Technical Activity Profile and Influence of Body Anthropometry on Playing Performance in Female Elite Team Handball

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Abstract

Michalsik, LB, Aagaard, P, and Madsen, K. Technical activity profile and influence of body anthropometry on playing performance in female elite team handball. *J Strength Cond Res* 29(4): 1126–1138, 2015–To determine the physical demands placed on female elite team handball (TH) players in relation to playing position and body anthropometry, female elite TH primarily field players were monitored during match-play using video recording and subsequent computerized technical match analysis during 5 regular tournament match seasons. Technical match activities were distributed in 6 major types of playing actions (shots, breakthroughs, fast breaks, technical errors, defensive errors, and tackles) and further divided into various subcategories (e.g., type of shot, hard or light tackles, claspings, screenings, and blockings). Furthermore, anthropometric measurements were performed. Each player had 28.3 ± 11.0 (group means ± *SD*) high-intense playing actions per match with a total effective playing time of 50.70 ± 5.83 minutes. On average, each player made 2.8 ± 2.6 fast breaks, gave 7.9 ± 14.4 screenings, received 14.6 ± 9.2 tackles in total, and performed 7.7 ± 3.7 shots while in offense, along with 3.5 ± 3.8 blockings, 1.9 ± 2.7 claspings, and 6.2 ± 3.8 hard tackles in defense. Mean body height, body mass, and age in the Danish Premier Female Team Handball League were 175.4 ± 6.1 cm, 69.5 ± 6.5 kg, and 25.4 ± 3.7 years, respectively. Wing players were lighter (63.5 ± 4.8 kg, $p < 0.001$) and smaller (169.3 ± 4.9 cm, $p < 0.001$) than backcourt players (BP) (70.6 ± 5.3 kg, 177.0 ± 5.4 cm) and pivots (PV) (72.5 ± 4.9 kg, 177.7 ± 4.9 cm). In conclusion, the present match observations revealed that female elite TH players during competitive games intermittently perform a high number of short-term, high-intense technical playing actions making modern female elite TH a physically demanding team sport. No sign of technical fatigue were observed, since the amount of intense technical playing actions remained unchanged in the second half. Marked positional differences in the physical demands were demonstrated, with wing players performing more fast breaks and less physical confrontations than BP and PV. Body anthropometry differed substantially between different playing positions. Consequently, this should lead to an increase in physical training in modern female elite TH directed at specific positions and individual physical capacity.

Key Words technical match analysis, physical confrontations, anthropometric measurements, player characteristics, positional differences

Introduction

Modern elite team handball (TH) is characterized by 60 minutes (2 halves of 30 minutes separated by a half-time break of 15 minutes duration) of repeated accelerations, sprints, jumps, shots, rapid changes of direction, and a high number of physical confrontations (e.g., tackles and screenings) with opponent players. A significant development in elite TH has occurred over the recent years concerning increased frequency and intensity of training and match-play and implementation of new rules, e.g., quick throw-off, which has changed the physical demands imposed on the players. Thus, it is a precondition to perform an in-depth working demand analysis of the game in order to identify the exact on-court requirements for present-day elite players. Such prior knowledge provides the needed basis for the planning and execution of effective training (13).

The game of TH imposes many other physical demands besides running. Tackles, shots, fakes, claspings, and screenings are all examples of technical playing actions that are integrated into modern TH, and these are often performed with maximal intensity to overcome opponent players. However, the relative involvement of these components is not well documented. Optimal physical working demand

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analysis includes locomotion match analysis (movement category, intensity, and distance) and technical match analysis (technical playing actions) (19). Excluding either of these classes of analyses will lead to a systematic underestimation of the working demands of the game.

Although TH enjoys worldwide popularity and is a recognized Olympic sports discipline, only sparse research data exist on the physiological and technical elements in elite TH match-play and almost entirely focusing on male players. Recently, we performed a complete working demand analysis in male elite TH (16,18). Because of physiological differences between the sexes (1), the data and conclusions obtained in male players cannot be extrapolated to comprise female players. Hence a strong need exists for increasing the knowledge about selected physiological and technical aspects of female elite TH. To the best of our knowledge, technical match analysis has not previously been performed in female elite TH players.

As both the scientific methods of analysis and the nature of the game of TH have evolved substantially during the recent decades, it seems of vital interest to conduct a scientific analysis of the physical demands imposed on modern-day female elite TH players. A vast majority of studies examining the physical working demands in various ball games have focused exclusively on the locomotion analysis of players during match-play. Because TH involves a great deal of physical contact and other technical playing actions, technical match analysis was conducted in the present study to reach a more full understanding of the physical demands of modern female elite TH. In addition, a separate locomotion match analysis of the same matches in the present group of players previously was performed, as reported elsewhere (20,21).

Furthermore, it seems of high relevance to identify potential positional differences in the physical demands. If such differences exist, physical training in elite TH should be planned more individually rather than implementing a uniform training scheme for all players. Moreover, it remains unknown whether match-playing performance in female elite TH is influenced by accumulative onset of fatigue during the time course of the match. Gaining increased knowledge about the potential accumulation of fatigue, and its influence on physical performance during match-play will contribute to improving the design, planning, and implementation of physical training in elite TH players. Finally, it also seems highly relevant to examine the body anthropometry of female elite TH players because previous studies in male TH players (3,8,28) have suggested that body anthropometry (body mass [BM] and body height [BH]) may significantly affect playing performance in modern elite TH. However, this aspect has only scarcely been evaluated in female elite TH with respect to specific playing positions.

The aims of the present study, therefore, were (a) to determine the physical demands placed on female elite TH players and (b) to identify any positional differences in physical demands and body anthropometry, and (c) to examine whether physical match performance is impaired during elite TH match-play. Since extensive differences in activity patterns may occur according to different matches, teams, and playing positions, respectively, this study comprised a large sample of players in the Danish Premier Female Team Handball League from various teams representing all playing positions.

Because of the complexity and high intensity of the TH game, we hypothesized that (a) female elite TH players would demonstrate a high capacity for a wide range of technical qualities including tackles and screenings, jump shots, and rapid directional changes during fast breaks; (b) physical demands and body anthropometry would differ between playing positions; and (c) signs of match-induced fatigue would emerge during match-play.

Methods

Experimental Approach to the Problem

This study comprised technical match analysis and anthropometric measurements in Danish female elite TH players during the entire regular tournament match season (September to May, with players performing 6–10 training sessions and 1–2 matches per week). The players were recruited from teams in the Danish Premier Female Team Handball League that is considered to be among the international top leagues in female TH. All analyzed matches were performed under indoor conditions, ensuring stable temperature (18–22° C) and humidity (50–70%). Because the activity patterns of goalkeepers differ markedly from those of field players, no match analysis was performed in goalkeepers.

Observations during match-play took place by means of video recordings of competitive games in the Danish Premier Female Team Handball League. A camera was designated to follow 1 player close up (field players only) without interruption throughout the entire time course of the match. Altogether, 46 tournament matches were video-filmed using multiple cameras, which provided a total of about 180 single player recordings. Because TH rules, in contrast to soccer rules for example, allow unlimited substitutions of players throughout the entire match, it was not possible to collect adequate individual data for the full duration of the match (60 minutes). Conversely, we aimed to only included players with substantial playing time, in order to ensure that their activity pattern would reflect the true physical demands of the game.

The inclusion criteria, therefore, were defined as being an effective on-court playing time for the whole match of 42 minutes or more (i.e., ≥70% of total effective match duration) with an effective on-court playing time in each half-time period of 18 minutes or more (i.e., ≥60% of total effective duration of 1 half). In case of substitution or injury to a player causing a substantial reduction in playing time, the recording was excluded from the investigation. A total of 84 recordings (20 different players, mean number of recordings per player: 4.2, range: 1–8) fulfilled these conditions and were analyzed according to established criteria (18).

The players examined in the present study on average played roughly 1 tournament match per week during the regular tournament match season (Danish National Championship), which is much different from the conditions of national team players when participating in international male elite TH tournaments, where each team typically play about 10 matches in 12–14 days (25). In such tournaments, players tend to be more frequently substituted on all playing positions, especially for backcourt players (BP) and pivots (PV) (18), in order to maintain or to limit a decrease in physical playing performance during the time course of the tournament.

Additionally, for mainly tactical reasons, some players rotate between every ball possession, i.e., some players specialize to play in offense only, whereas others play only in defense. However, only a limited number of specialized players were observed in this study. This is probably because at the club level, the best players will mostly have to take part in both offense and defense because of a less homogenous playing standard (fewer top performing players) among the players of the team. Consequently, the mean playing time for first-choice players was often high, with limited playing time for all other players.

Players with greatly reduced on-court playing time were not examined in the present study, since such players (playing for e.g., 15 minutes) are more likely to show a more intense activity pattern compared with players, who are involved for longer durations of the game. If the specialized or substituted players with short playing time were included, the average results would probably show a different picture of the activity pattern of elite TH players.

Moreover, anthropometric data (standing BH and BM) and relevant player characteristics (e.g., preferred playing position and playing experience) were obtained in all players from the Danish Premier Female Team Handball League.

Table 1. Offensive and defensive playing actions (group means ± *SD*), respectively, for the different playing positions and for all players combined (first and second half combined, respectively).

Offensive actions in total for the entire match: Positional differences				
Playing actions	All players combined ($n = 84$), number per match	Wing players ($n = 35$), number per match	Pivots ($n = 19$), number per match	Backcourt players ($n = 30$), number per match
Playing time (min)	24.57 ± 4.33	24.73 ± 4.88	24.50 ± 4.25	24.47 ± 3.82
Offensive breakthroughs	1.3 ± 2.2	0.6 ± 0.8*	0.2 ± 0.4†	2.7 ± 3.1‡
Fast breaks	2.8 ± 2.6	4.4 ± 2.8§	2.5 ± 1.8†	1.0 ± 1.3‖
Technical errors	2.9 ± 2.3	1.7 ± 1.6§	3.6 ± 2.2†	3.9 ± 2.4
Hard tackles	5.0 ± 4.0	2.2 ± 1.7§	8.4 ± 3.4†	6.0 ± 4.3‖
Light tackles	9.6 ± 6.2	5.3 ± 3.2§	17.0 ± 5.4†	9.9 ± 4.8‡
Claspings	1.2 ± 2.0	0.5 ± 0.9*	3.0 ± 3.3†	0.8 ± 1.1‡
Screenings	7.9 ± 9.8	0.7 ± 1.7	32.9 ± 9.9†	0.5 ± 1.0‡
Shots	7.7 ± 3.7	6.9 ± 2.9	7.4 ± 3.3	8.8 ± 4.6
Scoring percentage	51.9 ± 21.4	47.5 ± 20.1	68.0 ± 17.4†	46.8 ± 20.6‡
Defensive actions in total for the entire match: Positional differences				
Playing actions	All players combined ($n = 84$), number per match	Wing players ($n = 30$), number per match	Pivots ($n = 19$), number per match	Backcourt players ($n = 35$), number per match
Playing time (min)	26.13 ± 3.83	26.62 ± 4.07	26.62 ± 4.30	25.23 ± 3.28
Hard tackles	6.2 ± 3.8	3.6 ± 2.6§	7.4 ± 4.3†	7.8 ± 3.4
Light tackles	14.5 ± 7.4	8.2 ± 3.7§	20.1 ± 9.1†	16.9 ± 4.4‖
Claspings	1.9 ± 2.7	0.5 ± 1.0§	4.2 ± 4.1¶	1.9 ± 1.9‡
Screenings	4.2 ± 3.7	0.5 ± 1.0§	9.3 ± 6.9†	4.5 ± 3.8‡
Blockings	3.5 ± 3.8	0.3 ± 0.7§	8.8 ± 3.3†	3.3 ± 2.1‡
Defensive errors	5.1 ± 3.2	2.6 ± 2.4§	6.9 ± 2.9†	6.2 ± 2.8

*Difference between wing players and backcourt players $p \leq 0.05$.
†Difference between wing players and backcourt players $p < 0.001$.
‡Difference between wing players and pivots $p \leq 0.05$.
§Difference between wing players and pivots $p < 0.001$.
‖Difference between pivots and backcourt players $p \leq 0.05$.
¶Difference between pivots and backcourt players $p < 0.001$.

Subjects

Elite TH players from the Danish Premier Female Team Handball League including 2 top-ranked teams participated as experimental subjects in the study. During the entire study period, the 2 top-ranked teams were constantly positioned among the top 4 teams in the Danish Premier Female Team Handball League, which ensured entry into the season final play-off tournament for the Danish Championship. A majority of the players were competing in European TH club tournaments, and several players were also playing for their respective national teams representing multiple nations.

All players were fully informed about the experimental procedures and possible discomforts associated with the study before giving their written informed consent to participate. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the local Municipal Ethics Committee. The study was conducted over a 5-year period during which time all players belonged to teams ranked in the upper half of the Danish Premier Female Team Handball League. A number of different teams were monitored in the present study, with new players joining individual teams, whereas other players conversely were leaving the teams during the whole study period.

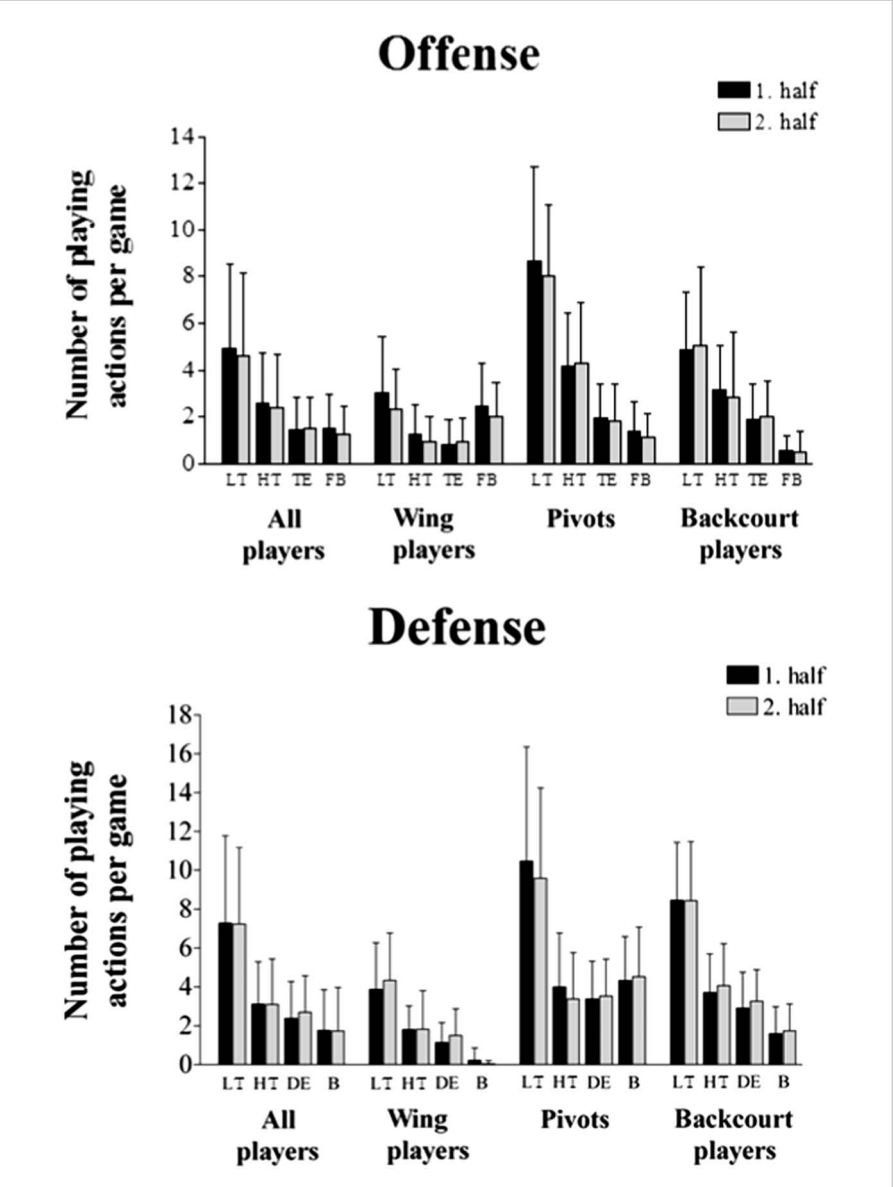

Figure 1. Number of selected playing actions in the first and second halves of Danish Premier Female Team Handball League tournament matches for players in offense (top panel) and in defense (lower panel) recorded for all players combined ($n = 82$) and in specific playing positions. Results are group means ± *SD*. Difference between the first and the second half *$p \leq 0.05$. LT = light tackles; HT = hard tackles; TE = technical errors; FB = fast breaks; DE = defensive errors; B = blockings.

Procedures

Observations During Match-Play—Video Recordings. The tactical and technical demands differ substantially between offense and defense during TH matches. The present computerized technical match analysis, therefore, focused separately on offensive and defensive technical playing actions, respectively. Field players were divided into 3 categories in both offense and defense, wing players (WP), PV, and BP, respectively. Since no study so far has reported about a complete technical match analysis in elite, a specific analysis program for the technical match analysis in TH was produced (22).

A total of 6 types of technical playing actions were defined and continuously registered throughout the entire game: shots, breakthroughs, fast breaks, technical errors (ball loss, taking more than 3 steps with the ball, double dribbling, etc.), defensive errors (actions resulting in free-throws, penalties, warnings, suspensions, and disqualifications), and tackles. Each playing action was further divided into a number of subcategories

(e.g., hard [performed with maximal intensity] or light [performed with submaximal intensity] tackles, blockings and type of shot performed), all of which were precisely defined according to standard descriptions of technical playing actions in TH match-play (23). Nevertheless, some player actions occasionally overlapped, for example an offensive breakthrough could result in a technical error, in a shot or in a tackle of a special category. In this way, the separate action was registered several places. Players, who regularly changed defensive position making it impossible to define a fixed defensive playing position, were excluded from the analysis of defensive playing actions.

During offense, offensive breakthroughs, fast breaks, hard tackles and shots were defined as high-intense playing actions, whereas in defense hard tackles, claspings and blockings were defined as high-intense playing actions. The number of physical confrontations was quantified by registering all tackles, screenings, claspings and blockings, i.e., by identifying all technical playing actions that involved physical contact between players. By performing computerized match analysis of the technical activity pattern of a large number of different players in various playing positions throughout the entire duration of the match and comprising a large number of games, a complete description of the players' technical characteristics in female elite TH can be provided. Furthermore, such extensive analysis makes it possible to examine whether the physical demands differ between different playing positions, and to evaluate if match-induced fatigue occurs during the time course of match-play (i.e., contrasting second half vs. first half).

To ensure consistency and reproducibility, all matches in the present study were analyzed by the same experienced observer. An identical approach has been used in previous studies (18,26). The first and the second half of each match were analyzed separately in a randomized order. Importantly, the observer had to adapt to certain skill criteria before initiating the analysis. This was achieved by conducting an intense practice period with studies of individual players' styles of locomotion and technical activity pattern. Additionally, several validations tests were performed in a selected subgroup of players to ensure a consistent allocation of players' activities into the predetermined categories of technical match activities. Sufficient competence of the analyst was considered to be reached when data from successive analysis of given periods

Table 2. Age, body height, body mass, and adult elite playing experience (group means ± *SD*) for all players combined and for the different playing positions (inclusive goalkeepers), respectively, in 2 top-ranked teams and in the entire Danish Premier Female Team Handball League in the first season.

	Body anthropometry			
	Age (y)	Body height (cm)	Body mass (kg)	Adult elite playing experience (y)
The 2 top-ranked teams				
All players combined ($n = 24$)	25.9 ± 3.8	174.2 ± 5.7	70.3 ± 7.4	6.9 ± 3.3
Wing players ($n = 10$)	25.4 ± 4.6	170.6 ± 5.0*	65.2 ± 2.7*	5.9 ± 3.1†
Pivots ($n = 7$)	26.3 ± 3.2	178.8 ± 3.4‡	76.5 ± 8.1‡	6.4 ± 2.6
Backcourt players ($n = 7$)	26.2 ± 3.8	175.1 ± 5.3	71.4 ± 6.1§	8.4 ± 3.7§
The entire Danish Premier Female Handball League in the first season				
All players combined ($n = 120$)	25.3 ± 6.0	175.1 ± 2.8	69.0 ± 6.2	6.7 ± 2.8
1st choice ($n = 69$)	26.3 ± 3.5‖	175.6 ± 5.8	69.1 ± 6.1	8.0 ± 3.8¶
2nd choice ($n = 51$)	23.9 ± 4.1	174.4 ± 6.1	68.8 ± 6.4	4.9 ± 3.6
Wing players ($n = 34$)	23.9 ± 3.1†	170.5 ± 4.9#	64.5 ± 6.3#	5.2 ± 2.6†
Pivots ($n = 22$)	24.2 ± 3.6	179.1 ± 4.3§	73.4 ± 4.5§	5.4 ± 4.2
Backcourt players ($n = 50$)	26.1 ± 3.2	175.0 ± 5.7**	69.1 ± 3.2**	8.0 ± 4.3§
Goalkeepers ($n = 14$)	26.2 ± 3.7††	179.6 ± 3.8	72.9 ± 5.3	6.7 ± 4.3
Danish players ($n = 86$)	24.5 ± 3.6‡‡	175.0 ± 5.9	69.0 ± 6.4	5.5 ± 3.4‡‡
Foreign players ($n = 34$)	27.1 ± 4.0	175.2 ± 6.1	69.0 ± 6.0	9.7 ± 4.0

*Difference between wing players and backcourt players $p < 0.01$.
†Difference between wing players and backcourt players $p \leq 0.05$.
‡Difference between wing players and pivots $p < 0.01$.
§Difference between wing players and goalkeepers $p \leq 0.05$.
‖Difference between wing players and all other playing positions $p < 0.01$.
¶Difference between pivots and backcourt players $p \leq 0.05$.
#Difference between backcourt players and goalkeepers $p \leq 0.05$.
**Difference between first-choice and second-choice players $p < 0.01$.
††Difference between first-choice and second-choice players $p < 0.001$.
‡‡Difference between Danish and foreign players $p < 0.01$.

of the same match differed by less than 3% for each of the technical playing actions. The validation tests also included a test-retest analysis of 15 matches, which were randomly selected. The 2 analyses were separated by at least 3 months. After these procedures, no systematic differences in the final intraobserver test-retest analysis outcome were observed (interclass correlation coefficient [ICC] >0.90) after the period of analyst training. Compared with the locomotion match analysis, it was easier to attain high reproducibility during the technical match analysis because the technical playing actions were easier to assess accurately and occurred with a significantly lower frequency.

Body Anthropometry. Anthropometric data (standing BH and BM) were recorded in all players from the 2 top-ranked teams ($n = 24$) during the physical tests sessions. In addition, body anthropometry and player characteristics were obtained for the remaining teams of the Danish Premier Female Team Handball League by the team physician or physiotherapist and subsequently reported to the principal author in the first season ($n = 120$) and the fifth season ($n = 157$), respectively. Specifically, information about the individual players' BH, BM, age, playing position, player choice (first or second choice), and playing experience (years of playing) at the adult elite level were obtained. The potential effect of body anthropometry, age, and playing experience on individual playing time, and hence on playing performance was illustrated by comparing first- (players who were selected for the team's starting line-up) and second-choice players.

Body mass was measured with players wearing light indoor clothing (short pants and t-shirt) and unshod, using commercially available electronic digital scales (measurement error ≤1%) that were routinely used and maintained (calibrated) by the medical staff of the involved clubs. During all laboratory tests, BM was measured using a Tanita Body Composition Analyzer (TBF-3000; Tanita Corporation, Tokyo, Japan, measurement error ≤0.5%). Standing BH was also measured by

Table 3. Age, body height, body mass, and adult elite playing experience (group means ± *SD*) for first-choice and second-choice players for all players combined and for the different playing positions (inclusive goalkeepers), respectively, in the entire Danish Premier Female Team Handball League in the fourth season.

Body anthropometry The entire Danish premier female team handball league in the fourth season Difference between first-choice and second-choice players				
	Age (y)	Body height (cm)	Body mass (kg)	Adult elite playing experience (y)
All players combined ($n = 157$)	25.4 ± 3.6	175.6 ± 6.2	69.8 ± 6.6	7.4 ± 3.8
1st choice ($n = 94$)	26.4 ± 3.3*	175.9 ± 6.0	70.1 ± 63	8.5 ± 3.5*
2nd choice ($n = 63$)	24.0 ± 3.5	175.0 ± 6.5	69.3 ± 7.1	5.8 ± 3.8
Wing players ($n = 41$)	23.7 ± 2.7†	169.3 ± 4.9‡	63.5 ± 4.8‡	5.4 ± 3.0§
1st choice ($n = 20$)	24.8 ± 3.1‖	170.1 ± 4.6	64.3 ± 5.6	6.6 ± 3.3‖
2nd choice ($n = 21$)	22.6 ± 2.1	168.5 ± 5.1	62.8 ± 4.0	4.2 ± 2.2
Pivots ($n = 27$)	25.1 ± 3.8	177.7 ± 4.9	72.5 ± 4.9	6.8 ± 3.0
1st choice ($n = 17$)	25.8 ± 3.4	178.1 ± 5.5	73.0 ± 5.4	7.5 ± 3.1¶
2nd choice ($n = 10$)	23.9 ± 4.3	177.7 ± 3.8	71.4 ± 3.7	5.6 ± 2.4
Backcourt players ($n = 63$)	26.2 ± 3.4	177.0 ± 5.4	70.6 ± 5.3#	8.5 ± 3.6#
1st choice ($n = 42$)	27.1 ± 3.1‖	176.2 ± 5.5	70.3 ± 5.3	9.5 ± 3.0‖
2nd choice ($n = 21$)	24.5 ± 3.4	178.8 ± 4.7	71.2 ± 5.3	6.5 ± 3.9
Goalkeepers ($n = 26$)	26.6 ± 4.0**	179.6 ± 4.1	75.1 ± 6.1	8.6 ± 4.0**
1st choice ($n = 15$)	27.3 ± 3.8	180.4 ± 3.9	74.3 ± 5.2	9.1 ± 3.7
1st choice ($n = 11$)	25.8 ± 4.2	178.5 ± 4.3	76.3 ± 7.4	7.8 ± 4.4
Danish players ($n = 103$)	24.7 ± 3.6††	174.6 ± 6.3‡‡	69.5 ± 6.7	6.3 ± 3.7††
Foreign players ($n = 54$)	26.9 ± 3.1	177.4 ± 5.8	70.5 ± 6.5	9.5 ± 3.2

*Difference between wing players and backcourt players $p < 0.01$.
†Difference between wing players and backcourt players $p < 0.001$.
‡Difference between wing players and goalkeepers $p < 0.01$.
§Difference between wing players and all other playing positions $p < 0.001$.
‖Difference between goalkeepers and backcourt players $p < 0.001$.
¶Difference between first-choice and second-choice players $p \leq 0.05$.
#Difference between first-choice and second-choice players $p < 0.01$.
**Difference between first-choice and second-choice players $p < 0.001$.
‡‡Difference between Danish and foreign players $p \leq 0.05$.
††Difference between Danish and foreign players $p < 0.001$.

the medical staff to the nearest singular millimeter using a wall-mounted stadiometer with players positioned in an erect posture against a wall without socks and shoes or in some cases using a portable stadiometer (Leicester Portable Height Measure; Seca, Hamburg, Germany) (measurement error ≤1 mm, corresponding to ≤0.05% relative error).

Statistical Analyses

All statistical analyses were conducted using R2 version 13.1 (University of Auckland, New Zealand). All data are expressed as group mean values ± *SD* unless otherwise stated. The assumption of Gaussian data distribution was verified using QQ-plots. When 2 normally distributed parameters were compared within the same group of subjects (e.g., differences between the first and second half), Student's paired *t*-test was used. Student's nonpaired *t*-testing was used to compare nonmatched subject groups (e.g., differences between first- and second-choice players). The assumption about similar variance was tested using residual plots.

Statistical differences between distinct groups of players (i.e., comparing the different playing positions) were identified using 1-way analysis of variance. Post hoc differences between groups were evaluated by Tukey's HSD test (normally distributed). Potential relationships between selected outcome parameters were evaluated using Pearson's product-moment correlation analysis. Cohen's *d* test was used to calculate effect size (*d*-values denoted as ES), which was reported along with all statistically significant results as an indicator of practical significance. The level of statistical significance was set at $p \leq 0.05$ (2-tailed test design).

Results

Game Duration and Total Effective Playing Time

Excluding the half-time break, the total duration of the tournament games examined in this study ($n = 46$) averaged 71.03 ± 2.28 minutes, corresponding to 18.4% extension compared with a normal match total effective playing time of 60 minutes (30 minutes each half). This was due to brief match pauses during for example suspensions, penalties, and injuries in addition to the time-outs taken by the coaches (2 in each half of 1 minute each). The full duration of the first and the second half did not differ (35.37 ± 1.62 vs. 35.67 ± 1.53 minutes), corresponding to an extension of 17.9 and 18.9%, respectively, relative to the nominal playing time of 30 minutes. Half-time duration was 16.2% reduced compared with the nominal half-time break of 15 minutes, meaning that the teams typically refrained from using the full half-time intermission. The mean total effective playing time for the analyzed players in an entire game ($n = 83$) was 50.70 ± 5.83 minutes. No difference in mean total effective playing time was observed between defense (26.13 ± 3.83 minutes) and offense (24.57 ± 4.33 minutes), between the first (25.40 ± 2.58 minutes) and the second half of the match (25.30 ± 2.75 minutes), or between the different playing positions (WP: 51.35 ± 6.88 minutes, PV: 51.12 ± 5.20 minutes, and BP: 49.70 ± 4.88 minutes).

Table 4. Age distribution (group means) for all players combined and for the different playing positions (inclusive goalkeepers), respectively, in the entire Danish Premier Female Team Handball League in the fourth season.

Age distribution The entire Danish Premier Female Team Handball League in the fourth season	Under 23 y (%)	Between 23 and 28 y (%)	Over 28 y (%)
All players combined ($n = 157$)			
Percentage	29.3	44.6	26.1
1st choice	19.2	48.9	31.9
Wing players ($n = 41$)			
Percentage	36.6	58.5	4.9
1st choice	20.0	65.0	15.0
Pivots ($n = 27$)			
Percentage	44.5	22.2	33.3
1st choice	35.3	29.4	35.3
Backcourt players ($n = 63$)			
Percentage	20.6	44.5	34.9
1st choice	9.5	50.0	40.5
Goalkeepers ($n = 26$)			
Percentage	23.1	46.2	30.8
1st choice	6.7	60.0	33.3

Technical Match Analysis

On average, when in attack, each player performed 2.8 ± 2.6 fast breaks and 7.7 ± 3.7 shots per match with a mean scoring percentage of 51.9 ± 21.4 and gave 6.2 ± 3.8 hard tackles in the defense (Table 1). Notably, differences between the numbers of WP and BP in offense compared with the numbers in defense were demonstrated (Table 1). No year-to-year differences were observed during the 5-year study period for any of the analyzed parameters.

Technical match actions differed between various playing positions (Table 1). Notably, WP performed considerable more fast breaks and had substantially less body contact than BP and particularly PV. In offense, WP received less tackles in total per match (7.5

± 3.5, $p < 0.001$) than PV (25.4 ± 7.1, ES = 3.20) and BP (15.9 ± 7.6, ES = 1.42), performed less screenings (0.7 ± 1.7) than PV (32.9 ± 9.9, $p < 0.001$, ES = 4.53), but demonstrated more fast breaks (4.4 ± 2.8, $p < 0.001$) compared with PV (2.5 ± 1.8, ES = 0.81) and BP (1.0 ± 1.3, ES = 1.56) (Table 1). No positional difference between the numbers of shots per match were observed, but PV had a higher mean scoring percentage (68.0 ± 17.4, $p < 0.001$) than BP (46.8 ± 20.6, ES = 1.11) and WP (47.5 ± 20.1, ES = 1.09).

In defense, WP performed less tackles in total per match (11.8 ± 4.5, $p < 0.001$) than PV (27.4 ± 11.3, ES = 1.81) and BP (24.7 ± 5.8, ES = 2.49) (Table 1). Furthermore, WP received less screenings (0.5 ± 1.0, $p < 0.001$) than both PV (9.3 ± 6.9, ES = 1.78) and BP (4.5 ± 3.8, ES = 1.44) along with less blockings (0.3 ± 0.7) and claspings (0.5 ± 1.0) compared with PV (8.8 ± 3.3, $p < 0.001$, ES = 3.56; 4.2 ± 4.1, $p < 0.001$, ES = 1.24) and BP (3.3 ± 2.1, $p < 0.001$, ES = 1.92; 1.9 ± 1.9, $p < 0.001$, ES = 0.92).

Differences Between the First and Second Half of the Match

No changes in the number of main technical playing actions in offense and in defense were observed from the first to the second half (Figure 1). This pattern emerged for all players combined and for the specific playing positions. On average, each player performed 28.3 ± 11.0 high-intense technical playing actions per match. With similar effective playing time in the 2 halves, no difference in the amount of high-

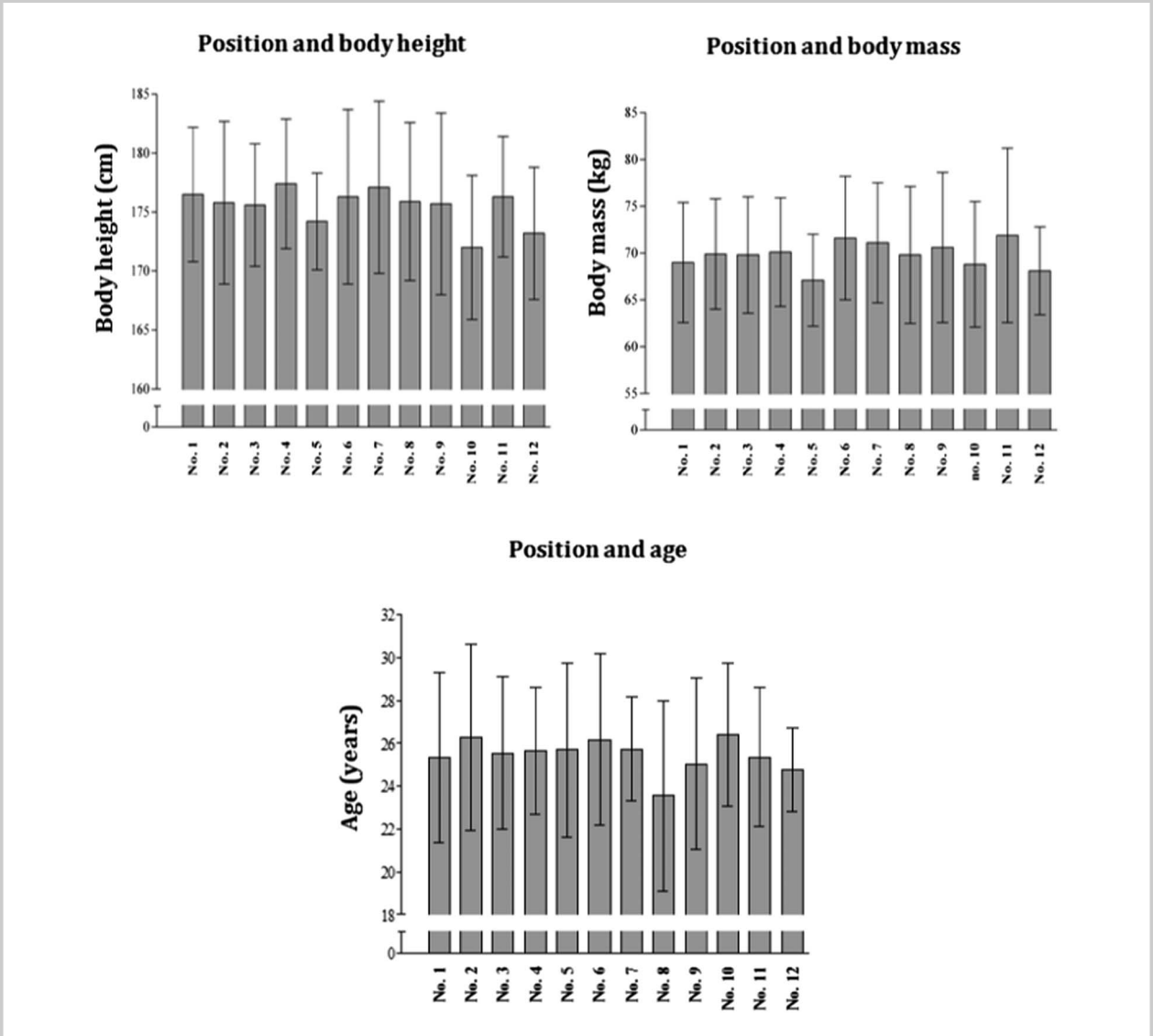

Figure 2. Body height, body mass, and age, (vertical axes) plotted as function of team ranking in the Danish Premier Female Team Handball League at the end of the fourth season (12 clubs; no. 1 was league winner, no. 2 was second ranked, etc.). Results are group means ± *SD*.

intense technical playing actions was observed between the first and second halves (14.6 and 13.8, respectively).

Anthropometric Characteristics of Female Elite Team Handball Players

The mean BH and BM for the players in the 2 top-ranked clubs were 174.2 ± 5.7 cm and 70.3 ± 7.4 kg, respectively, whereas the mean age and adult elite playing experience were 25.9 ± 3.8 years and 6.9 ± 3.3 years, respectively (Table 2). Wing players demonstrated lower BH (170.6 ± 5.0 cm) and BM (65.2 ± 2.7 kg) compared with both PV (178.8 ± 3.4 cm, $p < 0.01$, ES = 1.92; 76.5 ± 8.1 kg, $p < 0.01$, ES = 1.87) and BP (175.1 ± 5.3 cm, $p < 0.01$, ES = 0.87; 71.4 ± 6.1 kg, $p < 0.01$, ES = 1.31). When registered in the Danish Premier Female Team Handball League during 2 selected seasons ($n = 277$ in total), mean BH and BM were 175.4 ± 6.1 cm and 69.5 ± 6.5 kg, respectively, whereas mean age and playing experience were 25.4 ± 3.7 years and 7.2 ± 3.9 years, respectively. Positional differences in anthropometric characteristics were observed, and the picture was similar for the 2 seasons monitored (Tables 2 and 3). In brief, WP were lighter, smaller, younger, and less experienced on adult elite level than the rest of the players including goalkeepers. In contrast, PV were heavier and taller than the rest of the field players (first season) (Table 2).

In the first season, no differences in body anthropometry were demonstrated between first-choice and second-choice players. However, both for all players combined (Table 2) as well as for specific playing positions (except for goalkeepers), first-choice players were older and had more playing experience than second-choice players. Since no differences could be demonstrated for all players combined between the first ($n = 120$) and the fourth season ($n = 157$), the comparison on the specific playing positions is presented only with the latter players (Table 3). In the fourth season, no differences in mean BH and BM were observed between the 2 choices of players for all players combined, but first-choice players were older and more experienced than the second-choice players ($p < 0.001$). The same applied in almost all cases for all playing positions (Table 3). A similar pattern was demonstrated between Danish and foreign players in both seasons, where foreign players were older and had more playing experience than Danish players (Table 3).

The majority of players (fourth season) were between 23 and 28 years old (44.6%) (Table 4). Furthermore, this age group comprised the highest percentage of players, who were selected first choice (48.9%). For the different playing positions, PV showed the highest percentage of players younger than 23 years (44.5%), whereas WP had the lowest proportion of players older than 28 years (4.9%).

As the only playing position, WP also constituted a higher percentage of first-choice players in players younger than 23 years (20.0%) compared to players older than 28 years (15.0%). Conversely, goalkeepers and BP demonstrated the greatest proportion of players older than 28 years (30.8 and 34.9%, respectively) compared to players younger than 23 years (23.1 and 20.6%, respectively) with only a minor fraction of the latter players selected first choice (6.7 and 9.5%, respectively). No systematic relationship was observed between team rankings in the Danish Premier Female Team Handball League (fourth season) and BH, BM, and age, respectively (Figure 2).

Discussion

To the best of our knowledge, this is the first study to evaluate the physical demands in modern female elite TH by means of a complete technical match analysis. The specific physical demands were examined by performing a time distribution analysis of the technical playing actions (shots, breakthroughs, fast breaks, technical errors, defensive errors, and tackles) and concurrent intensity levels. The specific physiological demands associated with female elite TH (locomotion match characteristics) have been reported elsewhere (20,21).

As the main finding in the present study, substantial positional differences in physical demands and body anthropometry were observed. Furthermore, the present data demonstrated that female elite TH players are highly active during match-play while performing a large number of intense physical confrontations (tackles, screenings, claspings, and blockings) both in offense and defense. Although not directly assessed in this (or any other) study, it seems reasonable to assume that such vigorous playing actions require high mobility/agility as well as high levels of muscle strength and rapid force characteristics (rate of force development [RFD], (26)). A number of these technical playing actions were performed at high intensity in short-lasting intermittent time intervals and, therefore, most likely imposed high demands on anaerobic energy production in the active muscles.

In offense, WP showed markedly less physical confrontations with opponent players than BP and PV in accordance with previous results in male elite TH players (16,26). However, WP performed more fast breaks and high-intensity running in total and worked with a higher mean speed than all other playing positions. Pivots had numerous physical confrontations with opponents and performed a higher amount of high-intensity running than BP due to a large number of fast breaks. Despite a relatively fixed position along the 6-m line, PV covered a large running distance during organized attack (attack build-up), unlike that seen in male PV players who appear to remain more stationary (16). Attack build-up phases occur when the fast break (counterattack) is not successful, but the attacking team still possesses the ball.

Backcourt players had more physical confrontations than WP, but substantially less compared with PV. Backcourt players performed less fast breaks than any other playing position. Furthermore, as demonstrated by time-motion analysis (20,21) in the same players and matches examined in the present study, BP performed less high-intensity

running in total, but covered a relatively large total distance due to their central position in the offense, where they performed large amounts of nonstop motion characterized by many sideway movements. Offensive breakthroughs were only registered if they were successful. Obviously, a much higher number of offensive breakthroughs were attempted though not successfully according to the outcome criterion, which explains the relative small number breakthroughs registered per match for all players combined (1.3).

Mimicking the activity pattern seen in offense, the incidence of physical confrontations (tackles, screenings, claspings, and blockings in defense) differed in the order PV > BP > WP, in accordance with similar observations in male elite TH players (16,26). Wing players performed more high-intensity running than other players (20,21), but contrast to that seen in offense, WP (and PV) covered a greater total distance than BP while in defense. These findings indicate that WP performed many intense retreats in defense and in addition, they surprisingly spent less time in the standing still category compared to offense (20,21). Pivots demonstrated a high number of physical confrontations with opponents due to their middle defense position, similarly to previous rapports in male elite TH players (16,26). Unlike in offense, the amount of high-intensity running during defense was similar in PV and BP, while much less in WP. Furthermore, the total distance covered was much less in BP compared with all other playing positions because of spending more time standing still (20,21).

Based on the present observations of a high number of short-term technical playing actions performed intermittently both in offense and in defense, combined with previous results obtained by locomotion match analysis, physiological measurements and physical testing in the same group of players (20,21), female elite TH appears to impose a high aerobic workload on the players, accompanied by brief time periods with high anaerobic energy turnover rates. The latter notion was supported by the present findings that players had a mean of 28 high-intense technical playing actions of approximately 3 seconds duration per match. Thus, in accordance with our initial hypothesis female elite TH players were found to perform a variety of intensive, yet diverse activities such as running, sprinting, jumping, throwing, and regular in fights (pushing and clasping) with opponent players.

Based on the number of high-intense playing actions, higher anaerobic demands likely were placed on players, who played WP in offense and covered BP in defense than in players, who played BP in offense and covered WP in defense (Table 1). This suggests that the teams' tactical approach influence the technical performance in elite TH. Thus, various playing position-specific tasks performed during match-play as well as different offensive and defensive systems seem to have an impact on the physical demands imposed on the players. In support of this notion, considerable interplayer and intraplayer variability in the amount of technical playing actions was observed between different games and even within specific playing positions in the present study, possibly in part due to variable situational factors such as match location (home vs. away), quality of opposition (top, medium, and bottom), and match status (winning, drawing, or losing). However, due to the large number of matches and players analyzed in this study (46 matches of different tactical/strategic importance performed home or away, involving 84 analyzed players from several different teams recorded during 5 competitive seasons) the present data still represent a valid overall estimate of the nature and amounts of technical playing actions in female elite TH players during actual match-play.

Notably, in support of our initial hypothesis physical demands during elite TH match-play were found to differ substantially between various playing positions. The main physical performance characteristics of WP were a superior ability to move with high intensity as reflected by the large amounts of fast breaks (Table 1) and intense retreats, while concurrently demonstrating a large total distance covered (20,21). In contrast, great muscle strength and RFD in physical confrontations likely are the most important factors for PV due to large amounts of body contact with opponents observed in this playing position, although a high running capacity during fast breaks also seems of vital importance (Table 1). The large total distance covered by the present female elite PV differs from that seen in elite male PV (18) suggesting that female PV are more agile than their male counterparts.

Backcourt players were characterized by a relatively large number of physical confrontations and shots (Table 1) indicating a high demand for muscle strength and RFD, whereas the low number of fast breaks seems to suggest that anaerobic running performance is of secondary importance in this playing position. Likewise, the small total distance covered by BP (20,21) indicates that aerobic intermittent endurance exercise capacity is also of less importance for BP.

Disproving our initial hypothesis, no signs of cumulative fatigue were observed during match-play because the pattern (time frequency distribution) of technical playing actions did not differ between the first and second halves. Furthermore, no relationship was demonstrated between the number of high-intense technical playing actions and the magnitude of the relative workload (% of $\dot{V}O_2max$) (20,21). In contrast, the results from the locomotive match analysis (20,21) indicated that fatigue reflected by impaired physical performance may occur in female elite TH during the second half of the match, at least in some players. Apparently, overall movement patterns may be more heavily affected than playing skills (technical playing actions) during match-play. It should be recognized, however, that the present study did not examine specific fatigue factors, which were more thoroughly addressed in separate investigations from our laboratory (27,30).

The mean BH and BM in the Danish Premier Female Team Handball League (175 cm, 70 kg, $n = 277$) were similar to previous reports in Norwegian International top elite players (9,25) but substantially higher and heavier compared

with a large sample of players from the National League in Greece (166 cm, 65 kg, body fat 26%, $n = 222$) (2). Since the latter league stands a much lower ranking internationally than the Nordic female TH leagues, these data collectively suggest that BH, BM, and thus probably muscle mass and maximum muscle strength may have important influence on playing performance in modern international top-level female TH.

This notion is supported by world-class players showing similar BM, but higher BH and lean BM and performed better in various strength, jump, sprint, and endurance tests than amateur players (4). Like in other sports with many physical confrontations (boxing, wrestling, etc.), adult female elite TH players should maybe (PE) in the future be divided in various weight classes. Interestingly, the present players recruited from the Danish Premier Female Team Handball League were considerably taller and heavier than elite players in the Danish Premier Female Soccer League (12), suggesting marked physical differences to exist between the 2 types of ball games.

Based on the available data, female elite TH players have become taller and heavier probably with increased muscle mass compared with past time players. In the 1976 Olympic Games, mean BH for female TH players ($n = 82$) was 170 cm (10), and the average BM of the 3 best teams were 67 kg (11). In contrast, the 1994 winners of the European Female Team Handball Championship (Denmark) had a mean BH and BM of 174 cm and 68 kg, respectively (7). Similar values were observed for the Danish Female Team Handball Olympic Champions in 2004 (176 cm, 72 kg), which correspond to values in world-class players from the Premier Spanish League (176 cm, 70 kg) (4) and in today's (2014) Danish Female National Team (175 cm, 70 kg). The latter values are almost identical to those observed in the present group of elite TH players.

A taller BH is an advantage in several game situations, e.g., when shots are made over blockings in offense. Additionally, TH players, who are taller (and have a greater BM) have the ability to achieve a higher ball release speed in the jump throw (28), which is the most often applied throwing technique used by BP (29) who typically takes shots from behind the 9-m line as recently confirmed in male elite TH (16). Nevertheless, great individual differences in BH are often seen on teams in international TH mostly due to that key players can compensate the lack of BH by other helpful skills. Therefore, it may be advantageous to compose a team not only exclusively of tall players, but also with relatively smaller players in specific playing positions with other relevant abilities. This is due to the increasing problems with coordination, movement and speed that occur as the BH increases.

In support of this notion, Asian female TH players were reported to be shorter with less BM than European female TH players (6). These findings indicate that it may still be possible in female elite TH to compensate for lack in BH and BM. It is well known that the success of South Korea in female international TH is based on a selection of relatively small and light, but very fast players with exceptional technical and tactical skills.

Present-day female elite TH players are relatively lean (with approximately 20% body fat) (4–6), and the increased BM therefore is associated with a greater muscle mass. The players' absolute $\dot{V}O_2max$ (L O_2 min^{-1}) has continuously improved in line with the increase in muscle mass and BM, leaving relative $\dot{V}O_2max$ (ml $O_2 \cdot min^{-1} \cdot kg^{-1}$) unchanged (20,21). A high BM and muscle mass represent a clear advantage in the large number of physical confrontations with opponent players during match-play, which requires great muscle strength and RFD. In modern elite female TH, there is a need for players, who are relatively heavy, strong in breakthroughs, and hard to push away, while at the same time being mobile and fast both in defense and offense throughout the entire 60 minutes game.

The results from this study indicate a development in modern female elite TH of tall and heavy players with a relatively superior running ability. However, no relationships were observed between team rankings in the Danish Premier Female Team Handball League (fourth season) and BH and BM, respectively. Consequently, factors other than body anthropometry appear to influence the success of top-level TH teams. In support of this notion, no difference in BH and BM were found between first- and second-choice players at any given playing position.

The present study demonstrated several major positional differences in body anthropometry, although considerable individual variations were found as well in each playing position. Notably, WP were in both seasons lighter and smaller than the remaining of the players including goalkeepers, which from a physical point of view fits the physical demands of this playing position. Because of the reduced body contact, both in offense and defense compared with other playing positions, high BM and muscle strength seem of less importance for WP. In addition, WP only rarely perform high blockings in defense or execute jumps and shoots over the defense blockings during offense. The low BM and BH of WP enable this player type to move with high intensity over short distances and yet to perform high total amounts of running.

Pivots were the heaviest and together with BP the tallest of the field playing positions with a mean BM of 72.5 kg in the fourth season in line with the physical demands of this playing position. Great muscle strength and RFD potentially constitute important abilities in elite PV, and consequently, a large BM (likely associated with a large muscle mass) therefore is expected to have significant impact on PV's success, for example, during in-fights with opponent players. High BH in the middle defense to produce effective blockings also appeared crucial for playing performance. Compared to male elite TH players (16), however, the importance of a large BM and BH on playing performance for PV seems less pronounced in female elite TH players,

primarily due to a more mobile style of play in defense and especially in offense, which was reflected in a high total distance covered (20,21).

The BM and BH of BP were substantially taller than in WP, but smaller compared with PV, again reflecting a consistency between body anthropometry and the position-specific physical requirements during match-play, concurring with previous observations (24). Backcourt players need reasonable high BM (large muscle mass) to generate sufficient muscle strength and RFD in relatively large number of physical confrontations and in the many shots. Moreover, in offense BP also need to be relative tall to achieve a high ball release speed in jump throws and to surpass the defense blockings.

Wing players were younger with less playing experience than all other players. Inexperienced players are more frequently seen in this playing position due to a less involvement in organized play and a reduced need for great muscle strength caused by fewer physical confrontations. First-choice players were consistently older and more experienced than second-choice players. Furthermore, goalkeepers were significantly older than the rest of the players indicating that goalkeepers are better able than field players to sustain high levels of performance at higher age. This may be due to a relatively higher importance at this position of the progressively accumulated experience into various tactical aspects of the game (shot statistics, anticipation techniques, etc.), which for goalkeepers to a greater extent can compensate for the decline in physical shape.

For all players combined (fourth season), the majority of players were between 23 and 28 years of age. Notably, this age interval also contained the highest percentage of players selected first choice, indicating that the age range of 23–28 years represents an optimal combination of acquired game experience and sufficient physical shape. However, team rankings in the Danish Premier Female Team Handball League (fourth season) were unrelated to mean player age (Figure 2). Consequently, factors other than mean player age seem to have a governing impact on the success of top-level TH teams.

In conclusion, this study demonstrated that modern female elite TH is a physically demanding and complex team sport characterized by a high number of short-term, high-intense technical playing actions, which are performed intermittently throughout the entire match. No sign of technical fatigue were observed between or during the 2 halves of the match because the amount of intense technical playing actions did not drop in the second half. The physical demands differed greatly between playing positions both in offense and defense.

Female elite TH is a highly strenuous body-contact team sport, where body anthropometry plays an important role for playing performance, with various influence at the different playing positions. The technical match analysis indicated possible causes as to why some playing positions differ anthropometrically from others. The present findings may be used to design training regimens that can maximize the position-specific physical development in female elite TH players.

Practical Applications

In this study, considerable positional differences in physical demands were observed along with individual differences within the same positions. These findings provide important information that enables to design more individualized, and hence, more optimal physical training programs in modern female elite TH targeted for specific playing positions. Such individual training designs may be divided into separate physical training exercises related to the specific requirements in offense and defense, respectively. Furthermore, a strong focus on various aspects of strength training would appear desirable in the light of the apparent high demand for rapid force capacity (i.e., high RFD) during fast and hard shots, the need for rapid body accelerations and changes of direction, and the relatively high number of physically demanding confrontations (i.e., tackles, screenings, claspings, and blockings).

Concurrent with the anthropometric development toward heavier and taller players, it becomes vital for female elite TH players to sustain their functional capacity on the playing court (i.e., agility and sprint/jump/endurance abilities). Thus, players have to preserve or even improve their acceleration capacity, ability to perform rapid side-cutting maneuvers, maximum jump height and mobility as well as aerobic power despite at the same time becoming heavier (more muscular) to push away in a breakthrough and to more effectively tackle opponent players in defense. Consequently, specific physical training regimens to improve these functional capacities should be implemented, which may include on-court sprinting, maximal vertical jumping drills, and intermittent endurance exercises performed as game simulations (i.e., with ball handling involved) (15). Over the last decades, the increase in BH and BM has not been so pronounced among female as among male elite players (14,17), which indicates that the strength-related aspect of the game has, relatively speaking, not nearly as much importance in female elite TH.

In perspective, future studies should examine the impact of different training regimens (strength vs. anaerobic vs. aerobic exercise) for increasing the physical fitness in female elite TH players and to provide improved fatigue resistance during female elite TH match-play. In addition, future studies could be performed to evaluate the physical demands of players with reduced on-court playing time (i.e., substituted or specialized players) to provide valuable information about substitution/rotation strategies in female elite TH match-play. Furthermore, future research should be conducted to examine the specific physical demands related to given technical playing actions (e.g., tackles, screenings, and jumping) by measuring muscle activity (electromyography) and locomotive power output.

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