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Physical demands in elite team handball: comparisons between male and female players

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Aim. **The aim of the present study was to examine potential differences in the physical demands imposed on male vs. female adult elite team handball players during match-play.**
Methods. **Male and female elite team handball players were monitored over a six and five season time span, respectively. Each player was evaluated during match-play by use of video recording and subsequent computerized locomotive and technical match analysis. Furthermore, physiological measurements during match-play, physical testing and anthropometric measurements were performed.**
Results. **Female players (FP, N.=82) covered a longer mean total distance per match (4693±333 m, group means±SD) compared to male players (MP, N.=83, 3945±538 m) when playing full time (P<0.01). FP exercised at a greater relative workload (79.4% of VO_2-max) than MP (70.9% of VO_2-max, P<0.05), but performed less high-intense running per match (2.5% of total distance covered) than MP (7.9%, P<0.01). FP also spent less time standing still (10.8% of total effective playing time) compared to MP (36.9%, P<0.001) and showed fewer activity changes (663.8±99.7) compared to MP (1482.4±312.6, P<0.001). MP received more tackles in total in offence (34.5±21.3) and performed more tackles in total in defence (29.9±12.3) compared to FP (14.6±9.2, 20.7±9.7, P<0.05). Furthermore, MP performed more high-intense technical playing actions per match (36.9±13.1) than FP (28.3±11.0, P<0.05). The mean body height and body mass differed between MP (189.6±5.8 cm, 91.7±7.5 kg) and FP (175.4±6.1 cm, 69.5±6.5 kg, P<0.001).**
Conclusions. **Substantial gender-specific differences in the physical demands in elite team handball were observed, with MP performing more high-intense, strength-related playing actions and high-intensity running than FP. Conversely, FP covered a greater total distance and demonstrated a higher relative workload than MP. The physical training of male and female elite team handball players should be designed to reflect these contrasting needs.**

KEY WORDS: Physical exercise - Human body - Anthropometry.

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Team handball (TH) is a global ball game sport with professional leagues in many countries. Major international championships are held regularly, and TH has been a part of the Olympic Games both for men and women for more than 35 years. Most researchers believe that the game was invented in Denmark, where the first historical evidence dates from around 1897.[1] From the start it was a game for men, but women gained rapid interest in the game beginning to play TH as early as 1905. Over the last 20 years, Denmark and other Scandinavian countries have ranked among the absolute world elite in both male and female TH, winning a number of medals at the Olympic Games, World and European Championships, and also been winner of the Champions League for club teams numerous times.

Modern elite TH is a physically demanding contact team sport that is determined by the individual performance of each player as well as the tactical components and interaction of the players on the team. It is characterized by sixty minutes (two halves, each of 30 min effective playing time) of fast, intense and dynamic activities such as repeated accelerations, sprints, jumps, shots, rapid changes of

direction and high amounts of body contact between players.[2-6] Additionally, specific technical activities are performed in response to the varying tactical situations of the game.

The increasing number of matches and national/international tournaments has led to an extended competition period covering 9-10 months per year. Therefore, the physique of top level TH players has a governing influence on playing performance not only during each game throughout the entire regular season, but especially in various tournaments, where multiple matches are played over a short period of time. To plan and implement effective physical training in top level TH players, it is necessary to know the physical working demands of the game. A complete analysis of the physical working demands of modern elite TH have recently been conducted separately for male and female elite players.[2-7]

It is well known that physiological differences exist between the sexes, since men in general are taller, heavier with larger muscle mass, stronger, faster and have a higher VO_2-max than women.[8] However, these differences do not have any impact on the TH game itself as no match under normal circumstances is played against someone of the opposite sex. In fact, the only difference between male and female TH is that the ball is larger and heavier in the men's game (450 *vs.* 350 grams). So the question arises, whether from a physiological point of view differences exist between the physical demands imposed by male and female elite TH match-play, respectively. If this is the case, physical training in TH should be designed and performed in ways that reflect the specific demands placed on male (MP) and female players (FP), respectively. To the best of our knowledge no previous study has examined the gender-specific differences in physical demands in elite TH. Consequently, there is a need to examine the potential differences in the physical demands of modern elite TH between MP and FP thoroughly in order to evaluate, if the physical training for MP should differ from that of FP.

The aim of the present study, therefore, was to identify potential gender-specific differences in the physical demands imposed on players during modern adult elite TH match-play. The study was conducted by comparing the working demands in modern male elite TH [2-4] with a corresponding analysis of the working demands in modern female elite TH.[5-7] Both analyses used identical experimental assessment methods. It was hypothesized that gender differences in the physical demands would be observed.

Materials and methods

Subjects

A large group of male and female elite TH players were recruited for the study from teams ranked in the upper half of the Danish Premier Team Handball League. A majority of the participants played at the international top level (European Team Handball Champions League, multiple national teams). All players were fully informed of all experimental procedures and possible discomforts associated with the study before giving their written informed consent to participate. The conditions of the study were approved by the local Municipal Ethics Committee. The study was conducted in accordance with recognized ethical standards as described by Harriss & Atkinson [9] and with the principles of the Declaration of Helsinki.

The MP and FP were examined over a six-year and a five-year period, respectively. The study was carried out during the entire tournament match season (September to May, with players performing 6-10 training sessions and 1-2 matches per week). A number of different teams were monitored in the present study, with new players joining individual teams, while other players conversed were leaving the teams during the study period. No year-to-year differences were observed during the whole study period for any of the analysed parameters. All analysed matches were performed indoor under thermoneutral conditions in terms of temperature (18-22 ºC) and humidity (50-70%).

Experimental procedures

In the present study, the assessment of the physiological and physical demands in modern elite TH were based on video based player observations during match-play complemented by measurements of relevant physiological variables also during match-play (working demand analysis) and measurements of the physical capacity and body anthropometry in elite players (capacity analysis).

Observations during match play-video recordings

Observations during match-play took place by means of video recordings as described in detail

elsewhere.[4] In brief, one camera followed one player without interruption throughout the entire course of the match regardless what the player did. These video recordings mainly involved field players although a few recordings also were performed in goalkeepers. A large number of tournament matches in the Danish Premier Male (62) *vs.* Female (46) Team Handball League were monitored. On average 4 players were recorded per match, which provided a total of about 420 single player recordings. Since TH rules allow unlimited substitutions of players throughout the entire match, it was not possible to collect adequate individual data for a full match time of 60 min. Conversely, we aimed to only include 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, was determined as being an effective playing time for the whole match of 42 min or more (*i.e.* ≥70% of total effective playing time (TPT)) with an effective playing time in each half of the game of 18 min or more (*i.e.* ≥60% of total duration of one half). A total of 82 recordings of MP and 84 recordings of FP (a total of 52 individuals players on the teams studied, mean number of recordings per player: 3.2, range: 1-8) fulfilled these conditions and were analysed according to the established criteria.[3, 4]

The players examined in the present study on average played roughly one tournament match per week during the regular tournament match season (Danish National Championship). This is much different from the conditions of national team players when participating in international elite TH tournaments, where each team typically play about 8-10 matches in 10-14 days.[4] In such tournaments, players tend to be more frequently substituted on all playing positions, especially for backcourt players and pivots,[4] to enable players to consistently perform at a high level during the entire time course of the tournament.

Additionally, for mainly tactical reasons some players rotate between every ball possession, *i.e.* some players specializes to play in offense only, while others play only in defence. However, only a limited number of specialized players were observed in the present study. This is probably because at the club level the best players will mostly have to take part in both offence and defence, due to the relatively large differences in playing standards (fewer top performing players) among the team players. 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 an atypically high playing intensity compared to 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.

Tactical/technical demands differ substantially between offence and defence actions during TH matchplay. The present computerized match analysis, therefore, focused separately on offensive and defensive playing actions. In this differential analysis (offence vs. defence), field players were further divided into three categories, wing players, pivots and backcourt players, respectively. Each match was analyzed twice for each of the players. The first computerized analysis included locomotion match characteristics (running types, intensity and distance), which has previously been used in the analysis of other ballgames such as soccer, basketball and rugby.[4]

A total of 8 locomotive categories were registered in accordance with previous studies in elite soccer players.[10-12] Each movement category was classified by a precise definition of the form of locomotion and the locomotive speed measured in $km \cdot h^{-1}$. The speed was determined from detailed studies of the video recordings using lines on the playing court as spatial reference marks. The selected speeds were the same for all players, but a little higher in most categories for MP compared to FP. Using speeds given for the various locomotion categories, the distance covered for each activity within each interval was determined as the product of the total time and mean speed for that activity. Total distance covered during a match was calculated as the sum of the distances covered during each type of locomotion.

The movement categories and corresponding speeds for FP and MP, respectively, were low-intensity activities (standing still [0 $km \cdot h^{-1}$] and walking [4 $km \cdot h^{-1}$]), moderate-intensity activities (jogging [7 and 8 $km \cdot h^{-1}$], sideways movement [9 and 10 $km \cdot h^{-1}$], backwards running [9 and 10 $km \cdot h^{-1}$]) and running [12 and 13 $km \cdot h^{-1}$]), and high-intensity running ([fast

running - [15.5 and 17 km·h^{-1}] and sprinting [22 and 24 km·h^{-1}]).

Since TH involves large amounts of physical contact, computerized technical match analysis (technical playing actions) of each game was conducted to avoid an underestimation of the quantity of movement. Six types of playing actions were registered: shots, breakthroughs, fast breaks, tackles, technical errors and defensive errors. Each playing action was further divided into a number of sub-categories (*e.g.* hard or light tackles, clapings, type of shot performed and screenings), all of which were precisely defined.[3] A few actions did overlap, *e.g.* a breakthrough could result in a technical error, in a shot or in a tackle of a special category. Players, who regularly changed defensive playing position making it impossible to define a fixed defensive playing position, were excluded from the analysis of defensive 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.

For both match analyses, a special designed computer based analysis program for TH was used.[4, 13] To ensure high data reliability, all matches in the present study were analysed by the same experienced observer. An identical approach has been used in previous studies.[11, 12] No systematic differences in the intraobserver test-retest analysis outcome were observed after a period of intense analyst training. More details about the video analyses are given.[3, 4]

Physiological measurements during match-play

The physiological workload during matches in the Danish Premier Male *vs.* Female Team Handball League was registered by continuous HR monitoring in successive 5-second intervals. Approximately 45 minutes before match start, the players were equipped with a chest strap heart monitor (Polar Team System, Polar Electro OY, Kempele, Finland) with the receiver part located in the transmitter strap (no need for a wristwatch receiver during match-play). By registration of the time when the match was paused and when the player was not on the court due to substitution, suspension or injury, all inactive time periods could be excluded from the HR analysis. HR was analysed in three different time domains, namely total playing time (the time span of the whole match), effective playing time (the time span of actual playing time) and individual playing time (the time span, when the individual player is active on the court).

Physical testing

Laboratory treadmill testing

On a separate day, an incremental treadmill running test was performed, which consisted of a submaximal test followed by an exhaustive incremental maximal test (all-out test).[2, 5, 7] The protocol consisted of 6-min horizontal running, each period separated by 2-min rest periods (submaximal test). The running speed started at 8 km·h^{-1} for FP and at 10 km·h^{-1} for MP, respectively, and was increased with 2 km·h^{-1} each time. Subsequently after a 15-min rest period, an all-out test was performed. The all-out test was initiated at a running speed at 12 km·h^{-1} for FP and at 14 km·h^{-1} for MP for 2 min, followed by 1 min at 14 and 16 km·h^{-1}, respectively, and then continued with stepwise 1 km·h^{-1} speed increments every minute until exhaustion. Total running time to exhaustion during the all-out test was recorded.

Respiratory measurements were conducted using online analysis (AMIS 2001, Damec Research, Odense, Denmark and Oxycon Pro, Jaeger, VIASYS Healthcare, Hoechberg, Germany, respectively). During the submaximal test, VO_2 was measured in 30-second intervals during the final 2 min of steady-state running at each running speed. Individual maximal oxygen uptake (VO_2-max) and HR-max were determined as the peak values recorded in a 15- and 5-s period, respectively, during the final phase of the all-out test. In addition, the Fitness Index (ml O_2·min^{-1}·kg$^{-0.73}$) was calculated.[14]

HR was continuously recorded in 5-s intervals throughout the test (Polar S610 HR monitor, Polar Electro OY, Kempele, Finland). The individual HR-VO_2 relationship obtained during the treadmill test (correlation equation y=a·x+b) was used to estimate VO_2 during match-play based on the HR recording obtained during match-play according to previous soccer match analyses.[15-17] Subsequently, the relative workload during match-play could be determined expressed as% of VO_2-max.

Body anthropometry

Anthropometric data (body mass, standing body height) were recorded in all players from the top ranked teams during physical tests sessions. In addition, body anthropometry and relevant player characteristics for the remaining teams of the Danish Premier Male vs. Female Team Handball League were obtained by the team physician or physiotherapist and subsequently reported to the principal author in the first season (N.=120) and in the fourth season (N.=157) for FP and in the first season (N.=152) and in the fifth season (N.=191) for MP. Specifically, information about the individual players´ body mass, body height, age, playing position, player choice (first or second choice) and playing experience (years of playing) at the adult elite level were obtained.

Body mass was measured with the players wearing light indoor clothing (short pants, t-shirt) and no shoes, using commercially available electronic digital scales (measurement error ≤1%). Standing body height was measured to the nearest mm 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 (measurement error ≤1 mm, corresponding to ≤0.05% relative error).

Statistical analysis

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

Statistical differences between several groups (*i.e.* comparing different playing positions) were evaluated using one-way analysis of variance, ANOVA. Post Hoc differences between groups were evaluated by Tukey's HSD testing (normally distributed). The Pearson product-moment correlation analysis was used to evaluate potential relationships between selected parameters. Cohen´s d-test was used to calculate effect size (d-values stated as ES) to estimate the magnitude of the results (differences between subjects or groups), and were reported along with all statistically significant results as an indicator of practical significance. The statistical level of significance was set at P≤0.05 using a two-tailed test design.

Results

Locomotion characteristics, physiological measurements and physical testing

Marked differences were observed in the movement pattern between MP and FP during match-play (Table I). Standing still and walking combined constituted nearly the same amount per match for MP (76.4±10.4 of TPT) and FP (73.1±4.8%), but FP

Table I.—*Gender differences in offensive and defensive locomotive actions in total per match for male (N.=82) and female elite team handball players (N.=83) separated into in the eight movement categories. Results are mean.*

	Male players (N.=82) % of total playing time per match	Female players (N.=83) % of total playing time per match
Playing time (min)	53.85	50.70 *
Standing still	36.8	10.8 **
Walking	39.6	62.3 **
Jogging	8.6	18.8 **
Running	4.4	4.9
Fast running	1.4	0.7 **
Sprinting	0.4	0.1 **
Sideways movement	7.4	1.8 **
Backwards running	1.4	0.6 *
Total	100.0	100.0

Difference between male and female players *P<0.05 and **P<0.001.

spent less time standing still (10.8±3.8% of TPT) and equivalent more time walking (62.3±5.9% of TPT) compared to MP (36.8±8.6%, P<0.001, ES=3.91; 39.6±7.3%, P<0.001, ES=3.42). MP performed more high-intensity running (1.7±0.9% of TPT) than FP (0.8±0.5, P<0.001, ES=1.24) and also more sideways movement (7.4±2.7% of TPT) and backwards running (1.4±0.8% of TPT) compared to FP (1.8±1.3%, P<0.001, ES=2.64; 0.6±0.4%, P<0.001, ES=1.26).

FP covered a greater total distance per match (4002±551 m) than MP (3627±568 m, P<0.05, ES=0.67) in spite of that the analysed matches for FP were in average were 3.15 minutes shorter compared to MP (Table II). The same picture emerged when comparing full-time players (60 min playing time; 4693±333 m *vs.* 3945±538 m, P<0.01, ES=1.67). FP exercised at a greater relative workload during their time on the court (79.4±6.4% of VO_2-max) than MP (70.9±6.0%, P<0.05, ES=1.37), but performed less amount of high-intensity running per match (2.5±1.8% of total distance covered) than MP (7.9±4.9%, P<0.01, ES=1.46). Furthermore, FP worked with a lower mean speed (5.31±0.33 km·h^{-1}), which was calculated without the contribution of the standing still category, and had fewer mean number of activity changes (663.6±100.1) compared to MP (6.40±1.01 km·h^{-1}, P<0.001, ES=1.45; 1482.4±312.6, P<0.001, ES=3.53). MP showed a higher oxygen uptake than FP, irrespectively of normalisation procedure (Table II).

Position specific locomotion match profile

No differences in on-court playing time between the different playing positions were observed in either MP (Wing Players: 52.80±5.40 min, Pivots: 53.20±6.18 min, Backcourt Players: 54.72±5.52

TABLE II.—*Gender differences in selected categories of the physical demands during match-play (group means±SD) between Danish male and female elite team handball players.*

	Male players (N.=82)	Female players (N.=83)
Mean effective playing time (min)	53.85±5.87	50.70±5.83 *
Total distance covered (m)	3627±568	4002±551 *
Total distance covered, full-time players (m)	3945±538	4693±333 **
High-intensity running (% of total distance covered)	7.9±4.9	2.5±1.8 **
Standing still (% of total playing time)	36.8±8.6	10.8±3.8 ***
Sideways movement (% of total playing time)	7.4±2.7	1.8±1.3 ***
Mean speed (km·h^{-1})	6.40±1.01	5.31±0.33 **
Activity changes (number)	1482.4±312.6	663.6±100.1 ***
Relative workload (% of VO_2-max)	70.9±6.0	79.4±6.4 *
High-intense technical playing actions (number)	36.9±13.1	28.3±11.0 *
VO_2-max (l O_2·min^{-1})	5.18±0.66	3.49±0.37 ***
VO_2-max (ml O_2·min^{-1}·kg^{-1})	57.0±4.1	49.6±4.8 ***
Fitness Index (ml O_2·min^{-1}·kg$^{-0.73}$)	192.6±18.2	156.4±15.3 ***

Difference between male and female players *P<0.05, **P<0.01 and ***P<0.001.

TABLE III.—*Positional differences in total distance covered, amount of high-intensity running and relative workload during match-play, respectively, for Danish male (N.=82) and female elite team handball players (N.=83).*

	Wing players	Pivots	Backcourt players
Total distance covered (m)			
Male players	3641±501	3295±495	3765±532
Female players	4086±523 *	4067±485 *	3867±386
High-intensity running (% of total distance covered)			
Male players	10.9±5.7	8.5±4.3	6.2±3.2
Female players	3.6±1.5 **	2.3±1.5 **	1.3±0.9 **
Relative workload during match-play (% of VO2-max)			
Male players	73.2±4.9	73.8±5.9	67.9±5.6
Female players	78.4±5.9 *	83.1±4.9 *	75.8±6.5 *

Difference between male and female players *P<0.05 and **P<0.01.

min) or FP (Wing Players: 51.35±6.88 min, Pivots: 51.12±5.20 min, Backcourt Players: 49.70±4.88 min). MP exercised at all playing positions with a higher anaerobic load (more high-intensity running) and at a lower aerobic intensity (lower relative workload) compared to FP (Table III). In addition, for both MP and FP several differences were observed between various playing positions (Table III). Among MP, backcourt players (3765±532 m, P<0.05, EA=0.91) and wing players (3641±501 m P<0.05, ES=0.69) covered a greater total distance than pivots (3295±495 m), while female pivots were more agile and performed relative more running. Among FP, pivots (4067±485 m, P<0.05, ES=0.45) together with wing players (4086±523 m, P<0.05, ES=0.47) covered a greater total distance than backcourt players (3867±386 m). In both sexes, wing players performed more high-intensity running (MP 10.9±5.7%, FP 3.6±1.5% of total distance covered) than pivots (8.5±4.3%, P<0.05, ES=0.48; 2.3±1.5%, P<0.01; ES=0.87) and backcourt players (6.2±3.2%, P<0.01, ES=1.02; 1.3±0.9, P<0.01, ES=1.86).

Among MP, both pivots (73.8±5.9, P<0.05, ES=1.03) and wing players (73.2±4.9, P<0.05, ES=0.91) played at a higher relative workload than backcourt players (67.9±5.6), while female pivots were even more active and played at a higher relative workload (83.1±4.9) than both wing players (78.4±5.9, P<0.05, ES=0.87) and backcourt players (75.8±6.5, P<0.01, ES=1.27) (Table III). In both sexes, backcourt players were the least active of all players. Expressed relative to body mass (ml $O_2 \cdot min^{-1} \cdot kg^{-1}$) or as Fitness Index (ml $O_2 \cdot min^{-1} \cdot kg^{-0.73}$), VO_2-max did not differ between playing positions both for MP and FP.

Technical match profile

Gender differences were observed in the technical match analysis (Table IV). In offence, MP performed more fast breaks (6.0±4.2) than FP (2.8±2.6, P<0.001, ES=0.92), received more tackles in total (hard and light tackles combined, 34.5±21.3) than FP (14.6±9.2, P<0.001, ES=1.21) and did less technical errors (1.5±1.3) compared to FP (2.9±2.3, P<0.05, ES=0.75).

In defence, MP performed more tackles in total (29.9±12.7) than FP (20.7±9.7, P<0.01, ES=0.81) and did more claspings (3.9±3.0) and screenings (6.1±3.1) compared to FP (1.9±2.7, P<0.01,

TABLE IV.—*Gender differences in offensive and defensive technical playing actions in total (group means±SD) for the entire match for Danish male (N.=82) and female elite team handball players (N.=84).*

Technical playing actions	Male players (N.=82) Number per match	Female players (N.=84) Number per match
Offensive actions - 1. half and 2. half in total		
Playing time (min)	26.18±3.13	24.57±4.33
Offensive breakthroughs	1.5±1.4	1.3±2.2
Fast breaks	6.0±4.2	2.8±2.6 **
Technical errors	1.5±1.3	2.9±2.3 *
Hard tackles	7.5±4.4	5.0±4.0 *
Light tackles	27.0±18.4	9.6±6.2 **
Clasping	2.7±1.9	1.2±2.0 *
Screenings	4.8±8.3	7.9±9.8*
Shots	8.5±4.2	7.7±3.7
Scoring percentage	44.9±17.7	51.9±21.4
Defensive actions - 1. half and 2. half in total		
Playing time (min)	27.67±3.18	26.13±3.85
Hard tackles	5.8±3.6	6.2±3.8
Light tackles	24.1±12.6	14.5±7.4 *
Clasping	3.9±3.0	1.9±2.7 **
Screenings	6.1±3.1	4.2±3.7 **
Blockings	3.7±3.5	3.5±3.8
Defensive errors	3.8±2.5	5.1±3.2 *

Difference between male and female players *P<0.05 and **P<0.001.

ES=0.70; 4.2±3.7, P<0.05, ES=0.56). In total, MP performed a higher number of high-intense playing actions per match (36.9±13.1) than FP (28.3±11.0, P<0.05, ES=0.71).

Differences between first and second half of the match

Compared to the first half both MP and FP demonstrated a decrease during the second half of match-play in the amount of high-intensity running, HR, relative workload and in number of high-intense playing actions. As the only difference between MP and FP, the number of technical playing actions declined in MP, but not in FP in the second half.[3, 6]

Anthropometric and player characteristics

Mean body height and body mass in the Danish Premier Male Team Handball League were substantially higher (189.6±5.8 cm, 91.7±7.5 kg) compared to the Danish Premier Female Team Handball League (175.4±6.1 cm, P<0.001, ES=2.39; 69.5±6.5 kg, P<0.001, ES=3.16) corresponding to a mean difference between MP and FP in body height and body mass of 14.2 cm and 22.2 kg, respectively. No difference was seen in age and adult elite playing experience between the two sexes (Table V).

The potential effect of body anthropometry, age and playing experience on individual playing time and hence playing performance can be illustrated by comparing first (players, who were selected for the team's starting line-up and usually did get most on-court playing time) and second-choice players. In both sexes for all players combined, no differences in body height and body mass between the two choices of players were observed, but first-choice players were older and more experienced (P<0.001) than second-choice players (Table VI).

Position specific differences in technical characteristics and in body anthropometry

Technical playing actions differed at all playing positions between MP and FP with MP performing more fast breaks and physical confrontations with opponent players (tackles, screenings, claspings and blockings) than FP. Furthermore, a number of differences were observed between various playing positions for both MP and FP in regard to the various technical categories. Notably, wing players both for MP and FP had less physical confrontations in of-

TABLE V.—*Age, body height, body mass, and number of years played on adult elite level (group means±SD) for male (N.=348) and female elite team handball players (N.=277) inclusive goalkeepers, respectively, in the Danish Premier Team Handball League.*

	Male players (N.=348)	Female players (N.=277)
Age (years)	26.1±3.9	25.4±3.7
Body height (cm)	189.6±5.8	175.4±6.1 *
Body mass (kg)	91.7±7.5	69.5±6.5 *
Adult elite playing experience (years)	7.3±4.5	7.2±3.9

Difference between male and female players *P<0.001.

TABLE VI.—*Age, body height, body mass, and number of years played on adult elite level (group means±SD) for first and second choice players for male (N.=348) and female elite team handball players (N.=277) inclusive goalkeepers, respectively, in the Danish Premier Team Handball League.*

	Age (years)	Body height (cm)	Body mass (kg)	Number of adult elite years
Male players (N.=348)				
1. choice (n=187)	27.3±3.6 *	190.1±6.1	92.0±7.6	8.4±3.4 *
2. choice (n=161)	24.6±4.2	189.1±5.2	91.4±8.3	5.8±3.8
Female players (N.=277)				
1. choice (n=163)	26.4±3.4 *	175.8±5.9	69.8±6.2	8.3±3.6 *
2. choice (n=114)	23.9±3.7	174.8±6.4	69.1±6.8	5.5±3.7

Difference between first-choice and second-choice players *P<0.001.

fence and in defence than backcourt players and in particular pivots.

Additionally, female wing players performed more fast breaks (4.4±2.8) than pivots (2.5±1.8, P<0.01, ES=0.81) and backcourt players (1.0±1.3, P<0.01, ES=1.56), while male pivots (8.3±4.0) performed just as many fast breaks as wing players (8.9±3.1) and markedly more than backcourt players (3.4±3.2, P<0.05, ES=1.35). Male backcourt players performed more shots per match (10.5±3.4) than both pivots (7.0±2.0, P<0.05, ES=1.25) and wing players (5.8±2.5, P<0.005, ES=1.58) with similar scoring percentage (42.0±14.6) as pivots (48.8±24.2) and wing players (46.9±23.9). In contrast, no difference between the numbers of shots per match between the various playing positions among FP were observed, but pivots had a higher mean scoring percentage (68.0±17.4, P<0.001) than backcourt players (46.8±20.6, ES=1.11) and wing players (47.5±20.1, ES=1.09).

For both sexes, wing players were lighter, smaller, younger and less experienced on adult elite level than the rest of the players including goalkeepers, and pivots were heavier and taller than the rest of the field players. Body height and body mass did not differ between first and second choice players in various playing positions for both MP and FP, but first-choice players were in almost all cases older and more experienced than second choice players (P<0.001) except for male pivots and female goalkeepers, where no difference in age and playing experience between the two choices of players was demonstrated.

Discussion

This is the first study to examine differences in the physical demands in modern adult elite TH between MP and FP by means of a complete working demand analysis. The main findings of the present study were that substantial gender differences were observed as MP demonstrated more physical, strength-related confrontations with the opponents and performed more high-intensity work than FP, whereas FP showed a higher relative workload during match-play compared to MP. Not surprisingly, systematic anthropometric differences were observed between the two sexes.

Gender differences

Locomotion activity pattern

Based on the present results, clear gender differences were observed in the locomotion activity pattern of male *vs.* female elite TH players during actual match-play. The locomotive match analysis revealed that FP covered a greater total distance than MP also when comparing full-time players. Additionally, FP demonstrated a greater relative workload during match-play than MP, but performed less amount of high-intensity running per match compared to MP. The greater total distance covered in spite of less amount of high-intensity running with FP was partially the result of significant less time spent standing still compared to MP. The latter contributed to that FP showed a lower mean speed than MP, since the mean speed was calculated without the contribution of the standing still category. Furthermore FP demonstrated fewer activity changes compared to MP.

During organized attack, FP appeared to play in a relatively uniform pace with the players frequently walking, but rarely standing still. Likewise, FP demonstrated few intense tempo changes and changes in direction accompanied by relatively few fast breaks compared to MP. Consequently, the amount of high-intensity running constituted only a small fraction of TPT. On the other hand, numerous changes in ball possession resulted in large amounts of transition running involving rapid shifts between defence and offence actions. Compared to MP, FP showed less playing time spent in the organized attack explaining the high occurrence of transition running between offence and defence in these players.

Most likely, this was partly due to poorer technical skills in FP compared to MP, which is reflected by the higher number of technical errors in FP (twice as many technical errors per female player and hence also per team compared to MP). A reason for this observation may in part be due to gender differences in the relative size of the players´ dominant hand in relation to the size of the ball (“ball coverage index”, which indicates the percentage of the ball surface that the player’s hand is able to cover). The ball coverage is lower in adult elite female vs. male TH players.[18] More technical errors cause more switching between offence and defence and results in more continuous running with moderate intensity. The high total distance covered and the low number of

activity changes indicates that female elite TH players perform large amounts of un-interrupted running during much of the match, resulting in a relatively higher aerobic intensity. In contrast, the fewer fast breaks and activity changes and thus shifts of tempo and direction results in less anaerobic workloads being placed on the lower extremities.

Conversely, male elite TH players were characterized by a relatively steady pace of locomotion during organized attack, with players frequently standing still or walking. However, match-play still involved numerous intense tempo changes and changes of direction, which together with the relatively many fast breaks caused high-intensity running to represent a relatively high fraction of total distance covered, altogether suggesting that the ability to change pace and accelerate in specific game actions is very important for playing performance. Male elite TH match-play showed substantially more intermittent activity pattern compared to female elite TH, reflected by the more than two-fold higher number of activity changes in MP.

In result, male elite TH players were characterized by a bimodal activity pattern that contained both a markedly higher anaerobic load (more high-intensity running) and a lower aerobic load due to more low-intensity activity compared to female elite TH players. Notably, MP performed substantially more sideways movement both in offence and defence compared to FP, maybe due to need for high muscle strength in the lower extremities in order to perform fast sideway displacements carried out deep down in the legs.

The size of the TH court (identical for both sexes) is relatively bigger for FP compared to MP, given the smaller body dimensions in the former players. Possibly in partial consequence hereof, significant higher total distance covered and relative workload was observed for FP during match-play. Furthermore, studies show that FP reach a VO_2-max of just less than 80% of the value achieved by MP, while female TH players have a Fitness Index of 85% of male elite TH players,[14] indicating a higher demand for aerobic performance in the women's game. The data by Jensen *et al.* (2001) were collected in national TH players over a period of 10 years, suggesting that their players were optimally physically trained.

However, in the present study VO_2-max and the Fitness index of FP constituted 86% and 79%, respectively, of MP's values. Nevertheless, based on previous findings in female *vs.* male elite soccer players,[11, 19] where a positive correlation between VO_2-max and high-intensity running (an indicator of high physical match performance) was observed during female soccer games, whereas no such relationship was found in male elite soccer, maximal aerobic power may be more important for physical match performance in female elite team handball players players compared to their male counterparts. This may be explained by a lower anaerobic capacity in female elite players.

MP and FP exercised with a mean relative workload of 71% and 79% of VO_2-max during match-play, respectively, despite the fact that low-intensity activities (standing still and walking) constituted as much as 73% and 76% of mean TPT, respectively. Consequently, the amount of high-intensity, strength related technical playing actions such as tackles, claspings and one-to-one "in fight" situations appeared to have a significant influence on the relative workload in both genders without contributing substantially to the total distance covered.

Positional differences in locomotion activity pattern

Both similarities and differences in the locomotor profile were observed at the various playing positions. Female backcourt players were less active with a low total distance covered and mean speed, low amount of high-intensity running and fewer fast breaks than the other playing positions. Male backcourt players were also from a locomotive point of view the least active playing position, but with the difference that male backcourt players covered a high total distance due to they were relative more constant in motion in offence with lower intensity instead of standing still.

Conversely, female wing players had the highest total distance covered and mean speed, highest amount of high-intensity running and performed the most fast breaks and many retreats. Male wing players were also very active with the highest amount of high-intensity running, but male backcourt players covered more total distance and worked with a higher mean speed than wing players, and pivots performed must as many fast breaks.

Female pivots covered a high total distance, be-

cause during offence and defence these players showed only minor periods of standing still (~10% of TPT). Instead they mostly walked or performed a little running. In addition, they performed an average amount of high-intensity running and number of fast breaks. In contrast, male pivots covered a low total distance due to a high amount of standing still (~40% of TPT). When moving, however, these players showed relative high mean speeds and performed large amounts of high-intensity running with many fast breaks and retreats. Thus, female pivots in general appear to be more agile than their male counterparts, however during their active periods male pivots seem to move with greater intensity (higher speed).

Technical match profile and body anthropometry

The technical match analysis revealed that both in offence and defence the amount of high-intense playing actions and physical confrontations with opponents were markedly less for FP compared to MP. The fewer high-intense, strength-related playing actions suggest that with FP both the upper and the lower extremities are exposed to a less anaerobic load. Although a need still exist to work with high intensity (anaerobic work) and using large physical strength in FP, this need appears to be much less compared to MP. The differences between various playing positions were almost similar in FP and MP, and in both sexes wing players had considerable less body contact in both offence and in defence than both backcourt players and particularly pivots.

The differences presently observed in strength-related playing actions conform to the differences in anthropometry between the two sexes. MP showed markedly higher body mass and body height than their female counterparts. With substantially larger, heavier and stronger players it is not surprising that the amount of physical confrontations is higher among MP. Larger and heavier MP takes up relatively more space on the court. Consequently, this increases the possibility of more physical confrontations among MP.

With similar TH court size, FP simply takes up relatively less space on the court. Moreover, in TH as in many other ball games, there has always been a tradition for a more physical and aggressive style of play with MP than with FP. Although the women's game has become much more physical over the last decades, a fundamental difference in the style of play in modern elite TH still appears to exist between the two genders, which results in substantial differences in the proportion of high-intense and strength-related load *vs.* more aerobic loading patterns during match-play.

A study of Norwegian elite TH players of both sexes [20] found that during training the number of serious knee injuries were almost similar with MP and FP, but during match-play the incidence of these injuries were seven times greater with FP compared to MP. These observations indirectly suggest that the intensity and aggressiveness during training is lower in elite FP compared to elite MP. Consequently, FP may experience a relatively mismatch to the physical demands imposed during elite match-play than MP. Thus, the possibility exists that the daily training in female TH players may not be sufficiently optimized in terms of intensity and functional movement strength, potentially resulting in a less physical oriented activity patterns during competitive match-play.

For all players combined, there were no difference in age and playing experience between the two genders, which is somewhat surprising considering the possibility of an early TH career stop for FP because of pregnancy and higher incidences of anterior cruciate ligament injury.[20] The former aspect applies apparently not for female elite TH players, which maybe gives birth in a higher age than the average population or quickly are coming back on the TH court after birth. Also the differences in body anthropometry, age and experience on the various playing positions and in addition between Danish and foreign players were nearly identical for MP and FP. Thus, the only real difference between the two genders relates to the difference in the average size of players.

Differences between first and second half of the match

Although clear differences in the physical demands between MP and FP were observed, comparison of individual activity patterns between the two halves suggest that players of both sexes with a TPT over 50 min per match were experiencing temporary

fatigue during match-play, as reflected by a decrease in the amount of high-intensity running, HR, relative workload and in number of high-intense playing actions during the second half. However, it was not possible to establish, if the origin of the developed fatigue was identical between the sexes, since specific fatigue factors were not directly assessed.

It cannot be excluded that the observed declines in the analysed parameters during the second half could be influenced by situational variables such as match location, quality level opposition and match status, as previously indicated in elite soccer.[21-24] However, due to the large number of matches and players analysed in male vs. female elite TH (62 *vs.* 46 matches of different tactical/strategic importance, involving 82 *vs.* 83 analyzed players from several different teams) [8] our results probably revealed a realistic picture of the match-induced impairments in physical performance in the second half.

Conclusions

In conclusion, the present study demonstrated considerable gender-specific variations in the physical demands in modern adult elite team handball, and in addition clearly indicated that the physical demands differ greatly between various playing positions both in offence and in defence in the same manner for both male and female elite players. Consequently, physical training of female elite team handball players may benefit from a greater focus on aerobic training elements. Conversely, male elite team handball players would seem to benefit from an increased training focus on anaerobic exercise elements and strength training.

Alternatively, female elite team handball may be developed into a more intermittent and high-intensive game, with more physical confrontations with opponents, *i.e.* converging towards the characteristics of male elite team handball match-play. This approach would require female players in their daily training routines to focus more intensively on the areas of physical training that are pivotal to male players (anaerobic training and strength training). Regardless of gender, however, the planning and execution of physical training should be individually adjusted to the specific playing position and the players´ individual physical capacity.

Practical applications

In modern elite team handball, the physical capacity of the players has a pivotal influence on playing performance. In the present study, clear gender-specific differences in the physical demands of modern elite team handball were demonstrated, strongly suggesting that central areas of physical training should be conducted differently in female elite team handball compared to male elite team handball. Thus, the present data suggest that female players should focus relative more on aerobic training exercises and relative less on anaerobic training drills and strength training. In contrast, male players should focus mostly on anaerobic training and strength training, while aerobic training may be considered less important. Physical training in elite team handball should comprise exercises for improving players' ability to repeatedly perform high-intensity activities and to rapidly recover during less intense periods. Furthermore, our positional analysis shows that the planning of physical training should take the playing position and the players' individual capacity into account, irrespectively of gender.

If the goal of physical development in female players is to adopt a more intermittent, high-intensive and aggressive playing style with an increased number of physical confrontations with opponents (*i.e.* similar to male players), it would seem, on the other hand, a prerequisite that the daily physical training in female elite team handball should comprise an increased amount of anaerobic training elements and an increased focus on strength training. However, the two kinds of team handball will never be identical, if the number of players during match-play and the size of the court remains similar for the two sexes, because male players are bigger and taller than female players, and in general also have better technical and tactical abilities in team handball.

Development in the anthropometry of elite team handball players may also play a role for the development of the game. Thus, the difference in body height between the present male and female elite team handball players (14.2 cm) was of approximately the same size as the difference between men and women in same age group (20-35 years) in the Danish population (181.6 cm *vs.* 168.3 cm ~13.3 cm).[25] Conversely, the difference in body mass between the present male and female elite team handball players (22.2 kg) was markedly greater than the difference

in body mass between the two sexes reported for the same age range in the Danish population (82.5 kg *vs.* 67.8 kg ~14.7 kg).[25] This indicates that female elite team handball players may achieve further developments in muscle mass, in order to improve strength and power performance during on-court training and match-play.

It is important that the improvements achieved by physical training can be transferred to the actual team handball game on-court. Therefore, the training needs to be as functional as possible. Physical training in team handball as an example should as far as possible be performed on-court in game-like simulations (*i.e.* with ball handling involved).

Perspectives

Due to an increasing intensity of the game, the physical demands of modern elite team handball during match-play plays a relatively larger role in the players' total performance capacity than decades ago. Consequently, the specific design and implementation of physical training in team handball represent an essential tool to exploit and sustain player's technical and tactical qualities throughout an entire game. In addition, an improved level of physical capacity enables players to train at increased intensity and in achieving a large total quantity of training. Increased focus on anaerobic (and intensive aerobic) training elements also seems of relevance due to the fact that at least some players seem to develop temporary fatigue during the time course of match-play.

Physical training is only a supplement to the technical and tactical aspects of team handball training. Therefore, it is a matter of utilizing the time for physical training to the maximum. This is done by adapting the training in specific relation to the qualities of the individual player, to his/her playing position on the field as well as the need for restitution.[26] Total training dosage should also be individualized, since the training load during uniform types of team training may be appropriate for some players, but inadequately low or perhaps even too high for other players.

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