - Maximal strength | Hypertrophy | Explosivity | Explosivity-reactive strength |
| | Rationale | To develop jumping, sprinting, shooting abilities and better tolerate contacts and duels (Figure 2). | To better tolerate contacts and duels (Figure 2). | To develop jumping and sprinting abilities (Figure 2). | To improve reactivity and quickness |
| Speed | Main exercise format | 10 to 15 m | 10 m | 20 to 30 m | Specific movements |
| | Rationale | Shorter average sprinting distance (Figures 2, 3) | Shorter average sprinting distance (Figures 2, 3) | Longer average sprinting distance (Figures 2, 3) | No need for proper running speed (Figures 2, 3) |
| Metabolic function | Main exercise format | 30 s-30 s ; 20 s-20 s | 15 s-15 s | 10 s-20 s / 5 s-25 s/ sprint repetitions | 15 s-15 s – 30 s-30 s |
| | Rationale | Adjusted on the average activity time and attack/ defense ratio (Figures 2, 3) | Adjusted on the average activity time and attack/defense ratio (Figures 2, 3) | Adjusted on the average activity time and attack/ defense ratio (Figures 2, 3) | Reproducing game activity patterns does not allow to stimulate the cardiorespiratory system at high intensity, so other generic forms of intervals have to be considered – exercise modes can be modified as well for these players not used to running e.g., bike (Figure 3) |
| Injury prevention | Main muscle group | Rotator cuff | Core muscles | Hamstrings | Elbow - shoulder muscle - |
| | Rationale | To support the large number of passes and shots (Figure 2) | To support duels and contacts (Figure 2) | To prevent muscle strain due to high speed running (longer strides) (Figures 2, 3) | Prevent hyperextension of the elbow during ball impacts |

> **Whether physical fatigue does occur substantially during games remains unclear because, in the majority of studies, games were not examined under real competitive situations**

recovery periods between high-intensity runs lasted more than 90 seconds for backs; for wings, this was 63±18% of the recovery periods and for pivots this was 57±24% of the recovery periods. Similarly, 18±16% of recovery periods lasted from 0 to 30 seconds for backs, 17±13% for wings and 19±17% for pivots. Thus, the profile of position-specific repeated high-intensity actions is still unclear and further research is needed. Nevertheless, the data suggest that the time and activity between the vast majority of high-intensity actions (>60%) is probably sufficient for phosphocreatine resynthesis to occur, irrespective of playing positions (if we consider that phosphocreatine is recovered at 50 and 100% within 20 and 90 seconds, respectively[36,37]). Further research is required to examine more specific locomotor patterns (accelerations and changes of direction) and technical actions both during the attacking and defensive phases in order to complete the overall profiling of game demands[38].

**Table 2 (previous page):** Playing position-specific training recommendations for handball players with regard to technical, motion analysis and physiological demands presented in the review. For each physical quality (strength[57-59], speed[60], cardiorespiratory function[61] and injury prevention[62]), the first line shows the main training objectives, while the second line shows the rationale for the suggested training recommendations. s=seconds.

## PHYSIOLOGICAL DEMANDS

Playing handball requires a large number of high-intensity actions (Figure 2) and could lead to acute neuromuscular adaptations and subsequently to decreased neuromuscular performance[30]. Collisions and contacts are also known to increase indicators of muscle damage[39] and may further impair neuromuscular performance[40]. The progressive accumulation of muscles' bi-products can affect muscular contractility and impair neuromuscular performance throughout a game[41]. Despite the limited available data, it is reasonable to state that playing handball places large demands on the neuromuscular and musculoskeletal systems.

Handball triggers largely anaerobic glycolysis[37,42,43]. However, to date, the only available data examining the anaerobic glycolytic system contribution during games are limited to blood lactate measures, which are not without limitations[44,45]. Nevertheless, this study provides the available blood lactate values as a starting point to understand the anaerobic glycolytic requirements of the game. Blood lactate values were 3.7±1.6 $mmol.l^{-1}$ after the first half of the game in adult elite male Danish players[29] and 4.2±2 $mmol.l^{-1}$ (range 1.6 to 8.6) throughout the first half of the game in adult elite Portuguese players[24]. During the second half of the game, blood lactate were 3.1±1.8 $mmol.l^{-1}$ (range 1.3 to 8.4) during an elite Portuguese game[24] and 4.82±1.89 $mmol.l^{-1}$ during an elite Danish game. In line with the large between-position differences in match activity patterns (Figures 2 to 4), anaerobic glycolytic contribution would also be expected to differ between positions. However, this still requires investigation with a larger sample of players.

Game duration (individual playing time per match: 32 to 53 minutes[26,27]) and the repetition of high-intensity runs and actions in combination trigger aerobic metabolism at high levels. While oxygen uptake ($\dot{V}O_2$) assessment is the most valid tool to examine aerobic demands, there is to date no $\dot{V}O_2$ data from during real games. Since heart rate (HR) measures might not perfectly reflect $\dot{V}O_2$ responses during handball play[46], we recommend interpreting HR as actual cardiac work, rather than trying to extrapolate this to $\dot{V}O_2$ values.

Regarding motion patterns HR responses indicated large between-playing position variations in elite Portuguese handball

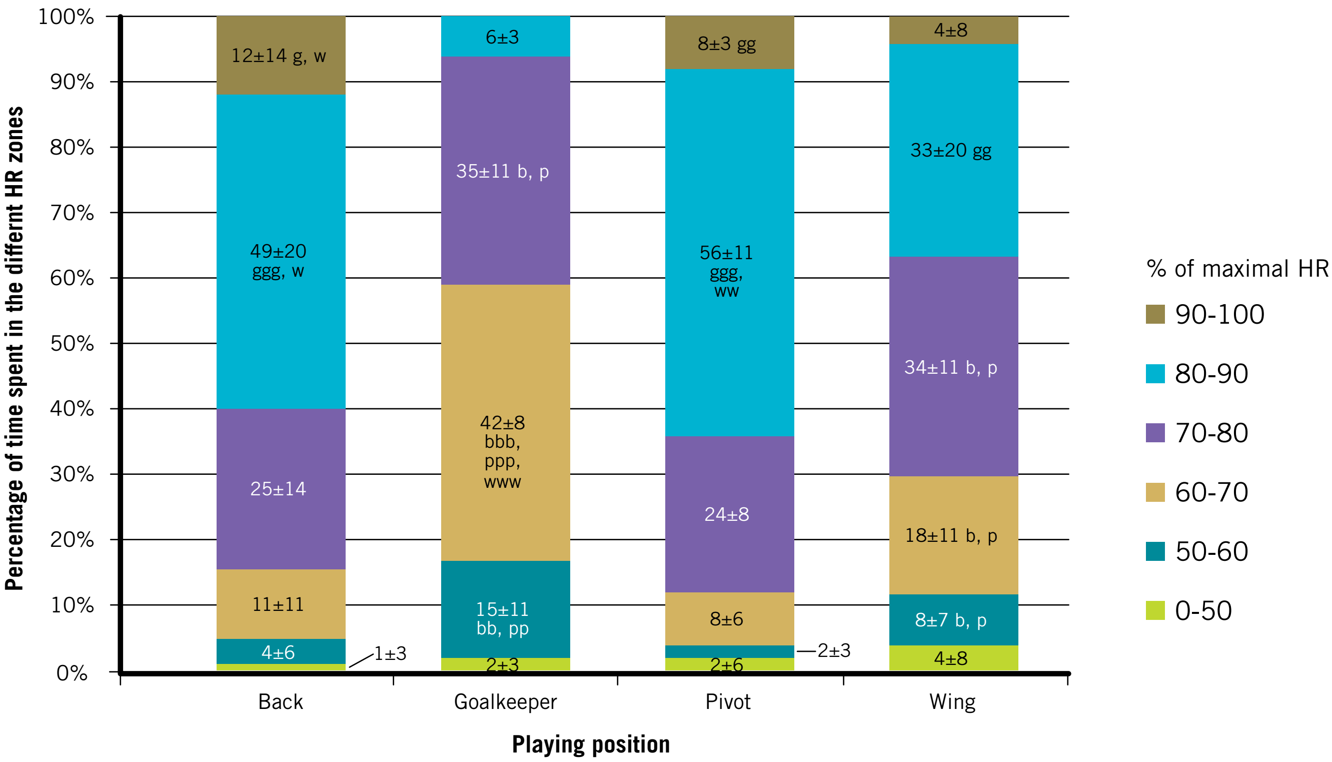



**Figure 4:** Heart rate (HR) responses during a Portuguese first league match expressed as a percentage of maximal HR (group means). Standardised differences in high-intensity actions between positions are interpreted using Hopkins' categorisation criteria, where 0.2, 0.6, 1.2 and >2 are considered small, moderate, large and very large effects, respectively[55]. The letter (b) stands for substantial standardised difference vs. backs, (p) vs pivot and (w) vs wings. The magnitude of these standardised differences between the different positions is indicated by the number of letters: 1 letter stands for a moderate difference, 2 for a large difference, 3 for a very large difference. These data have been retrieved from Povoas S. Estudo do Jogo e do Jogador de Andebol de Elite: Universidade do Porto; 2009.

(Figure 4). The goalkeepers showed the lowest HR demands, with ~60% of the time spent <70% HRmax and no time spent >90% HRmax. Wings spent the largest part of their time in the 70 to 80% and 80 to 90% zones (~30% in the two intensities), while backs and pivots spent more time in the 80 to 90% zone. The greater cardiac demands observed for these two latter positions (at or close to HRmax) suggest that there should be greater emphasis on cardiopulmonary function during training (Table 2), and/or that different rotational strategies should be implemented during games to prevent excessive fatigue development.

## PLAYER ROTATIONS AND FATIGUE OCCURRENCE DURING GAMES

In contrast to soccer, player rotations in handball are unlimited and can occur at any time during games. Despite some exceptions (such as Icelandic left wing Guðjón Valur Sigurðsson, who played all six games for his team during the 2012 European Championship), playing >90% of the total time during an international competition is not typical. For instance, only nine players (~3% of the players involved in the competition) played more than 90% of total game time during the 2012 European Championship; 14% played for more than 75%; 25% played between 75 to 50%; 34% played between 25 to 50% and 28% played between 0 to 25%[11].

At the elite level, mainly for strategic reasons, some players rotate at almost every ball possession (i.e. some players have only a defensive role, while others have only an offensive role). For example, in a French first league team (SC Sélestat, 2002), the average game rotations were 26±7 for pivots[47]. Playing time could be accumulated either continuously or intermittently (i.e. via the successive defensive phases for specialist players). To our knowledge, despite the potentially significant consequences of rotation strategies on technical activities and match running performance during team sport games[48], the effect on fatigue development has never been investigated in handball. During the 2007 World Cup (~170 players), wings (n~40; 38±2 minute) and goalkeepers (n~20; 37±3 minute) played significantly more than backs (n~60; 29±2 minutes) and pivots (n~25; 30±3 minute). This playing time distribution confirms the position-specific demands that were previously highlighted, which suggest that the wing and goalkeeper positions are less demanding than the back and pivot positions.

As aforementioned, the work recovery ratio between most high-intensity actions may allow sufficient recovery to maintain the performance level of the majority of these actions. Whether the decreased occurrence of high-intensity activities and HR[29,49] observed during the second vs first half of a game results exclusively from fatigue or more from changes in game dynamics, is unclear. For example, the importance of the final issue may force players to reduce the game pace, while disciplinary sanctions and team time out are generally more frequent during the second half of the game.

A small number of studies have considered fatigue related to playing position, however these studies' inclusion criteria were questionable[27,30] and the players' rotations were not considered[26,49].

Therefore, it is possible that the occurrence of fatigue during handball games may have been overestimated. We also suggest that the nature and occurrence of fatigue in a game are likely to be dependent on the playing position, as suggested by the differences in the positions' technical and physiological demands and total playing time[26]. Finally, our field experience suggests that coaches managing the rotation of players in an appropriate manner could actually avoid the excessive physiological loading of the players, thereby preventing fatigue appearance and improving player efficiency throughout the game.

## LIMITATIONS OF CURRENT GAME ANALYSIS AND IMPLICATIONS FOR FUTURE RESEARCH

There are many defensive systems (man-oriented defence, ball-oriented defence and mixed defence) and many player repartitions on the field (e.g. 5-1, 6-0 and 3-2-1). For example, for a given playing position in the field, the defensive role can change substantially based on tactical variations. In Croatian elite players, when comparing two playing positions (playing #1 in a 0-6 ball-oriented defence and defending #2 in 3-2-1 defence), player #1 is required to cover a much larger distance (4880±112 m vs 5270±274 m, respectively) with greater physiological demand (mean HR: 166 bpm vs 158 bpm)[50]. Similar effects of team structure or playing systems have been reported in other team sports[51,52].

Moreover, in all time-motion and physio-logical analyses to date in handball[10,24,26–28,49,53], distinctions between playing positions and the roles in offensive vs defensive phases have never been considered. Jonas Källman (2001 to 2014) plays in the left wing position in attack, but generally plays as an advanced defender in a 5-1 defence (#3 high). Pivots, who play in the middle court section in attack, frequently defend in position #2 and not necessarily in #3 high or low.

To summarise, defensive systems practised, defensive systems attacked and playing position-specific tasks that can vary both during and between consecutive games (strategic adjustments) all have large effects on technical, tactical and motion patterns and physiological demands. Unfortunately, these factors have not yet been researched. A better understanding of these specific requirements is likely to improve coaching and handball-specific training drills.

## CONCLUSION

This condensed summary of our previous work[8,25] provides a comprehensive analysis of the various technical and physical on-court demands placed on elite male handball players, with respect to playing positions. Attack build-up phases represent the larger part of ball possession (88±6%), while counter-attacks represent 12±6% of game possessions. The average running pace is between 53±7 and 89.9 m.minute$^{-1}$ [18,25]. Handball is clearly an intensive activity for all players, with a large number of high-intensity actions (jumps, duels, sprints, changes of direction and contacts) and significant variation in the technical and physiological demands between the different positions. However, this has not been addressed in the current available literature, and further study is required.

The data on goalkeepers are limited and, due to their particular activity profile, more detailed and specific analyses (such biomechanics) are required. Pivots generally cover the smallest distance on the field, yet they exercise at a relatively high-intensity due to the large number of body contacts they give and receive. Wings perform the greatest number of high-intensity runs, receive and give the smallest number of contacts and show the lowest physiological demands. Finally, the playing activity of backs is between those described for the other two on-field positions, while they shoot and pass substantially more than all other players. These results indicate that specific physical preparation in accordance to these demands is required (Table 2).

Whether physical fatigue does occur during games remains unclear because, in the majority of studies, games were not examined under real competitive situations. We conclude that, in practice, appropriate player rotations may allow players to maintain individual physical performance levels – or may at least limit a possible drop in physical/playing efficiency. As highlighted in this review, future research should essentially focus on the technical and physiological responses during games in relation to specific collective systems of play and individual playing roles. The occurrence of playing position-specific fatigue should also be better-examined when considering individual playing time and rotation strategies. In addition, we recommend that the match activities of goalkeepers be researched further. Finally, appreciating the relationship between training drills and game demands[54] might improve the future design of individualised handball-specific training programmes.

*References at www.aspetar.com/journal*

*Claude Karcher M.Sc.*
*Ph.D. Candidate*

*Martin Buchheit M.Sc., Ph.D.*
*Faculty of Sport Sciences*
*University of Picardie*
*Amiens, France*

*Sport Science Unit*
*Myorobie Association*
*Montvalezan, France*
*Contact: mb@martin-buchheit.net*
*www.martin-buchheit.net*