Relationship Between the Danish Handball Federations Physiological Profile and Selected Handball Specific Tests

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ABSTRACT:

The aim of the present study was to investigate the relationship between the tests included in the Danish Handball Federations(DHF) physiological profile and selected handball specific tests. 14 male handball players (age 20.6 ± 2.1 years; height 191 ± 6 cm; weight 91 ± 5.2 kg) participated in the study. Over the course of two days the players completed the tests included in DHF's physiological profile (5-Repetition maximum bench press(5RMBP), 5-repetition maximum squat(5RMS), agility test, 3000m and brutal sit-ups test) as well as three selected handball specific tests (jump height, throwing velocity and sprint ability). Pearson correlation coefficients were calculated between the tests included in the DHF's physiological profile and the handball specific tests. The $p \leq 0.05$ criterion was used for establishing statistical significance. Results showed a strong significant correlation between the 3000m test and sprint ability at 5(r = .6), 10(r = .68) and 20m(r = .64). As well as between the agility test and 5m sprint(r = .58). In conclusion, the present study demonstrated that performance in the 3000m test is strongly associated with sprint ability while performance in the agility test is strongly associated with 5m sprint. This suggests that coaches and players may use the 3000m and agility test for evaluating sprint ability. They may also benefit from incorporating middle distance running into their training regime for improving sprint performance.

Key words: 5RM, Countermovement jump, speed gates, radar, jump mat.

INTRODUCTION:

Team handball (TH) is a physical contact sport played by more than 27 million men and women worldwide. During a match, players work intensely for short time intervals while walking, running, sprinting, moving forwards and backwards, side-stepping while also being tackled, grappled and pushed (1). In addition to technical, tactical and mental skills, physical abilities such as jumping, sprinting and maximal ball throwing velocity have proved important for the performance capacity in elite TH players (2,3). Previous studies have implemented various types of physical training to improve TH performance (4–6) and the physical abilities of players remain an important variable as it has been shown to differentiate the elite from non-elite (2).

Due to the importance of a players physical capabilities it is relevant to be able to evaluate them. Preferably this should be done using tests that are as sport specific as possible. For example, a jump mat can be used to accurately measure a players jump height (7). A radar gun in combination with a standing throw (penalty throw) can be used to measure a players throwing velocity (7), and speed gates can be used to measure a players sprint ability (7). These are all sports specific skills that are important for a handball player and are therefore effective tests for evaluating players. However, outside of elite TH these tests are rarely available, as the equipment required is expensive and may require expertise to be used properly. In practice, field tests that correlate well with actual performance are therefore a good alternative.

In Denmark the Danish Handball Federation (DHF) has a physiological profile that enables coaches and physical trainers to evaluate both male (8) and female players (9) on a number of field tests and compare them to the elite. The profile includes five repetition maximum bench press (5RMBP), five repetition maximum squat (5RMS), 3000m running, brutal sit-ups and an agility test.

Unfortunately there is no information available as to how the tests chosen by the DHF correlate with handball specific tests, and thus to actual performance. Previous research has shown however, that there is a positive correlation between one repetition maximum bench press (1RMBP) and throwing velocity (4). As well as a positive correlation between one repetition maximum squat (1RMS) and jump height and sprint ability (10,11). However, despite correlations having been shown using 1RM there is a lack of research regarding the 5RM protocol that the DHF uses. As previous research provides clear evidence of the 1RM's association with performance variables this raises the question as to why DHF has chosen the 5RM over the 1RM protocol.

Research has also shown a positive correlation between core strength and throwing velocity (12). Finally, there is a lack of research on the 3000m running test included and its relevance in TH. But it has been concluded that handball players need a high aerobic capacity in order to be able to regenerate during the low intensity phases to ensure that they can play with a high intensity in the high intensity phases (3). Thus, the 3000m running test may not be the optimal choice for evaluating TH players as it doesn't represent the actual work done in TH as this is more interval based work.

In general, the above shows that the physiological profile used by DHF includes many of the tests used in previous research. However, some of the test protocols vary from those which research have found to correlate (5RM vs 1RM) while others simply lack investigation. Therefore, the aim of the present study was to investigate the relationship between the tests included in the DHF's physiological profile and selected handball specific tests in the form of jump height, throwing velocity and sprinting ability.

By investigating this relationship it is possible that the present study will support the choice of tests included in the DHF's physiological profile or raise awareness to the question as to why these tests are included. In this process new information may be discovered that will change the way we evaluate TH players. Based on previous research it was hypothesized that there would be a statistical significant correlation that was: (1) strong and positive between 5RMBP and throwing velocity, (2) strong and negative between 5RMS and sprint ability, (3) strong and positive between 5RMS and jumping height, (4) strong and positive between brutal stomach sit-ups and throwing velocity, (4) moderate to strong and positive between 3000m running and the agility test and (5) moderate to strong and positive between the agility test and sprint ability.

METHODS:

Subjects:

TH players (n = 14) from the Danish 1. Division were recruited for the study. The players had an average of 13 ± 3.7 years' experience with TH. They trained 3.5 ± 1 times per week and did 3.1 ± 1.1 physical training sessions per week in addition to regular match play(1 match every week in the TH season). Additional player characteristics are found in Table 1. Prior to testing, written informed consent was received from all participants.

Table 1: Mean age, height and weight ± sd of 14 subjects.

	Mean	Min	Max
Age	20.6 ± 2.1	19	25
Height	191 ± 6	183	203
Weight	91 ± 5.2	84	104.6

Procedures:

Testing occurred over two days at the end of the handball season. With the sprint, jump height, agility, throwing velocity and 3000m tests on the first day and the 5RMBP, 5RMS and brutal sit-ups tests on the second day. The players were divided into two teams (n = 7) to ensure each player could be tested without too much delay between tests. Before arriving for the tests the players were instructed to refrain from any kind of exercise for 24 hours prior to testing and to continue their regular eating habits. They were also instructed to refrain from intense exercise for the last two days before testing. Upon arrival for testing the players were first informed of the test order and test criteria. On the first test day anthropometrical data was also collected.

Testing on day one began with the 20m sprint during which 5 and 10m split times were noted. This was followed by the jump height test, agility test, throwing velocity test and 3000m running test. All tests were done on an indoor TH court except for the 3000m running test. Between each test the players were given a five minute break. Before testing, the players did a 10-minute general warm-up consisting of light running. This was followed by 4-8 self-organized acceleration runs where players increased their running speed across 60m from light jogging to sprinting. They then did some stretching of their own choice followed by a short break for personal preparation before the testing began.

20m sprint times were measured using speed gates from Witty (Witty, Microgate, Bolzano, Italy) with 4 sets of infrared beams. Each unit was mounted on a tripod 1m above ground and data from the beam sets were sent directly to the handheld monitor. Additionally, data was manually plotted in Excel and saved on a PC. During the 20m sprint test, time was also measured from 0-5m and 0-10m. The players started from a standing position 30 cm behind the starting line. They were then given three attempts to reach their best 20m sprint time which was used for the analysis of sprint performance at 5, 10 and 20m. Between each attempt players were given three minutes to recover.

Jump height was evaluated using a countermovement jump (CMJ) on a jump mat (Chronojump-Boscosystem®, Barcelona, Spain). Players were instructed in how to perform the CMJ and given a few submaximal attempts in order to familiarize with the jump. When performing the jump the players first stood on the jump mat with their hands on their hips. From this position, a downward countermovement was made until knee-angle reached approximately 90 degrees and was then followed by the jump. Each player was given three attempts to reach maximal jump height and were given three minutes to recover between each attempt. Only the highest jump was used for analysis.

The *agility test* was done on an indoor TH court using two sets of Witty speed gates, five cones and a handball goal. One set of speed gates was placed at the beginning of the track and one was placed at the end. The players started from a standing position 30 cm behind the starting line. For further illustration of how the agility track was arranged see Figure 1. Each player was given three attempts to reach their fastest time through the course and were given three minutes to recover between each attempt. The fastest time for each player was used for data analysis.

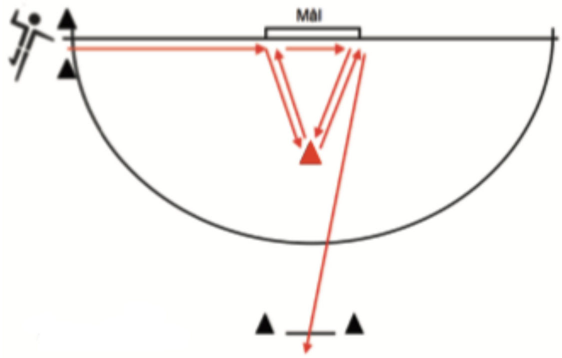

Figure 1: Graphical illustration of the agility test included in DHF's physiological profile(8).

Throwing velocity was measured using a standing throw from the penalty line on a TH court with a standard handball. Before testing, the players spent ten minutes doing some voluntary shoulder drills to prepare for the test. During testing the author stood 2m directly behind the throwing arm of the shooter and measured the throwing velocity with a Stalker Sports Radar (Stalker Sports Radar Pro II). Players were instructed to perform an overhand shot at the highest possible velocity while keeping at least one foot on the ground. The players were allowed to use resin as is accustomed in TH and were given three attempts to reach the highest possible throwing speed. The best throw from each player was noted and used for data analysis.

The *3000m running test* was performed on an outdoor bicycle track. Prior to testing the route had been measured using a Garmin GPS watch. Upon testing, players were sent off together and ran straight ahead along the bicycle path for 1500m, where an assistant indicated the turning point. They then turned around and followed the same path back to the starting line. Time spent was measured using a standard stop watch and players were instructed to complete the 3000m run as fast as possible.

Testing on day two began with the 5RMS followed by the 5RMBP and brutal sit-ups test. All tests were done in the TH gym and the players had a five minute break between each test. Before testing, the players did a general warm-up consisting of 10 minutes light running followed by some dynamic stretching of their own choice and a short break for personal preparation before commencing the tests.

5RMS was determined using a 20 kg Olympic bar, training discs and a squat rack. Before initiating the test the players were shown a squat, demonstrating the depth necessary for a successful lift. Players had to do a parallel squat, meaning that the crease of the hip had to fall below the top of the knee. To ensure consistency, depth was monitored by the same test leader. Lifts in which the player failed to reach parallel were considered unsuccessful and the player had to do another repetition in order for the test to be valid. Each subject was given four warm-up sets followed by two-four attempts to reach their 5RMS. The warm up sets consisted of one set x 8 reps with the bar, one set x 5 five reps at ~60%, one set x 3 reps at ~75% and one set x 2 reps at ~80% of estimated 5RMS. During the warm-up each player was given 90-120 seconds rest between sets. After the warm-up players began their actual 5RMS attempts and were advised to undershoot their estimated 5RMS on the first attempt. Weight was increased by five kg on each attempt unless the player felt they were very close to their 5RMS, in which case it was only increased by two and a half kg. Each player was given three minutes of rest between each attempt and all players reached their 5RMS within four attempts. The highest successful 5RMS of each player was used for analysis.

5RMBP was determined using a 20 kg Olympic bar and training discs. Before commencing the test players were shown a bench press demonstrating the parameters necessary for a lift to be approved. Players lay horizontally on the bench with their feet planted on the ground and elbows extended to reach the bar. The bar was then lifted off the rack and lowered in a controlled manner until it touched the chest. From here the bar was then lifted in a self-determined tempo. During each lift players were not allowed to lift their feet off the ground or their butt off the bench. Doing so would result in an unsuccessful lift and require the player to do another correct lift in order for the test to be valid. Each player was given four warm-up sets followed by two-four attempts to reach their 5RMBP. The warm-up sets consisted of one set x 8 reps with the bar, one set x 5 five reps at ~60%, one set x 3 reps at ~75% and one set x 2 reps at ~80% of estimated 5RMBP. During warm-up each player was given 90-120 seconds rest between sets. After the warm-up players began their actual 5RMBP attempts and were advised to undershoot their estimated 5RMBP on the first attempt. Weight was increased by five kg on each attempt unless the player felt they were very close to their 5RMBP, in which case it was only increased by two and a half kg. Each player was given three minutes of rest between each attempt and all players reached their 5RMBP within four attempts. The highest successful 5RMBP of each player was used for analysis.

The *brutal sit-ups* test was conducted using a "plest". Players hang from the plest with their head down while two teammates held their legs across the plest. The players folded their hands behind the neck during the entire test and had to raise the upper body to touch the legs with their elbows. Following this they returned to the starting position and began another repetition. Players were only successful if their elbows touched their legs and if they failed to do this twice the test was stopped and their number of successful reps was noted. There had to be a certain flow in the execution of the repetitions and therefore the players weren't allowed to take more than a couple of seconds between repetitions. The number of repetitions achieved before exhaustion or elimination was used for analysis.

Statistical analysis:

All statistical analyses were conducted using SPSS (IBM SPSS version 25). Results are presented as group mean values ± standard deviations (SD). The assumption of a linear relationship between DHF's physiological tests and the handball specific tests were visually verified using scatter-plots. The scatter-plots were also visually examined for any outliers. Outliers were defined as data points that didn't fit the pattern of the rest of the data set. Distribution of data was assessed using Shapiro Wilks test of normality. Pearson product-moment correlation analysis was used to evaluate the potential relationship between DHF's physiological profile(5RMBP, 5RMS, Agility, brutal sit-ups and 3000m test) and each of the handball specific tests(jump height, throwing velocity and sprint ability). The strength of the associations were determined using the following guideline; small correlation was between 0.1 < r > 0.3, moderate correlation was between 0.3 < r > 0.5 and a strong correlation was r > 0.5(13). The $p \leq 0.05$ criterion was used for establishing statistical significance (two tailed test design). Finally, achieved power was calculated using G*Power.

RESULTS:

Mean values of the assessed parameters ± SD as well as range are presented in table 2 and table 3. Due to the test criteria and TH related injuries not all players were able to complete all of the tests. 13 players were able to complete the 5RMBP, 10 players completed the 5RMS, 13 players completed the throwing velocity test, 12 players completed the agility test, 11 players completed the CMJ test, 12 players completed the 5, 10 and 20m sprint test, 12 players completed the 3000m test and all players were able to complete the brutal sit-ups test.

Table 2: Test results from the physiological profile tests (group means ± SD and range).

	Mean	Range
5RMBP (kg)	88.5 ± 18.5	62.5 - 135
5RMS (kg)	120 ± 23.5	85 - 170
Agility test (s)	7.98 ± 0.21	7.66 - 8.25
3000m (Min.s)	13.37 ± 1.16	11.57 - 16.37
Brutal sit ups (Reps)	17 ± 6	7 - 30

Table 3: Test results from the handball specific tests (group means ± SD and range).

	Mean	Range
CMJ (cm)	37 ± 3	31 - 42
Throwing velocity (km/t)	97 ± 7	87 - 111
5m Sprint (s)	1.02 ± 0.06	0.93 - 1.11
10m Sprint (s)	1.74 ± 0.07	1.64 - 1.86
20m Sprint (s)	2.98 ± 0.11	2.86 - 3.19

Relationship between DHF's physiological profile and the handball specific tests

Preliminary analyses showed all relationships to be linear and all variables to be normally distributed as assessed by Shapiro-Wilk's test ($p > .05$). While a few outliers were discovered during visual inspection of scatterplots these were still included as they represented genuine data points. Pearson product-moment correlations (r) are presented in Table 4 and achieved power in Table 5.

Table 4: Correlation coefficients (r) between DHF's physiological profile tests and the handball specific tests.

	5RMBP	5RMS	Agility	3000m	Brutal Sit-ups
CMJ	-.153	.311	-.424	-.431	.335
Throwing Velocity	-.096	-.066	-.516	.323	-.294
5m Sprint	-.093	-.295	.579*	.601*	-.464
10m Sprint	-.249	-.501	.536	.678*	-.575
20m Sprint	-.454	-.637	.522	.635*	-.502

** = p < 0.05.*

Table 5: Achieved power for all correlations between DHF's physiological profile tests and the handball specific tests.

	5RMBP	5RMS	Agility	3000m	Brutal Sit-ups
CMJ	0.07	0.12	0.29	0.29	0.18
Throwing Velocity	0.06	0.05	0.47	0.19	0.17
5m Sprint	0.06	0.12	0.6	0.65	0.38
10m Sprint	0.12	0.28	0.51	0.82	0.59
20m Sprint	0.33	0.5	0.48	0.73	0.44

CMJ & Throwing velocity. The correlations between CMJ and DHF's physiological profile tests as well as between throwing velocity and DHF's physiological profile tests were not statistically significant.

5m sprint. There was a statistical significant correlation between the 5m sprint and agility test (r = .579, p = .048)(power = .6) and between 5m sprint and 3000m test (r = .601, p = .039)(power = .65). The relationship between 5m sprint and the agility test is visually represented in figure 2 while the relationship between the 5m sprint and the 3000m test is represented in figure 3. There was no significant correlation between the other tests included in the DHF's physiological profile and 5m sprint. Therefore, the null hypothesis was only rejected for the agility test and the 3000m test.

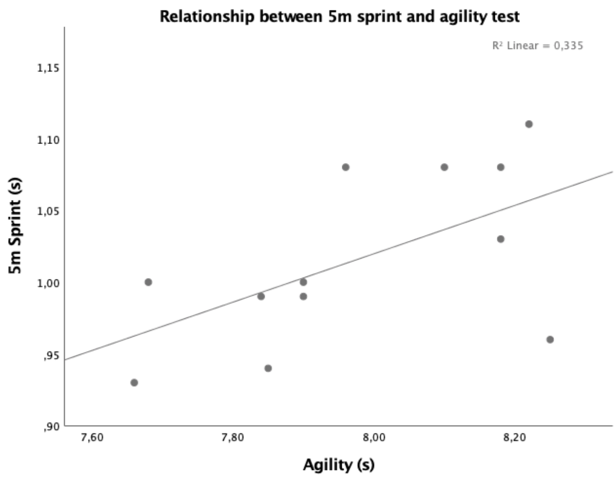

Figure 2: Relationship between 5m sprint and agility test of the individual players (n = 12).

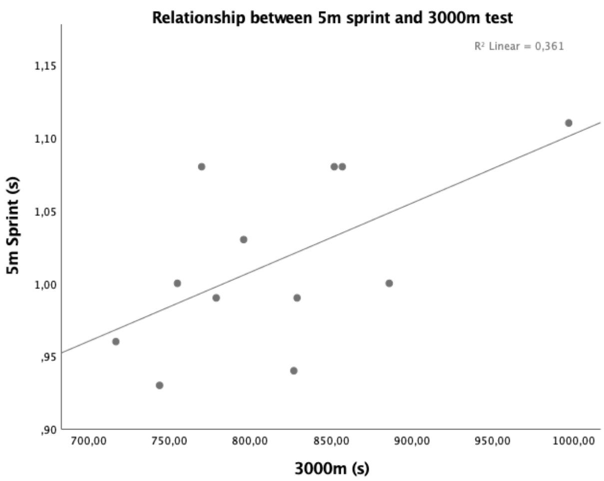

Figure 3: Relationship between 5m sprint and 3000m test of the individual players (n = 12).

10m sprint. There was a statistical significant, strong and positive correlation between 10m sprint and the 3000m test (r = .678, p = .015)(power = .82). The relationship between the 10m sprint and the 3000m test is visually represented in figure 4. There was no significant correlation between the other tests included in DHF's physiological profile and 10m sprint. Therefore, the null hypothesis was only rejected for the 3000m test.

20m sprint. There was a statistical significant correlation between 20m sprint and the 3000m test (r = .635, p = .026)(power = .73). The relationship between the 20m sprint and the 3000m test is visually represented in figure 5. There was no significant correlation between the other tests included in the DHF's physiological profile and 20m sprint. Therefore, the null hypothesis was only rejected for the 3000m test.

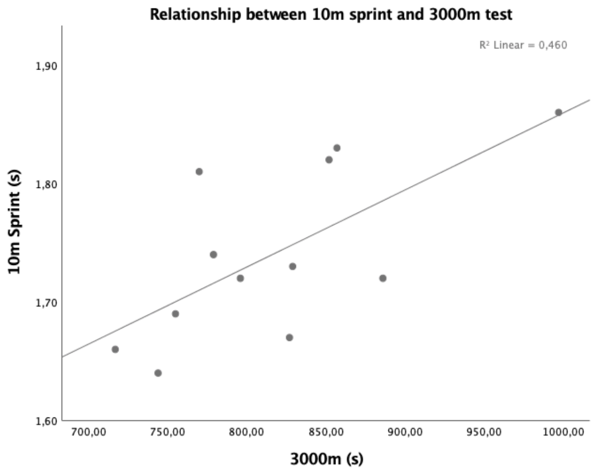

Figure 3: Relationship between 10m sprint and 3000m test of the individual players (n = 12).

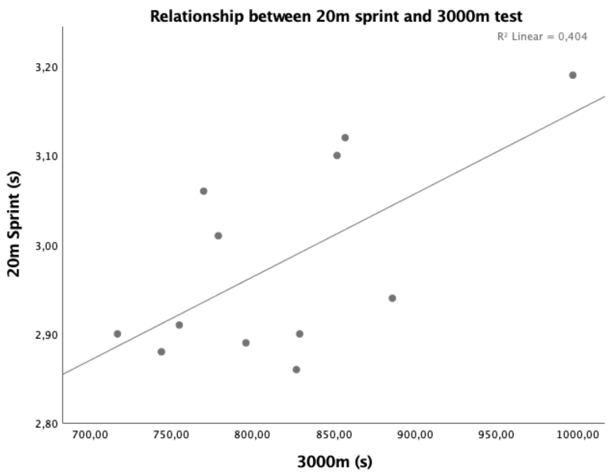

Figure 3: Relationship between 20m sprint and 3000m test of the individual players (n = 12).

DISCUSSION:

This was to the best of the authors knowledge the first study to examine the relationship between the tests included in DHF's physiological profile and selected handball specific tests(jump height, throwing velocity and sprint ability). The main findings of the study were a strong and positive correlation between the 3000m running test and sprint ability(5, 10 and 20m) as well as between the agility test and 5m sprint. No significant correlations were found between the other tested variables.

Jump Height

To the best of the authors knowledge no research exists on the relationship between 5RMS and CMJ. Despite of this the DHF has included a 5RMS in their physiological profile. While there is a lack of research using a 5RM protocol there is ample of research utilizing a 1RM protocol. In a study on young volleyball players they were able to show a significant correlation ($r = .68$, $p = .0014$) between 1RMS and vertical jump(CMJ)(11). A similar study on soccer players also showed a significant correlation ($r = .78$, $p = .02$) between 1RMS and jump height(CMJ)(10). It was therefore hypothesized that the 5RMS included in DHF's physiological profile would also correlate with jump height. The present study was however only able to show a moderate relationship ($r = .3$) between 5RMS and CMJ that was not significant ($p > .05$). The hypothesis that 5RMS correlates with jump height was therefore rejected. A reason for this may be the use of absolute strength, as one study investigating the correlation between 1RMS and jump height using both absolute and relative values found the greatest correlation using relative values(11). It is possible however to show a correlation using absolute strength (10,11). Another factor which may influence the correlation is the squat depth used as this seems to vary across studies. Above mentioned studies (10,11) used squats with a knee angle of 110 and 90 degrees, respectively. The present study didn't measure knee angle, but the test subjects were instructed to reach parallel squat which with the present protocol was estimated to be around 70 degrees. A study investigating the relationship between CMJ and multi-joint isometric and dynamic tests of strength found similar correlations to the present study(14). Just as this study they used deeper squats (70 degrees) and when correlated to jump height in a CMJ test they were also unable to show a significant relationship. However, when they used the 1RMS relative to body weight and correlated this with CMJ height they found a strong significant correlation ($r = .69$, $p < .05$)(14). To test the influence of relative strength a post study test was therefore done, correlating 5RMS/bodyweight to CMJ. Although this resulted in a higher correlation ($r = .42$) it remained insignificant while also being much weaker than what has previously been shown(14). Finally the reason may be the use of a 5RM protocol. CMJ is considered a simple, practical and reliable measure of lower-body power(15) just as the 1RM protocol is considered the golden standard for measuring maximum strength in non-laboratory environments(16). Research on the 5RM protocol is scarce however and thus it is does not share the same reputation as 1RM. While the 5RM protocol has been shown to correlate with 1RM(17), as well as being a good predictor of 1RM(18) it is not necessarily able to replace it. This is also supported by the present study as it only showed a moderate positive correlation that was statistically insignificant between 5RMS and CMJ. It is therefore also unclear why the DHF chose to include the 5RMS in their physiological profile.

Throwing velocity

As mentioned research utilizing a 5RM protocol is scarce but in regard to throwing velocity research utilizing a 1RMBP protocol has shown a significant correlation with throwing velocity. One study conducted on TH players showed a strong correlation ($r = .55$, $p < .001$) between 1RMBP and throwing velocity(19). This is further supported by another study on elite TH players, that also showed a strong correlation ($r = .637$, $p = .014$) between 1RMBP and throwing velocity(20). It was therefore hypothesized that the 5RMBP included in the DHF's physiological profile would correlate with throwing velocity. The present study was however unable to show a significant correlation ($r < .1$, $p > .05$) between 5RMBP and throwing velocity. The hypothesis that 5RMBP correlates with throwing velocity was therefore rejected. A reason for this may be the use of a full maximum BP test as used in the present study since neither of the studies showing a correlation between 1RMBP and throwing velocity used a full BP. A full BP is here defined as being a BP consisting of both the eccentric and concentric phase. The first study assessed the 1RMBP of each player using a Myotest device(19). The device was mounted on the bar and calculated the velocity at which the bar was pushed. When the velocity became to slow the test was stopped and the software calculated the 1RMBP. Thus, the test subjects never actually lifted their estimated 1RMBP. In the second study the bar was placed on the chest of the test subjects to minimize any countermovement effect(20). Thus, they only performed the concentric part of the BP. Based on the above it is therefore possible that while a concentric only BP or an velocity based estimation of 1RMBP correlates with throwing velocity, the use of a full BP protocol as used in the present study does not. Additionally, as with jumping height it is also possible here that the 5RM protocol doesn't share the same relationship with throwing velocity as a 1RM protocol.

Just as BP has been shown to correlate with throwing velocity, increased core strength has also been shown to increase throwing velocity. A study investigating the effect of core strength on throwing velocity recruited 30 players who underwent a 10 week core training program and increased their throwing velocity by 5% ($p < .001$)(12). And just as in the present study they used a standing penalty throw and a radar gun to measure throwing velocity. Based on this it was therefore hypothesized that the brutal sit-ups test included in the DHF's physiological profile would also correlate with throwing velocity. The present study was however unable to show a correlation ($r < .1$, $p > .05$) between the brutal sit-ups test and throwing velocity. The hypothesis that the brutal sit-ups tests correlates with throwing velocity was therefore rejected. One reason as to why the present study was unable to show a correlation may be the equipment used for testing. DHF normally uses a tool called a "plint". A gymnastics tool not used in many countries outside Denmark. It was however not possible to acquire a plint for testing and therefore a plest was used. The only difference between the two is that when hanging on a plint the player is able to touch the plint with their back, whereas on a plest they are hanging freely. Thus, players may have experienced the test as harder or easier depending on the individual players strengths. Another reason could be that the brutal sit-ups test doesn't properly reflect the movement pattern of a standing throw. Research has previously shown that TH players transfer energy from the trunk to the throwing arm through a combination of pelvis and trunk rotation(21). The importance of pelvis and trunk rotation as well as angle in TH throwing was also shown through strong correlations with throwing velocity($r > .5$)(21). This is also supported by the fact that the primary muscles responsible for rotation of the trunk are the obliques (internal and external). Further support was found in the fact the study showing a correlation between core strength and throwing velocity also included exercises such as cross curl ups which works the obliques(12). The brutal sit-ups test primarily works the rectus abdominis, therefore the reason for a lack of correlation in the present study may be due to the brutal sit-ups tests inability to reflect the actual work done during a standing throw. It is therefore also unclear as to why the DHF has chosen to include it in their physiological profile.

Sprint

As the agility test included in the DHF's physiological profile tests a players ability to move around on an actual TH court, one might argue that it should be considered a handball specific test. And therefore in itself is a good test for evaluating TH players. However, the specific agility test used by the DHF has to the best of the authors knowledge not been validated before while another agility test used in TH called GBPT(Game-based performance test) has been. The GBPT however, requires a lot of expertise to setup as well as expensive equipment which may be why the DHF has chosen to use their own(22). As the aim of the present study was to evaluate the relationship between the tests included in the DHF's physiological profile and selected handball specific tests the agility test was also included. As the test is comprised of short distance sprints (3-5m) it was hypothesized that it would at least correlate with 5m sprint, which was also the case ($r > .5$, $p < .05$).

In regard to the relationship between the 3000m test and sprint ability research is scarce. One study however investigated the relationship between 800m running and 10, 20m sprint(23). They tested 14 athletes and found a significant correlation between 800m running and 10m sprint($r = .59$, $p < .05$) as well as between 800m and 20m sprint ($r = .72$, $p < .05$) (23). Although they tested on a different running distance than the present study, 800m and 3000m are both considered middle distance running. Therefore, it was hypothesized that the 3000m running test would correlate with sprint ability. This was also the case as the present study showed a statistical significant strong correlation between 3000m and 5, 10, 20m sprint ($r > .5$). One reason as to why they correlate may be that sprinting is predominantly an anaerobic activity while long distance running is aerobic. During middle distance running (5km) however, it has been shown that anaerobic power is related to performance(24). And as the benefit of anaerobic power is expected to increase until a certain threshold at lower running distances (i.e. 3000m) this may explain why the present study was able to show a strong correlation between 3000m running performance and sprint ability.

As to the relationship between 5RMS and sprint ability there is also a lack of research. It has been shown on soccer players however, that there is a correlation between 1RMS and sprint ability(10). A previous mentioned study also found a significant correlation between 1RMS and sprint ability on 10($r = .94$) and 30m($r = .71$). In contrast another study also investigated the relationship between 1RMS and sprint ability, but on TH players(25). The study on TH players was however unable to show a significant correlation between 1RMS and sprint ability, indicating that there may be some uncertainty as to the relationship between the two. A third study conducted on American football players also found a correlation between 1RMS and sprint ability(26). They found a significant correlation between 1RMS and sprint ability at 10($r = .54$) and 40($r = .6$) yards(26). Despite some disagreements on the relationship between squat strength and sprint ability it was hypothesized that the 5RMS would correlate with sprint ability(5, 10 and 20m). Although the present study showed a strong correlation between 5RMS and 10($r = .5$) as well as 20m($r = .67$)

sprint, the results were statistically insignificant. The hypothesis that 5RMS correlates with sprint ability was therefore rejected. A reason as to why the present study wasn't able to produce significant results may be the use of absolute strength. As the three studies previously investigating the relationship between 1RMS and sprint ability used relative strength. A correlation was therefore calculated using relative strength in the 5RMS. This revealed a slightly stronger correlation for all the sprint distances and the correlation between relative 5RMS and 20m sprint became significant ($r = -.78$, $p = .023$). The correlation between relative 5RMS and 10m sprint was also close to significant ($p = .088$). In summary it seems that the present study would have benefitted from using relative strength when correlating 5RMS to sprint ability. But in general it seems that a 5RM squat protocol is not as good a predictor of sprint ability as the 1RM protocol. Which raises further support to the question as to why the DHF has chosen the 5RM protocol.

As a general summary the results of the present study indicate that the tests included in the DHF's physiological profile may not be the best tests for evaluating actual TH performance. It is however possible that other factors may have influenced the choice of tests. Also this study generally suffered from a low power and as such there is a high risk of type II errors. Additionally, a general limitation of correlation studies such as the present study is that a strong correlation does not necessarily imply a cause-effect relationship. Rather it is limited to shedding light on associations. Readers are therefore urged to have this in mind when reading the practical applications suggested. Additionally, the present investigation is considered a cross-sectional study as it was done on a Danish 1. Division TH team. The results are therefore a reflection of this specific team and not directly transferable to other populations.

In conclusion, not all of the tests included in DHF's physiological profile appear to correlate with actual TH performance variables. Specifically, the present study demonstrated that the 3000m running test has a strong correlation with sprint ability at 5, 10 and 20m. Additionally the agility test also strongly correlated with 5m sprint. While the 5RMS, 5RMBP and brutal sit-ups tests didn't seem to be associated with the selected performance variables (jump height, throwing velocity and sprint ability). This indicates that factors other than associations with actual TH performance may have influenced which tests the DHF's included in their physiological profile.

PRACTICAL APPLICATIONS

In this study, a strong correlation existed between the 3000m running test and sprint ability at 5, 10 and 20m. Thus, suggesting that coaches looking to evaluate players sprint ability may use the 3000m test to do so. Additionally, coaches and players looking to improve short distance sprint ability may also benefit from incorporating middle distance running into their training regimes. Likewise a strong correlation was found between the agility test and 5m sprint. Coaches may therefore use the agility test to also evaluate a players 5m sprint ability.

Similarly the results of the present study also indicate that an increase in a players 5RMS does not translate to an improvement in jumping height or sprint ability. It also seems that an increase in 5RMBP wont translate to a faster throwing velocity. Finally, an increase in the number of brutal sit-ups a player can do does not seem to be associated with a faster throwing velocity. As a general summary some of the tests included in the DHF’s physiological profile does not seem to reflect actual game performance when correlated with the selected TH specific tests (jumping height, throwing velocity and sprint ability).

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