Anthropometric, characteristic, physical fitness parameters- and throwing velocity in female Icelandic youth national handball players

by

Margrét Regína Grétarsdóttir

Thesis of 45 ECTS credits

Master of Science in Exercise Science and Coaching

May 2020

Anthropometric, characteristic, physical fitness parameters- and throwing velocity in female Icelandic youth national handball players

Margrét Regína Grétarsdóttir

Thesis of 45 ECTS credits submitted to the Sports Science Department, School of Social Sciences at Reykjavík University in partial fulfillment of the requirements for the degree of

Master of Science in Exercise Science and Coaching

May 2020

Main supervisor: Sveinn Þorgeirsson

Co-supervisor: Professor Jose M. Saavedra

Examiner: Dr. Demetrio Lozano

Abstract

Anthropometric, characteristic, physical fitness parameters- and throwing velocity in female Icelandic youth national handball players

The object of this longitudinal study were to i) analyze the difference in anthropometric characteristics, physical fitness- and throwing velocity performance between measurements during a two-year period, and to ii) analyze the difference in anthropometric characteristics, physical fitness- and throwing velocity performance between players during a two-year period. Data were collected from 22 Icelandic youth female national handball players (16.55 ±1.11 years old) from three different age groups (U15, U17, U19). Over two-year period players participated in at least four of six measurements as they were tested in height, weight, BMI, MBT, CMJ, 10 m sprint, 30 m sprint, Yo-Yo IR2, and throwing velocity. Statistical analysis was performed using one-way ANOVA to calculate the difference between measurements followed by Bonferroni post hoc test. Repeated measures were used to calculate the difference between players followed by Bonferroni post hoc test. Descriptive statistics were calculated for all the experimental variables as the results were presented as mean values with standard deviation. The result of this study showed a difference between measurements in handgrip strength, CMJ, and 10 m sprint. The difference between players was in height, weight, BMI, MBT, 10- and 30 m sprint.

Keywords: Handball, Measurements, Performance

Ágrip

Líkamleg færni, líkamlegir eiginleikar, og skothraði hjá ungum íslenskum landsliðskonum í handknattleik

Markmið þessarar langtíma rannsóknar var að i) greina mun á líkamlegri færni, líkamlegum eiginleikum og skothraða milli mælinga yfir tveggja ára tímabil, og að ii) greina mun á líkamlegri færni, líkamlegum eiginleikum og skothraða milli leikmanna yfir tveggja ára tímabil. Gögnum var safnað frá 22 ungum íslenskum landsliðskonum í handknattleik (16.55 ±1.11 ára) frá þremur aldurshópum (U15, U17, U19). Á tveggja ára tímabili tóku leikmenn þátt í að minnsta kosti fjórum af sex mælingum þar sem þeir voru mældir í; hæð, þyngd, BMI, MBT, CMJ, 10 metra sprett, 30 metra sprett, Yo-Yo IR2, og kasthraða. Tölfræðileg greining var framkvæmd með því að nota einfalt ANOVA próf til þess að skoða mun á milli mælinga og Bonferroni post hoc próf í framhaldið. Dreifigreining með endurteknum mælingum (e. Repeated measures) var framkvæmt til að skoða mun á milli leikmanna og Bonferroni post hoc próf í framhaldið. Lýsandi tölfræði var reiknuð fyrir allar breytur þar sem niðurstöður voru kynntar sem meðaltal með staðalfráviki. Niðurstöður þessarar rannsóknar sýndu mun á milli mælinga í gripstyrk, CMJ, og 10 metra spretti. Munur var milli leikmanna í hæð, þyngd, BMI, MBT, 10 metra- og 30 metra spretti.

Lykilhugtök: Handknattleikur, Mælingar, Frammistaða

Anthropometric, characteristic, physical fitness parameters- and throwing velocity in female Icelandic youth national handball players

Margrét Regína Grétarsdóttir

45 ECTS thesis submitted to the School of Social Sciences
at Reykjavík University in partial fulfillment
of the requirements for the degree of
Master of Science in Exercise Science and Coaching

May 2020

Student:

____

Margrét Regína Grétarsdóttir

Main Supervisor:

____

Sveinn Þorgeirsson

Co-Supervisor:

____

Professor Jose M. Saavedra

Examiner:

____

Dr. Demetrio Lozano

Acknowledgments

I am very grateful to be a sponsored student, involved in the collaboration between the Icelandic Handball Federation, *HSÍ* and Reykjavík University. I want to thank the Sport Science department for giving me this opportunity. Thank you for involving me in this project, allowing me to control measurements on the Icelandic youth national handball teams and make it my master thesis. I have gained great experience from this project, that will support me in my future endeavors. I would like to express gratitude to my supervisors, Sveinn Þorgeirsson and Dr. Jose M. Saavedra for their invaluable help, guidance, motivation, and support throughout the whole process. I have learned a lot from their experience. I am also very grateful to all the B.Sc. students who assisted with the measurements. Also, I want to thank Guðrún Dagný Einarsdóttir, as well as Pála Margrét Gunnarsdóttir for their valuable feedback. My five years of studying at Reykjavík University, graduating with B.Sc. and M.Sc. in Sport Science has been a real-life experience for me. During that time, I have learned a lot and at the same time started a future job connected to sports. I believe that my studies in Sports Science have helped me a greatly in getting to where I am today. Thanks to all the great teachers, teaching the various courses at the Sports Science department. I am very pleased with all the opportunities that I have been offered, as they have helped me advance my career in the Icelandic sports world. Lastly, I want to thank my family and those who have stood closest to me during my studies for their endless support.

Table of contents

List of tables

List of abbreviations

BMI	Body Mass Index
CMJ	Countermovement Jump
HSÍ	Handknattleikssamband Íslands (Icelandic Handball Federation)
M1	Measurement 1
M2	Measurement 2
M3	Measurement 3
M4	Measurement 4
M5	Measurement 5
M6	Measurement 6
MBT	Medicine ball throwing
Throwing 7 m	Maximal throwing velocity from 7 meters distance
Throwing 9 m with 3 steps	Maximal throwing velocity from 9 meters distance, after three steps
Throwing 9 m with jump	Maximal throwing velocity from 9 meters, after three steps and jump
U15	Icelandic national team under 15 years old
U17	Icelandic national team under 17 years old
U19	Icelandic national team under 19 years old
VO_{2max}	Maximum oxygen uptake
Yo-Yo IR2	Yo-Yo Intermittent recovery test level 2

Introduction

Team handball (handball) is a team sport played worldwide and has, in general, become more popular in time (Manchado et al., 2013). Handball is played at a highly professional level in many European countries (Póvoas et al., 2012), and is also a very popular sport in Africa, South America and Asia (Wagner et al., 2017). Major handball international championships are held regularly. Handball became an Olympic sport for male in 1972 and since the year 1976 handball has been a part of the Olympic Games both for male and female. It is said that handball was at first invented as a game just for males. With time female gained rapid interest in the game and began to play handball as well and have played ever since (Michalsik & Aagaard, 2015). Handball is now played by both genders and at all ages, whether it is at amateur, sub-elite, or elite levels (Milanese et al., 2012).

It wasn't until the year 1920 that the handball sport came to Iceland. The first male national match was played in 1950. The Icelandic female team played its first match on 19th of June in 1956 against Norway in Oslo (Lúðvíksson, 2012). Subsequently, the Icelandic Handball Federation (Handknattleikssamband Íslands, *HSÍ*) was founded on 11th of June in 1957. Since then has interest in the sport increased for both male and females in Iceland. The number of female handball practitioners has been rising constantly. In the 2017/2018 season, there were 2.143 female practitioners 15 years or younger and 839 female practitioners 16 years or older playing handball in Iceland (The National Olympic and Sports Association of Iceland, 2019). Since the beginning of handball in Iceland female handball culture is growing (Lúðvíksson, 2012). To the present day has the Icelandic female national team participated in three major tournaments, two times in the European Championships and one time at the World Cup (Lúðvíksson, 2012).

1.Theoretical background

1.1 Handball

Handball requires two teams of seven players each, six out court players in different positions; pivots, backs (right, left) and wings (right, left) and a goalkeeper (Krüger et al., 2014). Each specific position requires unique physiological and physical aspects relating to the technical and tactical requirements of that position in order to maximize the performance in the game (Ghobadi et al., 2013). A handball team consist of up to 14 players. The remaining players are substitutes but have the permission to enter the court at any time and repeatedly, if the players they are replacing have already left the court. Handball is played indoor on a playing court measuring 40 meters long and 20 meters wide. A standard match time consists of two 30 minute halves with a 10 minute halftime break (International Handball Federation, 2016).

The objective of the handball match is to play the ball between the teammates by using only their hands to dribble the ball and pass it on (Rogulj et al., 2011). Fundamentally, players of two opposing teams alternately take the role of either attackers or defenders, depending on which team has the ball. The aim of the attacking team is to play the ball through the opposing team's defense wall and score a goal and conceding as few as possible. The aim of the defense is to prevent opponents from scoring a goal and to assume the role of attackers, that is to win possession of the ball as soon as possible (Šibila et al., 2004). As in other field games, the team that scores more goals than the opposition wins (Rogulj et al., 2011).

1.2 Characteristics of handball players

Handball is a complex and multifactorial sport in which individual performance is a combination of many aspects, including physiological, technical and psychological as well as tactical components, physical fitness and other external influences (Wagner et al., 2014). Handball is an intense and dynamic game (Karcher & Buchheit, 2017) played in a confined area where a high degree of pressure is involved. In addition, officials and audience on the court may cause an increased psychological demand (Lage et al., 2011).

Handball includes both low- and high-intensity movements, defense and offense, and requires specific handball movements such as passing, catching, throwing, checking and blocking (Arifi et al., 2019; Póvoas et al., 2012). Also, the players must coordinate their movements well for running, turning, stopping, jumping, pushing and changing directions (Wagner et al., 2014).

In handball as other sports, conditioning is usually broken down into preseason, in-season, and postseason phases where the training is consistent with each season phase. Preseason training aims at maximizing the physical fitness parameters before the start of the competitive season, often called in-season. The goal is to maintain the physical fitness levels achieved during the preseason through in-season. By the end of the preseason phase it may be suggested that physical status should be at peaking time and be maintained throughout the entire competition period (Milanese et al., 2012).

Handball is said characterized by highly developed motor skills such as strength, power, speed, and endurance (Manchado et al., 2013; Sporis et al., 2010). These aspects can give a clear advantage in high-level competitions as well as technical and tactical skills (Peña et al., 2018). In addition, it has been shown that anthropometric characteristics and handball throwing velocity are also important aspects for success in elite levels of handball leagues (Gorostiaga et al., 2005) So, to reach maximum player performance in handball, it is important to consider all these aspects for the individuals (Manchado et al., 2013).

1.3 Anthropometric characteristics

Anthropometric is the method of measuring the human body or individual body parts (Gusic et al., 2017). Anthropometric characteristics provides important information of nutritional status in children and adults. In children, measurements reflect health status, whether the diet is adequate, growth, and development over time. However, in adults, body measurements are also used to evaluate disease risk and body composition (Fryar et al., 2016). In sports, body composition analysis is frequently carried out to assess changes in physiological status (Milanese et al., 2012).

The anthropometric characteristics of elite handball players, such as body height, body weight and body mass index are highly important for performance in the sport (Gorostiaga et al., 2005; Manchado et al., 2013). In addition, to meet the playing demands in all age groups in handball, anthropometric characteristics can be important (Sporis et al., 2010). The functional performance characteristics of players are therefore influenced by differences in body size and composition (Milanese et al., 2012). Specific anthropometric characteristics are considered to be associated with success in many team sports (Matthys et al., 2011). In general, more successful handball teams are taller than less successful teams (Ghobadi et al., 2013). However, handball players in different playing positions have different physical, physiological and anthropometric characteristics (Fieseler et al., 2017).

For handball players, age and anthropometric characteristics can affect a player’s performance (Lidor & Ziv, 2018). Youth players have lower body height as well as less body mass

(Hoppe et al., 2017). These characteristics will change for youth handball players as they grow older, because of natural pubertal development. Also, strength training becomes more effective as the players get older because of maturity and because handball players face greater demands as they grow older. These changes are most noticeable before and after the player's peak-height-velocity age, which occurs at an average age of 13.5 years in male and 11.5 years in females (Hammami et al., 2018). The age of peak sports performance coincides with training stages in which the volume is constant but is still different between sports. In general, female peak at a younger age than male (Saavedra et al., 2018).

All competitive sports trained at higher levels require that the body performs at the optimal biomechanical and physiological capacity. When it comes to selection in sports the morphological characteristics are important. A positive aspect regarding anthropometric measurements is that the comparison of anthropometrics can provide coaches with a better understanding of the specific demands of each playing position (Arifi et al., 2019). In youth handball performances, anthropometric characteristics are no less important determinants. However, there is a difference between individuals in growth, maturation, and trainability. Therefore, when searching for potential elite handball players, there should be more focus on the anthropometric, as well can biological maturation be a possible confounding aspect that needs to be considered (Matthys et al., 2013). In addition, the relationship between anthropometric characteristics and match demands may be more acute in female than in male players. Since development of match for females is recent, but many studies, in many years have been done on male handball players (Hasan et al., 2007).

1.3.1 Height and weight

Height and weight are the most frequently used anthropometric measurements to evaluate the nutritional state of the community (Neyzi et al., 2015). In handball, the body height of the players can for instance give an advantage (Matthys et al., 2012). The height is example important for throwing and blocking for one-on-one actions (Wagner et al., 2010). A greater height can therefore be a physical advantage for technical skills such as stealing, throwing and handling of the ball. Also, a large body can be helpful for handball performance (Bencke et al., 2002; Matthys et al., 2011). Taller players have the benefit to easily shoot through the opponent's defense and set a strong defense in front of their goal which causes opponents to have less chance of scoring (Arifi, Bjelica, & Masanovic, 2019). As an example, female handball players at the Montreal Olympic Games were examined in basic anthropometric parameters of height and body mass. It appeared that players in the medal winning teams were taller than the others, concluded that the height affected the success in handball (Hasan et al., 2007). It has also been observed that player's height seems to vary depending on the playing position. Wings showed the lowest body height (Fieseler et al., 2017), and the pivots and backs were the tallest players on the team (Fieseler et al., 2017; Peña et al., 2018). A study indicates that the averages for body height is 168.4 ± 6.2 cm for youth female handball players (Pastuszak et al., 2018). Similar average height was reported in another study, examined female handball players (16.1 ± 0.6 years) were it was 1.69 ± 0.05 m (Saavedra et al., 2018). However, higher average height was reported in a study on female Spanish handball players where it was 171.31 ± 7.42 cm (Vila et al., 2012). A study on Flemish youth handball players was conducted during three competitive handball seasons. It showed a difference in anthropometric characteristics. The average height of the older group (under 16, under 17, under 18) went from 172.4 to 180.5 cm during this period (Matthys et al., 2013).

A study examined youth female handball players (15-18 years), indicate that the averages for body weight is 68.8 ± 8.6 kg (Asker et al., 2018). Another study examined younger female handball players (12-13 years old) reported the average weight, in the first measurement the weight was 45.4 ± 7.6 kg and one year later 52.3 ± 7.5 kg, indicating that weight can change just slightly during one-year as the players grow older (Lidor et al., 2005). When examining older players their weight is heavier than in younger players in most cases. However, a study examined female Spanish handball players (25.74 ± 4.84 years), showed the average weight was 67.55 ± 8.06 kg (Vila et al., 2012), similar to youth players (Asker et al., 2018). In addition, female Norwegian national handball players (n=29) under 18 years weighted on average 62.7 ± 6.9 kg (Ingebrigtsen et al., 2013).

1.3.2 Body mass index

Body mass index (BMI) is a tool to monitor human's weight status for health purposes. BMI is used currently as a classification system (Keys & Brožek, 1953), using the same categories for all body types, male and female (Nikolaidis et al., 2019). It is used to categorize humans for obesity and is universally expressed as weight in kilograms divided by height in meters squared by the units of kg/m^2 (BMI = weight (kg)/ $[height(m)]^2$) (Keys & Brožek, 1953). Table 1 shows the categories for BMI.

Table 1. Categories for Body mass index

BMI	Weight status
Under 18.5 kg/m^2	Underweight
18.5 – 24.9 kg/m^2	Normal weight
25 – 29.9 kg/m^2	Overweight
30 kg/m^2 and above	Obese

BMI has been used widely as a simple summary measure of individuals in overweight (Cloe et al., 1995). Bodyweight is then correlated with body fat and height (Bellizzi & Dietz, 1999). However, BMI does not measure body fat directly, and the formula does not account for age, sex, ethnicity, or muscle mass in adults (Cloe et al., 1995), height and weight have a certain relationship that can give information about anthropometry of individuals. Therefore, weight adjusted for height is a far more useful index with which to assess overweight, than weight in itself. Although weight has been considered to refer to fatness, different height of children with the same weight can affect widely different levels of adiposity. BMI, however, adjusts for height by using the square power. The only flaw that could affect the relationship between BMI and height is that taller populations will seems to have a higher prevalence of obesity (Bellizzi & Dietz, 1999). However, one must have kept in mind that BMI changes substantially with age, therefore, when children's BMI is measured its needs to be assessed using age-related reference curves (Cloe et al., 1995). Although an ideal BMI will predict chronic diseases, the measure is also used to confirm that a high BMI reflects excess body fat and not height (Bellizzi & Dietz, 1999).

The purpose of the BMI measurements is multifaceted. It is widely used in sports where it can give coaches and players valuable information to identify talents, strengths, and weaknesses. Also, the measurements can be helpful to design a strength and conditioning program for every player (Chaouachi et al., 2009). It should also be noted that strength and conditioning training can lead to an improvement in body composition and performance (Kvorning et al., 2017). In a recent study on female handball players, the most common category was normal weight, between 18.5 to 25 kg/m^2, where the average BMI was 22.64 ±1.60 kg/m^2 (Pastuszak et al., 2018). Similar results were reported in a study examined female handball players (16.1 ± 0.6 years), the BMI was 21.7 ± 2.3 kg/m^2 (Saavedra et al., 2018). A bit lower BMI than female Spanish handball players were reported with, 22.97 ± 1.86 kg/m^2 (Vila et al., 2012). The Norwegian Handball Federation measured female youth national players, under 18 years, their average BMI was reported 21.7 ± 1.1 kg/m^2 (Ingebrigtsen et al., 2013) which is similar to the results on Icelandic youth female players (Saavedra et al., 2018). However, BMI only gives some idea about the player's body composition. Higher BMI can affect strength and agility, which are essential aspects of handball. It is therefore crucial to measure players BMI to understand what needs to be done to improve the position of players (Arifi et al., 2019; Keys & Brožek, 1953; Michalsik et al., 2015; Muratovic et al., 2014).

In a study on elite female handball players, no significant difference was found in anthropometric characteristic's measurement between preseason- and postseason. In the preseason the BMI was 23.23 ± 2.49 kg/m^2 and in the postseason it was 23.0 ± 2.3 kg/m^2. These findings show that the BMI of female handball players is similar preseason and postseason. Therefore, BMI does not seem to change much during the season (Milanese et al., 2012). Another study found similar BMI results for the preseason on youth female handball players (16.4 ± 0.8 years) were the average BMI was 24.4 ± 8.5 kg/m^2 (Asker et al., 2018). Elite Greek female handball players were examined in a study that reported the average BMI was 23.6 ± 2.7 kg/m^2. When the handball players were then divided into two competition levels (A1 and A2) the results showed that the BMI was lower for those players who played at higher level (A1 division) than A2 division (Bayios et al., 2006). Compared to other national teams and players, a variety of BMI results have been published. The BMI for elite Croatian players (24.49 ± 4.14 years) was 22.70 ± 1.99 kg/m2 (Čižmek et al., 2010), similar to the Poland national team (26.4 years) where the BMI was 22.1 kg/m^2 (Jadach & Ciepliňski, 2008). Lastly, youth Greece players (14.12 ± 1.09 years) reported that the BMI was 21.49 ± 2.35 kg/m^2 (Zapartidis et al., 2009).

1.4 Physical fitness in handball

In handball, the physical fitness of the players matters greatly. Handball is considered as one of the fastest team sports (Arifi et al., 2019). Since changes were made to the rule of restart after goal, also called "fast center", it made the game faster and more intense demands have been imposed on elite handball players and the physical demands led to a higher standard. Compared to some decades ago, the volume of training and matches played has increased (Michalsik et al., 2015a). Besides, handball requires a great strength because of the constant contact with the opponent's body and specific movements such as jumping, pressurizing, blocking and shooting (Arifi et al., 2019). Therefore, handball has specific requirements for anthropometric characteristics, technical skills, tactical understanding, and physical performance, where every single aspect has its role in improving the player's performance. Besides, handball is a strenuous intermittent team sport, the key characteristics are claimed to be endurance capacity, sprint performance, jumping ability, and throwing velocity, (Krüger et al., 2014). Identifying those demands for top performance in the sport is a complex process that requires good knowledge (Ghobadi et al., 2013).

Handball players must organize specific handball conditioning with some additional resistance to improve handball performance. Playing handball has a training effect on most of these qualities, but handball players normally perform additional physical training. When strength, sprint, endurance, sport-specific aspects, and competition are trained simultaneously during an entire season, then improved sport-specific performance appears (Jensen et al., 1997).

Size and maturation can affect the physical performance capacities of youth athletes. These aspects should be considered when evaluating the performance of talented youth handball players (Matthys et al., 2011). Because of differences in growth and maturation, it's difficult to identify performance-related characteristics in youth handball players. In addition, individual chronological age can differ by as much as 4 or 5 years from biological age within the same age group (Matthys et al., 2012; Saavedra & Saavedra, 2019). Players that mature early seem to have an advantage when it comes to strength, power, endurance, and speed, especially in sports where body mass is advantageous (Balyi & Way, 2009). However, those players who develop early may not necessarily hold on to these physical advantages until adulthood (Matthys et al., 2011).

It is important to consider that there are significant differences between male and female handball players regarding their physiological responses to the specific physical demands of the sport (Belka et al., 2014). Because of different unequal techniques, tactics and physical conditioning, sports training must be gender specific. Females and males' responses and adaptation to the same training loads can be completely different (Kirkendall, 2007). Male are thought to be faster, have more endurance, agility, strength, and power. Simply because of these biological differences, the female match is played at a slower pace (Kirkendall, 2007).

In terms of endurance, study have shown that female players reach a VO_2max of just less than 80% of the value achieved by male players. While female players have a fitness index of 85% of male elite players, indicating a higher demand for aerobic performance in female's match (Jensen et al., 2001). Due to physiological differences between the genders, conclusions based on male players cannot be transferred directly to female players (Michalsik et al., 2014). Besides, movement patterns or actions are different between male players and female players during match-play. The male players complete many more movements than female players during the same amount of time. For example, fast running is around 1.4% of total playing time per male match while it's 0.7% in a female match. The same applies to sprint, where it's 0.4% of total playing time per male match but only 0.1% in a female match (Michalsik & Aagaard, 2015)

1.4.1 Strength

Strength is defined as the ability of the muscle to generate force to resistance (Can, 2017) and is necessary for all sports that require physical activity (Brewer, 2008). Strength can be categorized in many ways, including dynamic strength, speed-strength, and strength endurance. Each sport requires a given level of certain strength qualities so the athlete can meet the physical capacity requirements with the best results (Newton & Dugan, 2002). In handball, muscle strength is a very important aspect of performance (Manchado et al., 2013). Dynamic muscle strength is thought to have a positive effect and is an important aspect in handball influencing throwing velocity and sprinting among other things (Chaouachi et al., 2009; Ortega-Becerra et al., 2018). In other words, more muscular and powerful players can have an advantage when it comes to handball (Gorostiaga et al., 2005).

Various types of strengths are important in handball. Improving the strength of the rotators of the shoulder could help players to achieve and maintain a faster throwing velocity and thus higher throwing effectiveness during a match (Zapartidis et al., 2007). It has also been suggested that there is a relationship between higher absolute maximal strength and an advantage in blocking, hitting and pushing (Manchado et al., 2013), as well as increasing the likelihood of successful performance in vertical jump, sprint, and endurance. Muscle strength and power should, therefore, be well developed for handball players so they can perform at the elite level (Matthys et al., 2011). On the other hand, a combination of strength and endurance training during the same period can prevent the development of strength (Bompa & Haff, 2009; Jensen et al., 1997)

Handgrip strength as well as hand anthropometry are important in handball for the reason that all shots and throws are finished with the wrist and fingers; the greater the finger length, the better the accuracy of the shot or throw (Visnapuu & Jürimäe, 2007). Players with large hands can grab the ball more tightly which gives the player confidence to accelerate the ball as much as possible throughout the whole movement pathway (Manchado et al., 2013). In several sports that require a sustained level of hand prehensile force to maximize control and performance, handgrip strength is often measured. When performing a handgrip strength test, the subject produces force with all fingers (Visnapuu & Jürimäe, 2007). It is often estimated in screenings of normal motor function as it is referred to as one of the most accurate and reliable clinical methods for estimating strength (Häger-Ross & Rösblad, 2002; Zapartidis et al., 2016). Handgrip strength measurement is a fast, simple, economical, well-established method and produces a result which is simple to record (Innes, 1999). However, there are different instruments and methods recommended

(Visnapuu & Jürimäe, 2007). The force can also be measured in many ways, in kilograms and pounds, in milliliters of mercury and in newtons (N) (Massy-Westropp et al., 2011).

Factors like gender, age, and physical fitness can influence handgrip strength (Leyk et al., 2007). A study on handgrip strength using the Grippit instrument method reported, the average peak grip strength for 16-year-old females 322 ± 53.7 N (Häger-Ross & Rösblad, 2002). In handball, the handgrip strength can affect the performance of players as it plays a major part in movements like throwing and catching (Visnapuu & Jürimäe, 2007). A strong handgrip can also benefit overall ball control (Matthys et al., 2013). A study examined female handball players (16.1 ± 0.6 years) reported that the average handgrip strength was 228.7 ± 40.8 N (Saavedra et al., 2018). However, higher results were found in the latest study, examined younger female handball players were the average handgrip strength was 241.9 ± 38.0 N (Saavedra et al., 2020). Moreover, in a study examining female Spanish handball players, the average handgrip strength was reported 346.72 ± 49.29 N (Vila et al., 2012).

1.4.2 Power

Power (P) can be defined as work (W) divided by time (t) [P= W/t] (Bompa & Haff, 2009). Power is the ability to exert a maximum strength or force in an as short amount of time as possible (Sabido et al., 2016). Power is therefore related to speed, which is related to quick movements (García et al., 2013). For athletes, it's the ability to generate high power output which may determine sporting success (Can, 2017; Newton & Dugan, 2002; Sabido et al., 2016). There is great interest in power development in sport science and how coaches and athletes can increase that power (Baker, 2001). Muscular power is one of the main aspects involved in sports that include high force production over a short time. One of the sports that is related to the application of high levels of power is handball (Sabido et al., 2016). The game is highly power-dependent since it involves high-intensity muscular actions that include specific movements and repeated explosive muscular contractions (Schwesig et al., 2016). The power of handball players can be divided into two parts; lower- and upper limbs. The sport requires muscle action for lower limbs include jumping and sprinting, and for upper limbs include throwing (García et al., 2013; Michalsik et al., 2015b; Schwesig et al., 2016; Srhoj et al., 2006).

Lower-limb strength is necessary for handball players to be able to create more power. With increased power the player is able to make higher jumps (Ortega-Becerra et al., 2018). The power of leg extensors is, therefore, an important aspect of performance in vertical jumps for handball players (Aura & Komi, 1986). The vertical jumping ability is a very influential aspect because it enables the player to reach a higher vertical position to throw above the defense wall and be more likely to get past the opponent and score a goal. Also, for the purpose of blocking and defending throws of the opposing team effectively (Krüger et al., 2014; Wagner et al., 2014).

Countermovement jumps (CMJ) is one type of vertical jumping and is widely used to evaluate motor development, functional ability, and motor capacity in youth athletes (Picerno et al., 2011). CMJ was one of the most extensively studied jump tests in the last two decades of the 20th century (Martin Acero et al., 2012). CMJ can be performed with arm swings or with none. When jumps with arm swing are compared with jumps without arm swings, the average height of the jump can be 10% greater when the arms are used (Martin Acero et al., 2012). The height of the CMJ is often estimated by applying the equation of free-fall to the motion of the center of mass during the flight phase (Picerno et al., 2011). The flight time is the most accurate and frequently used variable on vertical jumping and in the biomechanical analysis of athletic performance. The most common methods used for measuring flight time are contact platform, infrared platforms, force platforms, and video-based methods (Balsalobre-Fernández et al., 2014). In the video-based methods, a high-speed camera is used to record the jump. For each frame, the position of landmarks on the knee joint is determined with a motion-analyzer and the jumping height is then calculated by subtracting the landmarks from the highest position (Bobbert et al., 1986). However, there may be different results depending on the method used. In a longitudinal study on Flemish youth handball players (U16, U17, U18), CMJ with arm swings was recorded with an OptoJump, which is a video-based system of analysis. The average CMJ height increased over a three-year period, from being at average 37.2 cm at the first measurements to 43.4 cm in the second and 42.5 cm in the last measurements (Matthys et al., 2013).

Explosive power tests involving the upper limbs or trunk musculature are not as readily available as tests for the lower limbs (Stockbrugger & Haennel, 2001). Power in the upper limbs for handball players is connected to throwing velocity, which requires both accuracy and speed (Van den Tillaar & Ettema, 2006). To evaluate the explosive power of the upper-limbs, medicine ball throw (MBT) has been widely used (Leite et al., 2016). However, it is a very general and poorly validated test (Rivilla-García et al., 2011). MBT is considered to estimate extensors of shoulders, elbow, and trunk which is among other things the main elements of handball throwing (Lidor et al., 2005). Strength and speed are important elements in this case; with more strength, MBT can be improved (Hermassi et al., 2015). There are many types of MBT tests. Some examples are 1) backward overhead MBT which is a type of total body explosive power performance (Fathloun et al., 2011), 2) seated MBT by pushing the ball away from the center of the chest (Harris et al., 2011), 3) side MBT with a rotation of the trunk (Ikeda et al., 2007), 4) standing forward overhead MBT (Rivilla-García et al., 2011) and 5) tall kneeling MBT with both knees on the ground performed with chest pass and forward fall after releasing the ball (Sharrock et al., 2011). However, less is known about the kneeling forward overhead MBT which is used in this present study (Norweigian handball federation, 2017).

A study on handball players showed a high correlation between a light overhead MBT with one hand and throwing velocity (Rivilla-García et al., 2011). This strong correlation may be due to the similarity in coordination and technical performance. In this case MBT with light weighted ball was more suitable for handball players as it is more specialized for the sport itself. However, the results of the MBT test depend entirely on the procedure (Rivilla-García et al., 2011). In a standing overhead MBT using ball weighted 1 kg, female handball players were throwing average 7.73 m with a little increase of 0.45 m over a one-year period (Lidor et al., 2005).

MBT allows for movement through multiple planes and incorporate a variety of muscle contraction sequences and velocities. Explosive power generation using MBT involves high levels of reactive neuromuscular control. (Stockbrugger & Haennel, 2003). In many sports, the use of medicine balls in training is growing as practitioners see the wide range of skills that can be trained. Besides, MBT is also used as specific training method for success in sports (Stockbrugger & Haennel, 2001) like improving throwing velocity in handball (Rivilla-García et al., 2011). MBT training can be described as plyometric training (Szymanski et al., 2007) which is typically used to increase explosive power (Ikeda et al., 2007). The movement pattern in MBT allows the athlete to imitate the powerful, sequential, and rotational actions used in throwing (Szymanski et al., 2007). In addition to that, a study showed that there is a strong relationship between MBT test and core strength (Sharrock et al., 2011).

1.4.3 Speed

Speed is the ability to cover a distance quickly and is related and depends in large part on the players muscular strength. It’s a crucial ability that can affect performance in many sports (Bompa & Haff, 2009). When performing a sprint, the human body uses the anaerobic alactic metabolism or the ATP-PCR system (Karpan et al., 2015), which provide the muscles with energy in 3 -15 seconds (Larry et al., 2015).

Parts of the handball match can be very fast (Hermassi et al., 2015). In critical moment such as winning possession of the ball and scoring goals depend on such actions (Chelly et al., 2014). Fast changes between offense and defense activities require a well-developed acceleration and sprint performance (Krüger et al., 2014). Handball players need to be able to accelerate quickly over short distances, as well as being able to change direction suddenly in competition, therefore, sprint ability is a very important conditional aspect (Matthys et al., 2011). It is a crucial aspect to be able to intermittently perform short duration activities during games like sprinting to obtain a high level of performance in handball (Póvoas et al., 2012; Wagner et al., 2014). The capability to reproduce high intensity sprints can be examined requiring the athlete to reproduce an all-out sprint after a short recovery period. Distance of 30 m is recommended (Reilly, 2001) because handball players rarely run more than 30 m during a match (Chelly et al., 2014).

In youth handball match, high speed sprinting accounts for only 11% of the total distance covered (Chelly et al., 2014). Sibila et al. (2004) demonstrated that handball players perform on average 10 to 12 m sprints during 2.3 seconds. In addition, handball players complete on average 70 sprints per match with an average sprint distance of 6-8 m (Šibila et al., 2004).

In the northern region of Norway, the best female youth elite handball players within their age group (under 18 years and under 16 years) were examined as they performed 30 m sprint where the timing started automatically. The average 10 m sprint time was 2.04 ± 0.10 s and the average 30 m sprint time was 4.87 ± 0.22 s with the U18 players. The younger (U16) group ran slower, the 10 m sprint time was 2.11 ± 0.10 s and the 30 m sprint time was 5.03 ± 0.22 s (Ingebrigtsen et al., 2013). Similar results were found in a longitudinal study by Matthys et al. (2013) where the younger group (U14, U15, U16) ran slower than the older group (U16, U17, U18) both in 10 m sprint and 30 m sprint. In three measurements over a three-year period with the younger group, the average 10 m sprint time was 2.06 s in the first measurements, 1.94 s in the second and 1.91 s in the last measurements. In the older group the average 10 m sprint time was also always shorter with each measurement and rising age, from 1.91 s in the first measurements to 1.83 s in the last measurements. As for the 30 m sprint, there were also improvements in both groups, but the older group was faster, as with the 10 m sprint. The average time for the younger group was 5.02 s in first, 4.75 s in second and 4.61 s in the third measurements. In the older group the time for 30 m sprint was 4.56 s in the first measurements, 4.48 s in the second and 4.34 in the third measurements (Matthys et al., 2013).

1.4.4 Endurance

Endurance is the human body's ability to work for a long time, and can be divided into two types, aerobic and anaerobic endurance. Aerobic endurance is the body's ability to work for a long time with low intensity, while anaerobic endurance is the body's ability to work for shorter time with high intensity (Larry et al., 2015). In handball the physical effort is based on both types of endurance because the sport involves many cyclic movements and activities with only short breaks (Karpan et al., 2015). Endurance capacity, sprint performance, jumping ability and a high throwing velocity is reflected in a highly developed anaerobic endurance (Schwesig et al., 2017). Highly developed anaerobic endurance capacity is therefore considered to be necessary for players (Krüger et al., 2014) as intermittent actions like repeated jumps and struggling for the ball are a major part of the match (Matthys et al., 2012). On the other hand, aerobic mechanisms is around 90% of the energy during a handball match (Matthys et al., 2011). That's why improved aerobic capacity is also important. It helps players to achieve faster recovery in less time between high-intensity efforts (Matthys et al., 2011), like recovering between sprints, as there are a lot of repeated sprints during a match (Hermassi et al., 2015; Wagner et al., 2014).

Handball players work intensely for short, intermittent time intervals, while always changing between standing, walking, jogging and performing moderate running, sprinting and moving forwards, backwards and sideways at the same time as being tackled, grabbled and pushed (Michalsik et al., 2015a; Wagner et al., 2014). Therefore, a specific high level of endurance is essential for handball players (Wagner et al., 2014) so they can perform repeated high-intensity actions (Matthys et al., 2013) and keep up the high level of play during the entire sixty-minute match (Michalsik, 2018; Wallace & Cardinale, 1997). During a handball match, most distance covered is spent performing low-intensity anaerobic actions with a short duration of very high-intensity anaerobic actions (Póvoas et al., 2012). A study reported that on average, the distance covered was 3399.2 ± 262.3 m. Handball players then covered around 12% of the average distance while walking, 28% while jogging, 24% with medium intensity running, 16% with high intensity running, and sprinting accounted for 20% of the average distance (Belka et al., 2014). Another study showed similar results, in a female handball match where there were high aerobic demands compared to very brief periods of substantial anaerobic energy production on the players (Michalsik et al., 2013). Even though high-intensity endurance training should be looked at in more detail in the full training session planning, it appears that high aerobic capacity is no less important to maintain a high level of performance over the entire sixty-minute match (Manchado et al., 2013). Therefore, it seems logical to evaluate handball players ability to repeatedly perform intense exercise and with that the potential to recover from intense exercise (Krustrup et al., 2003). One intermittent field test that evaluates these requirements of simultaneous stimulation of the aerobic and anaerobic energy system is the Yo-Yo intermittent recovery (Yo-Yo IR) test (Krustrup et al., 2006) designed by Bangsbo (Bangsbo et al., 2008). The Yo-Yo IR test is easy and valid way to receive information of an individual's capacity to perform repeated high intensity activity for sustained period and to examine changes in performance (Bangsbo et al., 2008; Reilly, 2001). It has become one of the most extensively studied fitness test in sport science (Bangsbo et al., 2008).

There exist two levels of the Yo-Yo IR test. Level 1 (Yo-Yo IR1) starts at lower speed and is considered for untrained and less trained participants, while level 2 (Yo-Yo IR2) is for well trained and elite trained athletes and starts at a higher running speed than the level 1 test. It is assumed that level 2 is suitable for those who can run longer than 2880 m in level 1 or achieve maximum oxygen uptake (VO_{2max}) from 60,6 ml/kg/min or higher. The difference between the levels is that for a trained individual, the level 1 lasts from 10-20 minutes and is mainly focusing on an individual's endurance capacity. Meanwhile, the level 2 lasts from 2-15 minutes and aims to measure a trained individual's ability to recover from repeated exercise with a high contribution from the anaerobic system. The heart rate increases faster in the IR2 test, causing an increasing oxygen uptake (VO_2). As for the formula to estimate VO_{2max} from the result of the Yo-Yo IR2 test, the distance in meters is multiplied by 0.0136 plus 45.3. Another formula applies to Yo-Yo IR1 (Bangsbo et al., 2008). In addition, from the Yo-Yo IR2 score it is possible to calculate the VO_{2max} for each player and estimate it to ml/min/kg. Values of maximum oxygen consumption can though be different based on age and gender (Saavedra et al., 2018).

Measurement on elite athletes in sports that requires intermittent exercise showed that athletes are performing better in the Yo-Yo IR test when they are at higher level of competition. In addition, with rising age the performance increases for youth players in the Yo-Yo IR test (Bangsbo et al., 2008). The Yo-Yo IR test has been used frequently on athletes (Bangsbo et al., 2008). A study examined 47 female elite handball players in Yo-Yo IR1, the average distance covered was 1576 ± 311 m (Schmitz et al., 2018). The same study showed results in Yo-Yo IR2 for 67 male handball players, where the average distance covered was 752 ± 300 m (Schmitz et al., 2018). As has been said before, there is a difference between level 1 and level 2, therefore difficult to compare results (Bangsbo et al., 2008). Another study examined male elite handball players (17.7 ± 0.3 years), showed that the average distance covered in Yo-Yo IR1 was 1745.45 ± 404.08 m (Hermassi et al., 2014). That shows that males are able to run farther than females in the Yo-Yo IR2 based on these studies (Hermassi et al., 2014; Schmitz et al., 2018).

More common studies on females are using the Yo-Yo IR1 test rather than the Yo-Yo IR2 test (Kilic-Toprak et al., 2015; Moss et al., 2015; Schmitz et al., 2018). It seems then more common for male handball players to be examined using the Yo-Yo IR2 test (Kvorning et al., 2017; Schmitz et al., 2018). A study examined male Danish national handball players (29.5 ± 4 years), reported that 8 weeks of strength and conditioning training led to significant improvements in the Yo-Yo IR2 test. The male players were analyzed pre- and post the Olympic Games where they achieved 797 ± 175 m pretraining and 997 ± 167 m post-training, given that the performance increased by 25% in the Yo-Yo IR2 test (Kvorning et al., 2017). It should then be kept in mind that improved agility capacity might affect player's ability to perform the Yo-Yo IR2 test because of improved techniques relating to faster change of direction, acceleration, and decelerations (Kvorning et al., 2017)

A study examined female youth handball players, where the participants were classified as elite players (15.8 ± 1.3 years), from high standard European league club teams, and as top elite players (17.1 ± 1.1 years) who were European international players. The showed that elite players were running on average 935 ± 394 m as distance covered in the Yo-Yo IR1, while the top elite players were running on average 1663 ± 327 m (Moss, 2014). Similar results were reported in a study that examined female handball players in the A-team (23.7 ± 3.9 years), under 19 (18.3 ± 0.7 years), under 17 (16.1 ± 0.6 years) and under 15 (14.5 ± 0.5 years) national teams. Older players were achieving higher speed scores in the Yo-Yo IR2 test than younger players. Considering that the A-team was with a significantly higher speed score (19.7 ± 1.0 km/h^{-1}) than the other national teams (18.2-18.8 km/h^{-1}) (Saavedra et al., 2018).

1.5 Throwing velocity

Throwing ability is a part of specific handball skills and one of the most important elements and aspects for success in handball (Ferragut et al., 2018). It constitutes an important competitive skill that contributes to the performance of the athlete and also to the performance of the team (Zapartidis et al., 2007). The throwing movement is a typical example of an explosive action, where both speed and strength play a central role (Hermassi et al., 2015).

The throwing movement is a complex body activity with sequential activation of body parts. A right-handed thrower goes from the left foot to the right hand (Bayios et al., 2001). Three basic aspects are important regarding the efficiency of arm throwing: the throwing technique, the timing of the consecutive actions of the body segments, and upper and lower-extremity muscle strength and power (Gorostiaga et al., 2005). Around 53% of the velocity of the throws relates to arm action, while 47% is due to the step and body rotation (Bayios et al., 2001). To increase the speed of the ball release, increased trunk flexion, trunk rotation and shoulder internal rotation is important (Wagner et al., 2010). Besides, a study has shown correlations between throwing velocity and the maximal pelvis and trunk rotation angular velocity (Wagner et al., 2011).

For a throw to be effective it requires the highest velocity in combination with aiming accuracy (Zapartidis et al., 2007) as well as an element of surprise for the defensive players and goalkeeper. It is important to optimize the movement of the throwing arm, the velocity of the shoulder, elbow, and wrist (Wagner & Müller, 2008). First and foremost, the ball throwing velocity depends on the players ability to accelerate the ball with an overarm throw. By throwing the ball faster towards the goal, the shorter the time for the opponent's defenders and the goalkeeper to save the shot and the potential of scoring will be higher (Ferragut et al., 2018; Manchado et al., 2013). Therefore, the ability to score a goal depends upon the velocity of the ball and the accuracy of the throw (Bayios et al., 2001). It is claimed that older and more experienced handball players throw faster than youth or non-experienced players because they have had longer training time and more experience to develop a good throwing technique (Mohamed et al., 2009).

Faster throwing velocity can be achieved by improving the strength of the shoulder rotator muscles, especially of the internal rotator (Bayios et al., 2001; Edouard et al., 2013). Strength and power are considered to have a positive influence on each other. However, the velocity of a handball throws also dependent on body segments coordination and technical skills, not only on the muscular strength (Vila et al., 2012). In addition, it needs to be kept in mind that to optimize handball specific strength and power, training has to be specialized for gender and playing position (Wagner et al., 2014).

Throwing movements are often classified as underarm, overarm or sidearm. Overarm throws are characterized by lateral rotation of the upper arm in the preparation phase and its medial rotation in the action phase. This movement is one of the fastest joint rotations in the human body (Bartlett & Robins, 2008). Not only does the throwing movement involve rotations of all joints of the arm but it is also considered to be a complex movement (Zapartidis et al., 2007). Throwing also includes the hip and trunk, as well as elbow extension and wrist flexion. The velocity will be higher if more rotations are brought into the action. As with other throws, velocity it is based on different actions. It is estimated that 53.1% of the velocity of the overhand throws are attributed to arm action and 46.9% are due to the step and body rotation (Toyoshima et al., 1974). In addition, the internal and external rotators of the shoulder play a very important role in the stability of the glenohumeral joint and the kinematics of overarm throwing, possibly resulting in a greater throwing velocity (Bayios et al., 2001; Zapartidis et al., 2007). A study has shown that the internal shoulder rotation angular velocity at ball release, maximal elbow extension and the timing of the maximal pelvis angle are important contributors to throw velocity (Wagner et al., 2011).

The throwing technique in handball are several and different from each other (Wagner et al., 2011). The physical demands of handball include various types of throwing (Schwesig et al., 2017). The standing throw involves keeping the lead foot in contact with the floor during the throw and is typical for the penalty throw in handball. In the standing throw with run-up, one foot is planted on the floor after three regular steps or run-up before releasing the ball. Lastly, the jump throw is performed with a vertical jump off one leg after the run-up (Wagner et al., 2011). Throwing techniques are often based on playing positions and are dictated by the movements of the defensive players (Wagner et al., 2010).

Sport-specific skill tests like measuring throwing velocity, are probably the most useful for long-term development of athletes (Matthys et al., 2012). In an average handball match in the Portuguese National League, each player takes about seven shots on the goal (Póvoas et al., 2012). The most common throwing technique or 75% of all throws during a match are jump throws after a run-up (Wagner et al., 2014). The advantage of the jumping throw technique is that it enables a better throwing position, throwing over the rival block, and gives more time for decision making, like, watching the goalkeeper before throwing the ball (Lage et al., 2011; Wagner et al., 2011). However, the standing throw with run-up is the throwing technique with the highest throwing velocity, followed by the jump throw, and then the standing penalty throw (Vila et al., 2012). Throwing techniques also aim to different movements of the lower limbs which can cause achieving different throwing velocity (Gorostiaga et al., 2005; Rivilla-García et al., 2011; Vila et al., 2012). Because of increased acceleration of the pelvis and trunk in the standing throw with run-up, greater throwing velocity can be achieved (Wagner et al., 2011, 2014)

Studies have suggested that anthropometric characteristics such as height and weight are related to throwing velocity (Debanne & Laffaye, 2011; Matthys et al., 2011; Van den Tillaar & Ettema, 2004; Wagner et al., 2010; Zapartidis et al., 2007). Positive correlation was found between height and weight and throwing velocity in jump throws in elite handball players (Schwesig et al., 2017). It must be kept in mind, that there is difference between gender in throwing velocity. Muscle mass and height can be the reason for this difference (Van den Tillaar & Ettema, 2004). In addition, different training methods can enhance throwing velocity in handball players (Andersen et al., 2018; Cherif et al., 2016; Hermassi et al., 2010, 2015; Marques & González-Badillo, 2006). Especially when the upper body is invoved in the routines. It is claimed that with certain strength training, throwing velocity can be improved. A study showed significant throwing velocity improvements after 10 weeks of heavy load training in both standing throw with run-up and the jump throw (Hermassi et al., 2018).

1.6 Measurements and performance

Relations between different sports and physical characteristics is a factor to consider in the success of every sport. In some sports there is a certain physical profile necessary to reach the highest levels of performance. Positions in the playing field also require certain physiological and physical attributes. This is important in handball because each specific position requires certain skills related to each position’s specified tasks (Vila et al., 2012).

In many ball sports such as handball, coaches use physical and technical tests on regular basis in early stages of talent identification and development, to find individuals who can attain the highest level in a certain sport (Lidor et al., 2005). Researchers have observed that physical fitness tests can be useful to measure physical skills that are required in handball to identify expectant top elite handball players (Massuça et al., 2014). The tests help the coach to gather information on the sport's abilities and helps determine whether the athlete fulfills the basic requirements of the sport (Lidor et al., 2005). The measurements can also give a great insight into the current status of the players (Sporis et al., 2010), as it helps coaches to consider strength and weaknesses of each player during training sessions (Krüger et al., 2014). By targeting specific strength qualities with certain training and testing, greater efficiency of training effort can be achieved resulting in enhanced athlete performance (Newton & Dugan, 2002). Measurements also allows coaches to evaluate the players and to implicate the right training volume and intensity to raise their capabilities (Sporis et al., 2010). An appropriate planning of the training procedure is necessary for the development of athletic performance (Krüger et al., 2014). In addition to technical and tactical skills, the most important aspects that can give a clear advantage for success in elite levels of handball leagues are anthropometric characteristics and high levels of strength, muscle power, and handball throwing velocity (Gorostiaga et al., 2005).

To be able to have a full understanding of youth handball concerning maturation, future research might look at tracking 1) the effect of maturation on selection in the sport, 2) the effect of maturation at different age and standards of play, and 3) how coaches perceive and react to players with different maturity. This could be done to check for trend in elite handball populations over time and to have more handball-specific skill tests (Matthys et al., 2012).

It is therefore necessary to study the development of the handball players performance in many areas such as anthropometric characteristic, physical fitness and throwing velocity. Most previous studies (Fieseler et al., 2017; Ghobadi et al., 2013; Massuça et al., 2014; Michalsik et al., 2015a; Schwesig et al., 2017; Wagner et al., 2014; Ziv & Lidor, 2009) analyzed these aspects on adult players and in most cases, male players. Sport performance is of course influenced by gender and age of the players. There are fewer studies on youth handball (Matthys et al., 2013; Mohamed et al., 2009; Visnapuu & Jürimäe, 2009; Zapartidis et al., 2009). In addition, relative to those of male players, there have been few studies on female handball players (Ferragut et al., 2018; Granados et al., 2007, 2013; Hasan et al., 2007; Lage et al., 2011; Michalsik et al., 2014; Vila et al., 2012) in different age groups. However, not nearly as much in comparison with male handball studies. Therefore, it is important to examine the status of youth female handball players and do more studies who study these aspects and has increased in recent years.

2. Objectives

The objective of this study were:

i. To analyze the differences over two-years in anthropometric characteristics, physical fitness and throwing velocity between measurements
ii. To analyze the difference over two-years in anthropometric characteristics, physical fitness and throwing velocity between players in three selected measurements

3. Methods

3.1 Study design

This is a cross-sectional and longitudinal study done in collaboration with the Icelandic Handball Federation, *HSÍ*. As the Icelandic youth national handball players were examined. The independent variables in this study were the results from each test; anthropometric characteristics (height, weight, BMI), physical fitness tests (handgrip strength, countermovement jump, medicine ball throw, 30 meter sprint with 10 meter split time, Yo-Yo Intermittent recovery test) and throwing velocity. The dependent variable was a two-year period of training and competing, which was examined in two ways, by measurements and by players in three selected measurements.

Table 2. Tests variables

Independent variables	Dependent variable
Height (m)	Measurements
Weight (kg)	Players
BMI (kg/m^2)	
Handgrip strength (N)	
Countermovement jump (cm)	
Medicine ball throw (m)	
10 m sprint (s)	
30 m sprint (s)	
Yo-Yo Intermittent recovery test (m)	
Throwing 7 m (km/h)	
Throwing 9 m with 3 steps (km/h)	
Throwing 9 m with a jump (km/h)	

3.2 Participants

A total of twenty-two female handball players (age 16.55 ± 1.11 years), members of the Icelandic youth national teams, under 15 years (U-15), under 17 years (U-17) and under 19 years (U-19) participated in this study. Table 2 lists descriptive statistics on participants between measurements over a two-year period.

Table 3. Descriptive statistics on participants between measurements

	Date of measurements	Season	Participants (n)	Age (M ± SD)
Measurement 1	January 2017	Transition	22	15.51 ± 0.86
Measurement 2	June 2017	Off-season	15	15.94 ± 0.86
Measurement 3	September 2017	In-season	20	16.24 ± 0.86
Measurement 4	May 2018	In-season	12	16.89 ± 0.86
Measurement 5	September 2018	In-season	14	17.24 ± 0.86
Measurement 6	January 2019	Transition	22	17.50 ± 0.86

M = mean, SD = standard deviation, n = number of participants

The players that participated were selected by the coaches of each national team when the national teams were practicing together at the time of the measurements. Data was collected from all players in each national team, but the data used was only by those players that attended to measurements from January 2017 to January 2019 or participated in at least four measurements. The main reason for dropout between measurements were injuries, sickness, non-availability on the testing day, cessation of handball activities or the player was not selected for the national team project again. In addition, players were excluded from the testing if they experienced pain or severe muscle stiffness, or if the national team coach concluded that it was not safe for the player to participate. It should be kept in mind that during this two-year period the players were measured in at different times during the playing season. The Icelandic handball league is played over a 9-month period. The competition season starts in September and ends in May, but with a training break or transition season from the middle of December to the end of January. After the competition period ends in June, the off-season starts were players are training themselves, and then the preparation or pre-season starts in July. Table 2 lists descriptive statistics on participants between measurements, showing at what time in the season the measurements were conducted.

3.3 Procedures

Six measurements were analyzed, from January 2017 to January 2019. This two-year period was chosen since it provided the most information for the objective of the study. In addition, other similar studies have examined the development of athletes within two- or three-year periods (Lidor et al., 2005; Matthys et al., 2012, 2013).

The tests taken for this study were standardized and decided in consultation with the Icelandic Handball Federation and the Sports science department. Therefore, these same tests have been repeated for several years. The measurements include test to evaluate anthropometric characteristics, handgrip strength, power in two ways; countermovement jump and medicine ball throw, speed with 30 m sprinting test, endurance with Yo-Yo intermittent recovery test level 2 and throwing velocity (7 m-throwing, 9 m -after 3 steps, and 9 m after 3 steps with jump). The results of these tests were examined between six measurements and examined between players in three selected measurements, where each player was compared to himself over two years to see if there were any differences. Only three of six measurements were used to examine longitudinal development changes between players because of unequal participation in the measurements. The measurement chosen were the measurements with the highest participation. Those measurements were measurement 1 (January 2017), measurement 3 (September 2017), and measurement 6 (January 2019).

The participants were measured six times during a two-year period of training and competing with the Icelandic youth female national handball teams. Data were collected from January 2017 to January 2019. All measurements were part of the first training to a weekend-long training camp with their youth national team. All the measurements took place on Friday mornings at the sports center of the sport club *Víkingur* in the indoor court, which is located at Traðarland 1, 108 Reykjavík. Every measurement was organized in the same way and the set up was the same for each test. As these tests were conducted for the Icelandic Handball Federation, *HSÍ*, the data were treated without reference to each player's name. The results cannot be generalized to the whole group, because the study is based on individuals, not the whole national team. However, all clubs within the association can access results for their players, as well as average values and highest and lowest values for each national team. The study was approved by *HSÍ* and Reykjavík University and respected the principles of the Declaration of Helsinki.

3.4 Measurements

3.4.1 Testing schedule

A multidimensional test battery was used, including general as well as handball specific tests. The participants were carefully familiarized with the testing protocol, as most of them had been previously tested on several times in previous seasons. All participants were assessed on the same day. Every national team was called one at a time for hour-long measurement from 9 am to 12 pm. First, the participants were measured in those tests that affect physical ability the least, two basic anthropometry measures such as height and weight, and then handgrip strength. After the anthropometry measurements, the participants performed a standardized 15-minute warm-up procedure consisting of stretching exercise, 4-6 repetitions of 30 m doing different exercises (knees up, lunge walk, etc.), 5-7 accelerations of 30 m building up the speed, and 10 minutes of passing. Full recovery was ensured between each of the trials (Saavedra et al., 2018). Following the warm-up, players perform the physical fitness tests. The tests contained a countermovement jump (CMJ), medicine ball throw (MBT), 30 meter sprint with 10 m split time and a throwing velocity test.

The participants were grouped into four groups after the warm-up and each group was placed on one station where the tests were performed. Participants completed two trials on each station and the best score was recorded for further analysis. When all four groups had performed four tests, the whole group completed the last test together in the end, which takes the most effort on the body to perform, the Yo-Yo intermittent recovery test level 2 (IR2).

3.4.2 Anthropometric characteristics

Reference: Balyi & Way (2009) and Keys & Brožek (1953).

Anthropometric measurements were taken using standardized protocols. The participants were measured in height and weight in light clothes without shoes using Scale SECA. The participants stood in an upright position on the scale with heels, buttocks, and shoulder pressed against the stadiometer and arms hanging freely by the side. The participants looked straight ahead and stood as tall as possible. The measuring bar was drawn down to the participant's head and standing height was recorded to the nearest 0.1 cm (Balyi & Way, 2009). The height was measured in meters (m) and the weight in kilograms (kg). To evaluate the relationship between height and weight, body mass index (BMI) [weight (kg)/ height^2 (m)] was then calculated for each participant, recorded in kg/m^2 (Keys & Brožek, 1953).

3.4.3 Handgrip strength

Reference: Visnapuu & Jürimäe (2007).

To evaluate the isometric strength of flexors of wrist and fingers of the throwing hand a Vernier hand dynamometer (Vernier, Orlando, USA) was used (Visnapuu & Jürimäe, 2007). The participants performed one repetition at maximum intensity while sitting on a chair, back against the backrest, with feet on the ground, and elbows flexed at 90 degrees (Saavedra et al., 2019). The dynamometer was held freely with the dominant hand without support or wrist movement and without touching anything. The purpose of the test was to squeeze the dynamometer as tightly as possible for a few seconds. The players tried to get the maximal force effort in one trial and the highest number was used for the analysis. The handgrip strength was recorded in Newtons (N).

3.4.4 Countermovement jump

Reference: Balsalobre-Fernández et al. (2014), Bosco et al. (1983) and Granados et al. (2013).

To evaluate the power of the extensors of the knee and hip the participants performed maximal countermovement jump (CMJ) with no arm swing (Bosco et al., 1983). Starting from an upright standing position, the aim was to jump as high as possible (Gorostiaga et al., 2005). The CMJ was evaluated by measurements of high-speed video recordings (Casio, Exilim camera, 300 frames/s) during jumping. Once the jumps made by the participants had been filmed, the jump height was calculated using Kinovea software.

The video camera was placed on a tripod at a distance of 1.5 m perpendicular to the players' sagittal plane and the filming zone (Balsalobre-Fernández et al., 2014). The jumping zone was marked out on the floor. A stick marked with 50 centimeters was placed in the front of the jumping zone in line with the participant's left leg. A tape was placed as a marker on the participants lateral knee joint (lateral condyle). The height of the jump was then determined using the open-license motion-analyzer software package, Kinovea (Kinovea 0.8.15 for Windows; available at http://www.kinovea.org) by comparing the marker on the participants knee the video recording to the stick (Bobbert et al., 1986; Saavedra et al., 2018). Jumping height was measured by following the marker from standing position before the take-off which was marked with 0 and the highest position in the air based on the knee joint marker (Balsalobre-Fernández et al., 2014). If the jump did not meet the criteria for a successful jump it was repeated (Balsalobre-Fernández et al., 2014). The participants got two trials of successful jumps for the maximal jump height. The highest jump was then recorded in centimeters and used for further analysis.

3.4.5 Medicine ball throw

Reference: Norweigian handball federation (2017). Adapted by Lidor et al. (2005), Rivilla-García et al. (2011) and Sharrock et al. (2011).

To evaluate the power of extensors of the upper-limbs; shoulder, elbow, and trunk the medicine ball throw (MBT) was used (Leite et al., 2016). Participants had to stay in a kneeling lunge position with one knee on the floor and the other one in 90- degree flexion. The toe had to be in line with the beginning of the measuring tape which was used to measure the length of the throw. Body toward throwing direction and ball symmetrically adapted with both hands under hips. The aim was to throw a ball that weighed 3 kilograms with both hands in an overhead position, extending trunk with elbows flexed, and with an explosive movement to throw as far as possible (Lidor et al., 2005; Rivilla-García et al., 2011; Sharrock et al., 2011). The distance from the throwing line to the landing point of the ball was measured in meters. Participants were not allowed to lift the knee or toe from the ground, otherwise, the throw was invalid, and participants had to repeat the throw. The participants got two trials for maximal MBT and the longest throw was scored as a distance (m) achieved (Lidor et al., 2005).

3.4.6 10- and 30 meter sprint

Reference: Adapted by Lidor et al. (2005).

To evaluate the participant's speed and acceleration the participants performed a sprint running test consisting of two maximal sprints of 30 m with 10 m split time (Lidor et al., 2005). Time was recorded using three sets of laser light barriers (TCi Wireless Timing System, Brower Timing Systems, Draper, Utah, USA), each consisting of an infrared sender and an infrared emitter with antennas. Each unit was mounted on a tripod placed at the starting line (0 m), after 10 m, and at 30 m from the start (Reilly, 2001; Saavedra et al., 2019). The short distance (10 m) was for split time and supposed to indicate acceleration speed. The participants performed the sprint when ready from a standing position 1 m behind the starting line. The time was automatically activated as the participant passed the first gate at the 0-mark and the split time was recorded at 10 m and 30 m. The data were then sent from the Brower Timing Systems sets directly to the handheld coach monitor. The participants got two trials to perform maximal sprints of 30 m as fast as possible, with resting between while walking back to the starting line (Gorostiaga et al., 2005). The results were recorded in seconds and the fastest sprint of each distance, both in 10 meters and 30 meters were selected for further analysis.

3.4.7 Yo-Yo intermittent recovery test

Reference: Krustrup et al. (2006).

To evaluate the aerobic and anaerobic energy system, the Yo-Yo intermittent recovery test level 2 (IR2) was used. The test examines the body's ability to recover from repeated anaerobic work and gives a good idea of players intermittent endurance performance (Krustrup et al., 2006). The Yo-Yo IR2 consists of repeated 2 x 20 meters shuttle runs. The speed increases progressively by a starting sound controlled by audio signals from a tape recorder after every round and between each running round the players have a 10 seconds active recovery period consisting of 5 m rest space. The aim is to run as many rounds back and forth as possible until the participant is exhausted (Krustrup et al., 2006). The results depend on how far the player reaches, the longer the distance will be, the higher the score will be (Bangsbo et al., 2008; Reilly, 2001).

The participants were divided into two groups to take the endurance test in one trial, on an indoor surface. The first group ran while the second group counted the running rounds and levels for their partner in the first group. Then the opposite is done. The rules are such that if the player fails twice to reach the line in the required time or if the participant feels unable to complete another shuttle at the dictated speed, the test is considered as complete (Schwesig et al., 2017). The Yo-Yo IR2 begins at speed level 11 (0-40 m), then it immediately raises to level 15 and then to speed level 17 which consists of four running bouts (120-180 m). Thereafter it continues with stepwise speed increments after every running bout until exhaustion. The total distance covered as the position achieved in speed levels were recorded in meters.

3.4.8 Throwing velocity

Reference: (Gorostiaga et al. (2005) and Vila et al. (2012).

Specific explosive strength in handball was evaluated by overarm throw (Granados et al., 2013). Throwing velocity was assessed with Sports Radar 3600 Gun (Perform Better, Warwick, UK) to measure the speed of the ball when the participants performed three different protocols of throw (Vila et al., 2012). The throwing velocity was measured on an indoor handball court in this particular order; 1) a standing throw at the penalty line from 7 meter (Throwing 7 m), 2) a 3-step running throw from 9 meter (Throwing 9 m with 3 steps) and 3) a jumping throw after 3 steps-run from 9 meters (Throwing 9 m with a jump) (Vila et al., 2012). For each type, the participants were instructed to throw a standard handball as fast as possible in a standard handball goal, using their own personal technique with no opposition or any instructions regarding accuracy (Gorostiaga et al., 2005).

In the standing throw, the lead foot had to be in contact with the floor behind the 7 m penalty line (Gorostiaga et al., 2005), in the 3-step running throw the players were allowed to do a preparatory run, limited to three regular steps before releasing the ball behind the 9 m line from the goal (Gorostiaga et al., 2005), and in the jumping throw after 3-steps, players made a preparatory 3-step run before jumping vertically 9 m from the goal, releasing the ball while in the air (Vila et al., 2012). Two throws of each type with the dominant hand with maximum effort were performed. However, if they missed the goal, they had to repeat the shot until two correct throws were recorded (Saavedra et al., 2019). The Sport Radar Gun measured the speed of the ball in kilometers per hour (km/h) and the highest throwing velocity for each throw was selected for further analysis.

3.5 Statistical analysis

The data was inserted in an excel file where it was examined, then transferred to the statistical software package IBM SPSS statistics version 25.0 (SPSS Inc., Chicago, IL, USA) where the statistical analysis was performed for the present study. Descriptive statistics were calculated for all the experimental variables (height, weight, BMI, MBT, CMJ, 10 m sprint, 30 m sprint, Yo-Yo IR2, and throwing velocity), as the results were presented as mean values with standard deviation. Because the objectives of this study were to examine longitudinal development changes in two ways, two different statistical analysis was required. To know the first objective, one-way ANOVA was used followed by Bonferroni post hoc test to identify the difference in anthropometric characteristics, physical fitness- and throwing velocity performance between six measurements over a two-year period. To know the second objective, repeated measures ANOVA were used to identify the difference in anthropometric characteristics, physical fitness- and throwing velocity performance between players in three selected measurements over a two-year period. Statistical significance was set at $p<0.05$ for all analyses in the present study.

4. Results

4.1 Differences between measurements

Tables 4, 5 and 6 present the means and standard deviations of each variable, the results of F-values and P-values of one-way ANOVA and differences between six measurements using Bonferroni post hoc test.

Table 4 shows the means and standard deviations of each anthropometric variable, and the results of the one-way ANOVA in six measurements over two years. No significant difference was found in any of the variables between the measurements for anthropometric characteristics, in height, weight or in BMI.

Table 4. Anthropometric characteristics in six measurements over a two-year period

Variable	M1 January 2017 n= 22	M2 June 2017 n= 15	M3 September 2017 n= 20	M4 May 2018 n= 12	M5 September 2018 n= 14	M6 January 2019 n= 22	F	p	Difference
	M ± SD	M ± SD	M ± SD	M ± SD	M ± SD	M ± SD			
Height (m)	1.70 ± 0.05	1.71 ± 0.04	1.72 ± 0.05	1.72 ± 0.04	1.71 ± 0.04	1.72 ± 0.05	0.568	0.724	n.s.
Weight (kg)	63.57 ± 7.8	67.02 ± 7.49	66.93 ± 7.76	67.03 ± 6.33	69.08 ± 6.86	67.08 ± 7.51	1.086	0.373	n.s.
BMI (kg/m^2)	21.93 ± 2.34	22.93 ± 2.11	22.57 ± 2.25	22.50 ± 2.00	23.69 ± 1.76	22.60 ± 2.16	1.211	0.310	n.s.

M = mean, SD = standard deviation, n = number of participants, n.s. = not significant, M1 = measurement 1, M2 = measurement 2, M3 = measurement 3, M4 = measurement 4, M5 = measurement 5, M6 = measurement 6.

Table 5 shows the means and standard deviations of each physical fitness variable, and the results of the one-way ANOVA in six measurements over two years. Differences were found between measurements in the handgrip strength [$F(1,5) = 2.422$, $p=0.042$] between M1 and M5, countermovement jump [$F(1,5) = 14.660$, $p<0.05$] between M2 and all the others measurements (M1, M3, M4, M5, and M6) and 10 m sprint time [$F(1,5) = 4.815$, $p=0.001$]. However, there were no significant differences between measurements in MBT, 30 m sprint time, or in the Yo-Yo Intermittent recovery test. Detailed results for each test are further listed in table 5.

Table 5. Physical fitness performance in six measurements over a two-year period

Variable	M1 January 2017	M 2 June 2017	M3 September 2017	M4 May 2018	M5 September 2018	M6 January 2019	F	p	Difference
	M ± SD	M ± SD	M ± SD	M ± SD	M ± SD	M ± SD			
Handgrip (N)	n= 22 232.18 ± 39.12	n= 15 254.64 ± 45.32	n= 19 263.84 ± 43.87	n= 12 263.84 ± 43.87	n= 14 281.75 ± 55.16	n= 10 246.08 ± 11.44	2.422	0.042	M1<M5
CMJ (cm)	n= 22 36.26 ± 3.0	n=15 28.94 ± 4.0	n= 20 36.15 ± 1.9	n= 12 39.05 ± 4.2	n=14 38.69 ± 4.4	n= 10 37.0 ± 4.3	14.660	<0.001	M2<M1,M3,M4,M5,M6
MBT (m)	n= 17 4.72 ± 0.66	n= 14 5.28 ± 0.66	n= 18 5.29 ± 0.77	n= 12 5.49 ± 0.73	n= 14 5.23 ± 0.71	n= 21 5.06 ± 0.64	2.180	0.063	n.s.
10 m sprint (s)	n= 22 1.92 ± 0.08	n=14 1.85 ± 0.86	n= 19 1.96 ± 0.07	n= 12 1.88 ± 0.09	n= 14 1.87 ± 0.08	n= 21 1.87 ± 0.07	4.815	0.001	M3>M2,M5,M6
30 m sprint (s)	n= 22 4.76 ± 0.23	n= 14 4.61 ± 0.21	n= 19 4.77 ± 0.20	n= 12 4.62 ± 0.22	n= 14 4.68 ± 0.22	n= 21 4.66 ± 0.20	1.741	0.133	n.s.
Yo-Yo IR2 (m)	n= 20 262 ± 82.56	n= 14 310 ± 90.38	n= 18 266 ± 93.05	n= 12 290 ± 85.91	n= 13 263 ± 93.03	n=20 274 ± 87.32	0.671	0.647	n.s.

M = mean, SD = standard deviation, n = number of participants, CMJ = countermovement jump, MBT = medicine ball throw, Yo-Yo IR2 = Yo-Yo intermittent recovery test, n.s. = not significant, M1 = measurement 1, M2 = measurement 2, M3 = measurement 3, M4 = measurement 4, M5 = measurement 5, M6 = measurement 6.

Table 6 shows the means and standard deviations of each throwing velocity variable, and the results of the one-way ANOVA in six measurements over two years. No difference was found in any of the variables between measurements in throwing velocity, neither in maximal throwing velocity from 7 meters distance, from 9 meters distance after three steps or throwing velocity from 9 meters after three steps and jump.

Table 6. Throwing velocity in six measurements over a two-year period

Variable	M1 January 2017 n= 21 M ± SD	M2* June 2017 n= 0 M ± SD	M3 September 2017 n= 19 M ± SD	M4 May 2018 n= 12 M ± SD	M5 September 2018 n= 14 M ± SD	M6 January 2019 n= 22 M ± SD	F	p	Difference
Throwing 7 m (km/h)	69.47 ± 5.7		71.47 ± 7.7	69.75 ± 7.7	69.78 ± 6.8	68.54 ± 5.3	0.585	0.675	n.s.
Throwing 9 m with 3 steps (km/h)	72.19 ± 6.5		76.26 ± 7.8	74.33 ± 7.3	73.28 ± 7.2	73.45 ± 6.5	0.901	0.467	n.s.
Throwing 9 m with jump (km/h)	71.28 ± 5.1		74.21 ± 9.1	73.08 ± 5.2	69.92 ± 8.1	72.36 ± 6.6	0.890	0.474	n.s.

M = mean, SD = standard deviation, n = number of participants, Throwing 7 m = maximal throwing velocity from 7 meters distance, Throwing 9 m with 3 steps = maximal throwing velocity from 9 meters distance after three steps, Throwing 9 m with jump = maximal throwing velocity from 9 meters after three steps and jump, n.s. = not significant, M1 = measurement 1, M2 = measurement 2, M3 = measurement 3, M4 = measurement 4, M5 = measurement 5, M6 = measurement 6.

*No results were obtained from measurements 2 because of some technical problems with the Speed Radar Gun which was used to measure the throwing velocity.

4.2 Differences between players

Tables 7, 8 and 9 present the means and standard deviations of each variable, the results of F-values and P-values of general lineal model (repeated measures) and differences between players in three selected measurements (M1, M3, and M6) using Bonferroni post hoc test.

Table 7 shows the means and standard deviations of each anthropometric variable, and results of the repeated measures in three measurements over two years. Significant differences were found in height [$F(1,2) = 53.861$, $p<0.05$], weight [$F(1,2) = 20.767$, $p<0.05$] and BMI [$F(1,2) = 8.762$, $p<0.05$]. Differences were found between players in M1 and M3, and also between M1 and M6 in all variables.

Table 8 shows the means and standard deviations of each physical fitness variable, and results of the repeated measures in three measurements over two years. There were no differences between players in handgrip strength, countermovement jump, or in the Yo-Yo Intermittent recovery test. However, there were differences in medicine ball throw [$F(1,2) = 23.726$, $p<0.05$], 10 m sprint time [$F(1,2) = 6.649$, $p=0.020$] and 30 m sprint time [$F(1,2) = 11.534$, $p=0.003$]. The difference between players in MBT was between M1 and M3, and between M1 and M6. In the 10 m sprint time, the difference between players was between M1 and M3, and between M3 and M6. In 30 m sprint time, the difference between players was in M1 and M6 and in M3 and M6.

Table 7. Anthropometric characteristics between players in three measurements over a two-year period

Variable	M1 January 2017 n= 20	M3 September 2017 n= 20	M6 January 2019 n= 20	F	p	Difference
	M ± SD	M ± SD	M ± SD			
Height (m)	1.70 ± 0.05	1.72 ± 0.05	1.72 ± 0.05	53.861	0.000	M1<M3,M6
Weight (kg)	63.16 ± 7.6	66.93 ± 7.7	67.25 ± 7.5	20.767	0.000	M1<M3,M6
BMI (kg/m^2)	21.76 ± 2.25	22.57 ± 2.25	22.62 ± 2.14	8.762	0.008	M1<M3,M6

M = mean, SD = standard deviation, n = number of participants, n.s. = not significant, M1 = measurement 1, M3 = measurement 3, M6 = measurement 6.

Table 8. Physical fitness performance between players in three measurements over a two-year period

Variable		M1 January 2017	M3 September 2017	M6 January 2019	F	p	Difference
		M ± SD	M ± SD	M ± SD			
Handgrip (N)	n= 8	235.12 ± 38.13	243.29 ± 19.44	245.36 ± 12.39	0.401	0.547	n.s.
CMJ (cm)	n= 19	35.99 ± 1.86	36.09 ± 1.97	36.97 ± 4.40	1.389	0.254	n.s.
MBT (m)	n= 13	4.67 ± 0.74	5.30 ± 0.76	5.22 ± 0.70	23.726	0.000	M1<M3,M6
10 m sprint (s)	n= 18	1.91 ± 0.07	1.96 ± 0.07	1.87 ± 0.08	6.649	0.020	M3>M1,M6
30 m sprint (s)	n= 18	4.72 ± 0.23	4.77 ± 0.21	4.66 ± 0.21	11.534	0.003	M6<M1,M3
Yo-Yo IR2 (m)	n= 15	277.33 ± 71.66	277.33 ± 96.17	269.33 ± 76.29	0.231	0.638	n.s.

M = mean, SD = standard deviation, n = number of participants, CMJ = countermovement jump, MBT = medicine ball throw, Yo-Yo IR2 = Yo-Yo intermittent recovery test, n.s. = not significant, M1 = measurement 1, M3 = measurement 3, M6 = measurement 6.

Table 9 shows the means and standard deviations of each throwing velocity variable, and results of the repeated measures in three measurements over two years. There were no differences between players in any of the throwing velocity variables, neither in throwing 7 m, throwing 9 m with 3 steps or in throwing 9 m with a jump.

Table 9. Throwing velocity between players in three measurements over a two-year period

Variable	M1 January 2017 n= 18	M3 September 2017 n= 18	M6 January 2019 n= 18	F	p	Difference
	M ± SD	M ± SD	M ± SD			
Throwing 7 m (km/h)	70.16 ± 5.80	72.39 ± 6.81	69.11 ± 5.28	1.000	0.331	n.s.
Throwing 9 m with 3 steps (km/h)	73.61 ± 5.09	77.22 ± 6.81	74.27 ± 6.48	0.322	0.578	n.s.
Throwing 9 m with jump (km/h)	71.61 ± 5.50	75.77 ± 6.26	73.33 ± 5.84	3.293	0.087	n.s.

M = mean, SD = standard deviation, n = number of participants, Throwing 7 m = maximal throwing velocity from 7 meters distance, Throwing 9 m with 3 steps = maximal throwing velocity from 9 meters distance after three steps, Throwing 9 m with jump = maximal throwing velocity from 9 meters after three steps and jump, n.s. = not significant, M1 = measurement 1, M3 = measurement 3, M6 = measurement 6.

5. Discussion

The objective of this study were: i) to analyze the differences over two-years in anthropometric characteristics, physical fitness and throwing velocity between measurements, ii) to analyze the difference over two-years in anthropometric characteristics, physical fitness and throwing velocity between players in three selected measurements. The main finding of this longitudinal study revealed no differences between measurements in anthropometric characteristics (height, weight, BMI), nor in the following physical fitness performance; MBT, 30 m sprint, Yo-Yo IR2 and in throwing velocity. However, there was a difference in handgrip strength, CMJ, and 10 m sprint between measurements. When performance in three selected measurements were considered to examine the difference between players, other results were found. Differences were observed between players in all the anthropometric characteristics variables, MBT, 10 m sprint and 30 m sprint in three selected measurements over two years. However, no differences were between players in handgrip strength, CMJ, Yo-Yo IR2 or in any of the throwing velocity variables in three selected measurements during two years.

5.1 Difference between measurements

5.1.1 Anthropometric characteristics

During the six measurements over two years, the present study showed no significant difference between measurements in anthropometric characteristics. The height remained stable, the weight increased a little and so did the BMI (table 4). Comparing the present study to other studies on female handball players (Pastuszak et al., 2018; Saavedra et al., 2018) the average height is similar. However, the height in the present study is slight lower than was reported in a study on female Spanish handball players (25.74 ± 4.84 years) (Vila et al., 2012). As expected, when players are younger, they have lower body height (Hoppe et al., 2017). Similar results were found in a study which was done for one year, where female player's weight changed just slightly between years as they got older (Lidor et al., 2005). Another study where elite and sub-elite female handball players (age 22.8 ± 6.49) were examined, the BMI did not change much over the season (Milanese et al., 2012). That is similar to the present study, despite the BMI increased, it did not increase enough to show a significant difference over a two-year period. Comparing the BMI in the present study to others national teams' players, the results are similar to Croatian-, Polish, and Greek female players (Bayios et al., 2006; Čižmek et al., 2010; Jadach & Ciepliňski, 2008). This characteristic as others will change as the players grow older which can be connected to natural pubertal development, muscle growth and the beginning of strength training (Hammami et al., 2018). Assuming that female players in the present study have gone beyond that step. But of course, there is a difference between each individual in growth, maturation, and trainability (Matthys et al., 2013). Players also have different body structures and receive different training.

5.1.2 Physical fitness

The female handball players were tested in six physical fitness tests on six occasions during two years and during that time, players are expected to improve their physical performance.

In *handgrip strength*, a difference was found between M1 and M5 (table 5), where the handgrip strength increased significantly in M5. Based on the one and a half year in between the measurements, it can be concluded that players have become stronger during the measurement period. The handgrip strength plays a major part in handball movements like throwing and catching, so, increased handgrip strength can have a positive effect on player's performance (Visnapuu & Jürimäe, 2007).

In *CMJ* there was a difference between M2 and all the other measurement (M1, M3, M4, M5, M6) (table 5). The jumped height was considerably lower in M2 compared to the other measurements. That might be due to poor attendance, as the measurements were in June, the end of the handball season. It is a question of how motivated the players were at this point to perform the test. However, except for M2, the Icelandic female players have similar results from the CMJ test and as another longitudinal study shows (Matthys et al., 2013).

In terms of *MBT*, it is not possible to compare the results with another comparable study where the procedure was the same. In a study (Lidor et al., 2005), the MBT was done completely different from the present study (Norweigian handball federation, 2017) and the results gave a much longer throw distance than in the present study. Therefore, MBT test results depends a lot on the procedure, it needs to be specialized enough to measure the right aspects (Rivilla-García et al., 2011). There was no significant difference between measurements in the MBT over the two years (table 5). Interestingly, the fact that with more strength, MBT can be improved (Hermassi et al., 2015), seems not to appear in the present study, since there was an improvement in handgrip strength. It can, therefore, be said that the handgrip strength is not reflected in the MBT test.

In the *10 m sprint*, there was a difference between M3 and M2, M5, and M6. It is interesting that the 10 m sprint was the slowest in M3, considering that the players have been working hard during the preparation season since July. In the *30 m sprint*, there was no significant difference. According to game analysis, high speed sprinting accounts only for 11% of the total distance covered in handball match (Chelly et al., 2014). If the sprints are not performed that often at training or in match, it is difficult to expect an improvement, which may be relevant to this study.

Although increased aerobic endurance can benefit handball players like helping them to achieve faster recovery between sprints (Hermassi et al., 2015; Wagner et al., 2014), it is difficult to demonstrate increasing aerobic capacity then the focus may not be the same regarding to different aerobic training. Despite no significant difference between measurements in the *Yo-Yo IR2* over two years (table 5), the results showed that the players were running longest in M2 which was performed in June. The second-longest run was in M4 in May the next year. That should not be a surprise, given that players have been training and competing for 9 months and should be in good physical condition by the end of the season. As for the Yo-Yo IR2, it is considerable whether level 2 was too fast for this group of participants to get reliable results, giving that level 2 is intended for those who run longer than 2880 m in level 1. It is then worth mentioning that there were not many other studies who used Yo-Yo IR2 test and reported the distance covered. However, compared to a study examine male handball players (Schmitz et al., 2018), the female players in the present study are running much shorter distance in the Yo-Yo IR2.

5.1.3 Throwing velocity

No difference was found in throwing velocity between measurements (table 6). Giving these results, it is important to know how to use the body properly to gain more throwing velocity, for example, trunk flexion, rotation, and shoulder rotation (Wagner et al., 2010). It has been established that with greater internal shoulder rotation, it might cause greater throwing velocity (Wagner et al., 2010). If players in the present study have not work on their joint mobility or strength, it could influence the performance and as the results showed, given no improvements. It is said that older and more experienced handball players throw faster than younger or non-experienced players because of the training age which led to developed throwing techniques (Mohamed et al., 2009). This does not fit the results of the present study in terms of age between measurements over two years. Besides, no distinction was made on training age in the present study. Player's positions can also affect the results, as each position tends to be better at certain throwing techniques, for example, goalkeepers are not shooting nor performing jump throw. In the present study, the highest throwing velocity was in the shots that are performed by throwing after 3 steps. Same results were found in older study (Vila et al., 2012). Although, the most common throwing technique is the jump throws after a run-up (Wagner et al., 2014). The jump throw is considered to have the second highest throwing velocity (Vila et al., 2012), the same applies to the results of the present study. Despite these findings, it is a little disappointing that no difference was found between measurements over two years since sport-specific skill tests like throwing velocity are considered to be probably the most useful for the long-term development of athletes (Matthys et al., 2012). Except that two years is not enough to make an impact. In addition, in other studies where differences have been found, different training methods were used to improve throwing velocity (Andersen et al., 2018; Cherif et al., 2016; Hermassi et al., 2018; Marques & González-Badillo, 2006). Then the question is whether the female players of the present study are not getting enough specialized strength training with the right volume and intensity, since it is claimed that with certain strength training, throwing velocity can be improved (Hermassi et al., 2018).

5.2 Difference between players

5.2.1 Anthropometric characteristics

Over the two-year period, when considering the three measurements (M1, M3 and M6), the present study showed difference between players in anthropometric characteristics (table 7). In terms of the body height, similar results as in the present study were found on Flemish youth handball players where the average height increased during three competitive handball seasons (Matthys et al., 2013). It can be a factor that playing position was not taken into account in the present study, for example, if bigger part of the participants were pivots and backs, which are the playing positions that are considered to have the highest average height (Fieseler et al., 2017; Peña et al., 2018), then the average height would have been even higher in the present study. During handball training and competing, the players were gaining weight in the present study. Despite the weight gain, players were increasing their ability in power aspects such as MBT, 10 m sprint and 30 m sprint time. This could be attributed to increased muscle mass (Hammami et al., 2018). When comparing the present study to other study on female handball players, it fits the fact that player’s weight is heavier when they are older (Asker et al., 2018). A study (Vila et al., 2012) reported similar weight results as found in the present study. However, the female players in the present study were on average heavier than the female Norwegian national handball players (Ingebrigtsen et al., 2013). In the present study, player’s BMI categorizes them to normal weight which is between 18.5-24.9 kg/m^2 (table 1), which is also the most common classification in other studies (Ingebrigtsen et al., 2013; Pastuszak et al., 2018; Saavedra et al., 2018; Vila et al., 2012). Even though the same players are being investigated over two-year period it should be considered that it is well known that within the same age group, individual chronological age can differ in biological age (Matthys et al., 2012; Saavedra & Saavedra, 2019).

5.2.2 Physical fitness

No significant difference was found between players in handgrip strength. It is odd that no difference was found in CMJ between players over two years. Although the jump height was increasing over time, it did not increase significantly between players. Players, however, improved their performance over two years in power aspects, by throwing the MBT further and sprinting faster in both 30 m and 10 m sprint tests (table 8). In MBT there was a difference between players, assuming that the MBT distance was the shortest in M1 (table 8). The reason for that could be because those measurement were performed in January when players were in transition season. Also, it's difficult to estimate player's condition right after Christmas break when some teams are training extra while some don't. That could both have a bad and a good impact on the results. Yet, M6 was also performed in January and there it does not appear to affect the results as much, compared to there were improvements in M6 from M1. The same applies to differences between players as when comparing the difference between measurements. Despite increased MBT performance the strength does not seem to have had any effect, as shown in other studies (Hermassi et al., 2015; Ikeda et al., 2007; Szymanski et al., 2007). It should be pointed out that MBT is a poorly validated test (Rivilla-García et al., 2011) despite being popular and widely used in other sports (Leite et al., 2016).

In the sprint test there was a difference between players in both 10 m, and 30 m sprint. The difference in *10 m sprint* was between players in M3 and two other measurements, M1 and M6, as the 10 m sprint time was slowest in M3 (table 8). In the *30 m sprint* the difference was between players in M6 and the other two measurements, M1 and M3, as the 30 m sprint time was the fastest in M6. Finally, according to the time in the sprints (10 m and 30 m), the slowest sprint was in M3 and fastest in M6. Indicating that players can hold on to the acceleration through the sprint. Acceleration is one of the sprint abilities that are important for handball players (Krüger et al., 2014). Compared to the female handball players in the northern region of Norway (Ingebrigtsen et al., 2013), the female players in the present study were faster in both the 10 m and 30 m sprint. Another study showed similar results (Matthys et al., 2013), the female players in the present study were faster than the younger group (U14, U15, U16) in 10 m sprint, but similar to the older group (U16, U17, U18). The 30 m sprint results in the present study were much closer to the younger group rather than the older group, who ran the 30 m sprint much faster than the female players in the present study (Matthys et al., 2013). Is should also be expected that players will be faster with increasing age and more training, as stated in a study by Matthys et al. (2013). The results are consistent with that, as the players are getting faster during two years of training and competing.

In terms of the *Yo-Yo IR2* performance, the results of the present study are not consistent with other study who indicate that the performance in the Yo-Yo test for youth athletes increases with rising age. Same was reported in another study where older players were achieving higher speed scores in the Yo-Yo IR2 test than younger players (Saavedra et al., 2018).That does not apply to this present study as there was no significant difference between players over a two-year period since the players were stable in the Yo-Yo test for two years (table 8). That could be caused by high difficulty of level 2 test and therefore difficult to obtain improving performance.

Regardless, physical advantages cannot necessarily be retained on to adulthood if players develop early (Matthys et al., 2011). It can not be expected that the players who score high in the first measurement will achieve as good results in the last measurement, since the measurements takes place over a two-year period and during that time there are all kinds of changes that can affect a player's performance like physical growth and injury.

5.2.3 Throwing velocity

In the present study, no improvements were observed in throwing velocity between players (table 9). That could be due because players are maybe not doing any extra specific exercises to increase the throwing velocity, except throwing and shooting frequently during each training. Based on previous research (Chaouachi et al., 2009; Ortega-Becerra et al., 2018), specialized exercises have helped players improve their performance. It is interesting that another test (MBT) that estimates also extensors of shoulders, elbow, and trunk which is among other things the main elements of throwing (Lidor et al., 2005) showed improvements (table 8) but these attributes did not develop in the throwing velocity test.

The throwing velocity was the highest in M3 of those three measurements (table 9). That applies to all types of shots; throwing 7 m, throwing 9 m with 3 steps, and throwing 9 m with a jump. However, there was no difference between players in any of the throwing techniques. As throwing velocity is connected to strength (Wagner et al., 2014), it is understandable that throwing velocity did not increased since the handgrip strength did also not increase between players (table 9). Although, it needs to be kept in mind that to optimize handball specific strength and power training there are different demands for each playing position (Wagner et al., 2014) The throwing techniques are often based on player's playing position and are dictated by the movements which they are accustomed to performing according to the position on the court (Wagner et al., 2010). In this study, the playing position of the players was not taking into account or if players had sustained an injury that could have slowed their physical progress and affect the results.

6. Limitations

The present study has several limitations. First, the sample (U15, U17, U19 national teams) included a limited number of participants after it was decided to look only at the development of the players who had attended at least four of the six measurements. This resulted in a total of 22 participants being included in this study. In most cases, they were not present in all six measurements during the two years. This limitation is an important one to keep in mind when considering the results. With such a small sample size therefore, the results reflect only this group and not the whole population.

Secondly, the players' playing positions were not considered in the present study. So, there is no playing position balance, causing unknown variety of different body types as each specific position requires unique physical attributes, physiological and anthropometric characteristics to maximize the performance (Ghobadi et al., 2013). Not only are players different in those attributes, but they are also receiving different training regarding their playing position (Matthys et al., 2011; Milanese et al., 2012). When considering the throwing velocity, the throwing techniques are also based on the player's position. Also, goalkeepers were included in this study even though they may have influenced the variables studied. In this case, it was not possible to have goalkeepers excluded or divide players by playing positions as there were so few participants sampled.

Thirdly, it should be considered that the measurements were taken at a different time of the year. Some were taken during in-season while others during pre-season or post-season which may affect players motivation. In addition, during the two year period there were different assistants in the measurements which may affect the quality of measurements, and therefore the results. As for each season period there are different emphases in training which can cause different performance. Of course, the aim of the present study was to examine the development of players during two years. However, it should be kept in mind that the same performance cannot be expected in such a different season period. Player's development depends on how players train with their club. Coaches have different emphases on how they train their teams. For example, it can differ between teams how they conduct strength training, what kind of exercises are done and how specialized they are.

7. Conclusions

In summary, the aim of the present study was to explore two aspects, whether there was a difference between measurements- and between players in anthropometric characteristics, physical fitness, and throwing velocity that takes place during a two-year period of handball training and competing.

I. **Anthropometric measurements**

   The study has shown that there was no difference in anthropometric characteristics (height, weight, BMI) between measurements. Indicates that it is more difficult to find a difference when individuals are not taken into account, but only the whole group considering between measurements over a certain period of time.

II. **Physical fitness measurements**

   Differences were between measurement in handgrip strength, CMJ, and 10 m sprint performance. Indicates that the isometric strength of flexors of wrist and fingers have increased with strength training. Difference was in CMJ between one measurement (M2) and all the others, where the result was much lower in M2. This raises ideas about whether that particular measurement was properly implemented.

III. **Throwing velocity measurements**

   The throwing velocity measurements showed no difference between measurements. One reason for this result can be concluded that the female players of the present study are not getting enough specialized training with the right volume and intensity to have an impact on throwing velocity.

IV. **Anthropometric players**

   The study has shown that there were differences between players in all anthropometric characteristic's variables (height, weight, BMI). Findings confirm that higher BMI does not necessarily have to be a negative factor on player's physical fitness as the present study showed that players were nevertheless improving their performance in upper-limb power and speed. Player's weight and BMI were on average highest in M6, but at the same time, players ran the 10- and 30 m sprint fastest and threw longest in the MBT test.

V. Physical fitness players

Difference were between players in MBT, 10 m sprint, and 30 m sprint, based on three selected measurements, which seems to indicate that as the sample decreased, the differences in tests increased. In addition, the number of participants in the handgrip strength were only 8 players, making it more difficult to detect a difference between players. Interesting, no differences were found in CMJ between players, as players were still showing a difference in other lower-limbs aspects such as sprinting. In terms of the Yo-Yo IR2 test, higher weight did not have a positive effect as the shortest distance was run in M6 where players were on average heaviest.

VI. Throwing velocity players

No difference was found between players in throwing velocity. Possibly there is a need for more specific training since players are not improving their performance in aspect that at least out court players train the most in handball, which is throwing. This does not apply to goalkeepers who are on the other hand included in the results which may be affecting.

8. Future research

Future research could aim to increase the value of collected data by including ongoing research with a higher number of participants. To increase the number of participants then it is necessary to improve the process of the measurement by ensuring that information about the measurement and the results after they are made is available to participants and coaches. It would be relevant to follow the player's process as they grow older, especially those who stay in the national team for the long term. One of the most important is to encourage participants to attend the measurements so there will be more data on each phase of the players' journey in the national team, from the youngest teams and up. It would also be interesting to do a study like this for a longer period. In such a study, it might be possible to do an intervention, such as a national team training, where players receive training that aims to improve the elements tested in the measurements such as explosive power, speed, and throwing velocity. That way it could be shown whether certain training could improve player's physical fitness more.

References

Andersen, V., Fimland, M. S., Cumming, K. T., Vraalsen, Ø., & Saeterbakken, A. H. (2018). Explosive resistance training using elastic bands in young female team handball players. *Sports Medicine International Open*, *2*(6), 171–178. https://doi.org/10.1055/a-0755-7398

Arifi, F., Bjelica, D., & Masanovic, B. (2019). Differences in anthropometric characteristics among junior soccer and handball players. *Sport Mont*, *17*(1), 45–49. https://doi.org/10.26773/smj.190208

Asker, M., Holm, L. W., Källberg, H., Waldén, M., & Skillgate, E. (2018). Female adolescent elite handball players are more susceptible to shoulder problems than their malecounterparts. *Knee Surgery, Sports Traumatology, Arthroscopy*, *26*(1), 1892–1900.

Aura, O., & Komi, P. V. (1986). Mechanical efficiency of pure positive and pure negative work with special reference to the work intensity. *International Journal of Sports Medicine*, *7*(1), 44–49. https://doi.org/10.1055/s-2008-1025734

Baker, D. (2001). Acute and long-term power responses to power training: Observations on the training of an elite power athlete. *Strength and Conditioning Journal*, *23*(1), 47–56.

Balsalobre-Fernández, C., Tejero-González, C. M., del Campo-Vecino, J., & Bavaresco, N. (2014). The concurrent validity and reliability of a low-cost, high-speed camera-based method for measuring the flight time of vertical jumps. *The Journal of Strength & Conditioning Research*, *28*(2), 528–533. https://doi.org/10.1519/JSC.0b013e318299a52e

Balyi, I., & Way, R. (2009). *The role of monitoring growth in long-term athlete development* (pp. 1–30).

Bangsbo, J., Iaia, F. M., & Krustrup, P. (2008). The Yo-Yo intermittent recovery test: A useful tool for evaluation of physical performance in intermittent sport. *Sports Medicine*, *38*(1), 37–51. https://doi.org/10.2165/00007256-200838010-00004

Bartlett, R., & Robins, M. (2008). Biomechanics of throwing. In Y. Hong & R. Bartlett (Eds.), *Routledge Handbook of Biomechanics and Human Movement Science* (1st ed., pp. 285–286). Routledge.

Bayios, I. A., Anastasopulou, E. M., Sioudris, D. S., & Boudols, K. D. (2001). Relationship between isokinetic strength of the internal and external shoulder rotators and ball velocity in team handball. *Journal of Sports Medicine and Physical Fitness*, *41*(2), 229–235.

Bayios, I. A., Bergeles, N. K., Apostolidis, N. G., Noutsos, K. S., & Koskolou, M. D. (2006). Anthropometric, body composition and somatotyoe differences of Greek elite female basketball, volleyball and handball players. *Journal of Sports Medicine and Physical Fitness*, *46*(2), 271–280.

Belka, J., Hulka, K., Safar, M., Weisser, R., & Samcova, A. (2014). Analyses of time-motion and heart rate in elite female players (U19) during competitive handball matches. *Kinesiology*, *46*(1), 33–43.

Bellizzi, M. C., & Dietz, W. H. (1999). Workshop on childhood obesity: Summary of the discussion. *The American Journal of Clinical Nutrition*, *70*(1), 173S-175S. https://doi.org/10.1093/ajcn/70.1.173s

Bencke, J., Damsgaard, R., Saekmose, A., Jørgensen, P., Jørgensen, K., & Klausen, K. (2002). Anaerobic power and muscle strength characteristics of 11 years old elite and non-elite boys and girls from gymnastics, team handball, tennis and swimming. *Scandinavian Journal of Medicine & Science in Sports*, *12*(3), 171–178. https://doi.org/10.1034/j.1600-0838.2002.01128.x

Bobbert, M. F., Mackay, M., Schinkelshoek, D., Huijing, P. A., & van Ingen Schenau, G. J. (1986). Biomechanical analysis of drop and countermovement jumps. *European Journal of Applied Physiology and Occupational Physiology*, *54*(6), 566–573. https://doi.org/10.1007/BF00943342

Bompa, T., & Haff, G. G. (2009). *Periodization: Theory and methodology of training* (5th ed.). Human Kinetics.

Bosco, C., Luhtanen, P., & Komi, P. V. (1983). A simple method for measurement of mechanical power in jumping. *European Journal of Applied Physiology and Occupational Physiology*, *50*(2), 273–282. https://doi.org/10.1007/BF00422166

Brewer, C. (2008). *Strength and conditioning for sport: A practical guide for sports coaches*. Armley: Coachwise Ltd.

Can, I. (2017). Comparison of power, velocity and force parameters during loaded squat jump exercise in the handball and arm wrestling players. *Journal of Education and Training Studies*, *5*(12), 92–98. https://doi.org/10.11114/jets.v5i12.2057

Chaouachi, A., Brughelli, M., Levin, G., Boudhina, N. B. B., Cronin, J., & Chamari, K. (2009). Anthropometric, physiological and performance characteristics of elite team-handball players. *Journal of Sports Sciences*, *27*(2), 151–157. https://doi.org/10.1080/02640410802448731

Chelly, M. S., Hermassi, S., Aouadi, R., & Shephard, R. J. (2014). Effects of 8-week in-season plyometric training on upper and lower limb performance of elite adolescent handball players. *The Journal of Strength & Conditioning Research*, *28*(5), 1401–1410. https://doi.org/10.1519/JSC.0000000000000279

Cherif, M., Chtourou, H., Souissi, N., Aouidet, A., & Chamari, K. (2016). Maximal power training induced different improvement in throwing velocity and muscle strength according to playing positions in elite male handball players. *Biology of Sport*, *33*(4), 393–398. https://doi.org/10.5604/20831862.1224096

Čižmek, A., Ohnjec, K., Vučetić, V., & Gruić, I. (2010). Morphological differences of elite croatian female handball players according to their game position. *Hrvat. Športskomed. Vjesn.*, *25*(1), 122–127.

Cloe, T. J., Freeman, J. V., & Preece, M. A. (1995). Body mass index reference curves for the UK, 1990. *Archives of Disease in Childhood*, *73*(1), 25–29.

Debanne, T., & Laffaye, G. (2011). Predicting the throwing velocity of the ball in handball with anthropometric variables and isotonic tests. *Journal of Sports Sciences*, *29*(7), 705–713. https://doi.org/10.1080/02640414.2011.552112

Edouard, P., Degache, F., Oullion, R., Plessis, J.-Y., Gleizes-Cervera, S., & Calmels, P. (2013). Shoulder strength imbalances as injury risk in handball. *International Journal of Sports Medicine*, *34*(7), 654–660. https://doi.org/10.1055/s-0032-1312587

Fathloun, M., Hermassi, S., Chelly, M. S., & Bensbaa, A. (2011). *Relationship between medicine ball explosive power tests, throwing ball velocity and jump performance in team handball players*. *4*(1), 164–170.

Ferragut, C., Vila, H., Abraldes, J. A., & Manchado, C. (2018). Influence of physical aspects and throwing velocity in opposition situations in top-elite and elite female handball players. *Journal of Human Kinetics*, *63*(1), 23–32. https://doi.org/10.2478/hukin-2018-0003

Fieseler, G., Hermassi, S., Hoffmeyer, B., Schulze, S., Irlenbusch, L., Bartels, T., Delank, K. S., Laudner, K. G., & Schwesig, R. (2017). Differences in anthropometric characteristics in relation to throwing velocity and competitive level in professional male team handball: A tool for talent profiling. *The Journal of Sports Medicine and Physical Fitness*, *57*(7–8), 985–992. https://doi.org/10.23736/S0022-4707.17.06938-9

Fryar, C. D., Gu, Q., Ogden, C. L., & Flegal, K. M. (2016). Anthropometric reference data for children and adults; United States, 2011-2014. *Vital and Health Statistics*, *39*(3), 1–38.

García, J. A., Sabido, R., Barbado, D., & Moreno, F. J. (2013). Analysis of the relation between throwing speed and throwing accuracy in team-handball according to instruction. *European Journal of Sport Science*, *13*(2), 149–154. https://doi.org/10.1080/17461391.2011.606835

Ghobadi, H., Rajabi, H., Farzad, B., Bayati, M., & Jeffreys, I. (2013). Anthropometry of World-class elite handball players according to the playing position: Reports from men's handball world championship 2013. *Journal of Human Kinetics*, *39*(1), 213–220.

Gorostiaga, E. M., Granados, C., Ibáñez, J., & Izquierdo, M. (2005). Differences in physical fitness and throwing velocity among elite and amateur male handball players. *International Journal of Sports Medicine*, *26*(3), 225–232. https://doi.org/10.1055/s-2004-820974

Granados, C., Izquierdo, M., Ibáñez, J., Bonnabau, H., & Gorostiaga, E. M. (2007). Differences in physical fitness and throwing velocity among elite and amateur female handball players. *International Journal of Sports Medicine*, *28*(10), 860–867. https://doi.org/10.1055/s-2007-964989

Granados, C., Izquierdo, M., Ibáñez, J., Ruesta, M., & Gorostilaga, E. M. (2013). Are there any differences in physical fitness and throwing velocity between national and international elite female handball players? *The Journal of Strength and Conditioning Research*, *27*(3), 723–732.

Gusic, M., Popovic, S., Molnar, S., Masanovic, B., & Radakovic, M. (2017). Sport-specific morphology-profile: Differences in anthropometric characteristics among elite soccer and handball players. *Sport Mont Journal*, *1* (1), 3–6.

Häger-Ross, C., & Rösblad, B. (2002). Norms for grip strength in children aged 4–16 years. *Acta Paediatrica*, *91*(6), 617–625. https://doi.org/10.1111/j.1651-2227.2002.tb03290.x

Hammami, R., Sekulic, D., Selmi, M. A., Fadhloun, M., Spasic, M., Uljevic, O., & Chaouachi, A. (2018). Maturity status as a determinant of the relationships between conditioning qualities and preplanned agility in young handball athletes. *The Journal of Strength & Conditioning Research*, *32*(8), 2302-2313. https://doi.org/10.1519/JSC.0000000000002390

Harris, C., Wattles, A. P., DeBeliso, M., Sevene-Adams, P. G., Berning, J. M., & Adams, K. J. (2011). The seated medicine ball throw as a test of upper body power in older adults. *The Journal of Strength & Conditioning Research*, *25*(8), 2344–2348. https://doi.org/10.1519/JSC.0b013e3181ecd27b

Hasan, A. A., Reilly, T., Cable, N. T., & Ramadan, J. (2007). Anthropometric profiles of elite Asian female handball players. *Journal of Sports Medicine and Physical Fitness*, *47*(2), 197–202.

Hermassi, S., Chelly, M. S., Fathloun, M., & Shephard, R. J. (2010). The effect of heavy- vs. Moderate-load training on the development of strength, power, and throwing ball velocity in male handball players. *The Journal of Strength & Conditioning Research*, *24*(9), 2408–2418. https://doi.org/10.1519/JSC.0b013e3181e58d7c

Hermassi, S., Chelly, M. S., Wollny, R., Hoffmeyer, B., Fieseler, G., Schulze, S., Irlenbusch, L., Delank, K. S., Shephard, R. J., Bartels, T., & Schwesig, R. (2018). Relationships between the handball-specific complex test, non-specific field tests and the match performance score in elite professional handball players. *The Journal of Sports Medicine and Physical Fitness*, *58*(6), 778–784. https://doi.org/10.23736/s0022-4707.17.07373-x

Hermassi, S., Gabbett, T. J., Spencer, M., Khalifa, R., Chelly, M. S., & Chamari, K. (2014). Relationship between explosive performance measurements of the lower limb and repeated shuttle-sprint ability in elite adolescent handball players. *International Journal of Sports Science and Coaching*, *9*(5), 1191–1204.

Hermassi, S., van den Tillaar, R., Khlifa, R., Chelly, M. S., & Chamari, K. (2015). Comparison of in-season-specific resistance vs. A regular throwing training program on throwing velocity, anthropometry, and power performance in elite handball players. *The Journal of Strength & Conditioning Research*, *29*(8), 2105–2114. https://doi.org/10.1519/JSC.0000000000000855

Hoppe, M. W., Brochhagen, J., Baumgart, C., Bauer, J., & Freiwald, J. (2017). Differences in anthropometric characteristics and physical capacities between junior and adult top-level handball players. *Asian Journal of Sports Medicine*, *8*(4), 1–10. https://doi.org/10.5812/asjsm.60663

Ikeda, Y., Kijima, K., Kawabata, K., Fuchimoto, T., & Ito, A. (2007). Relationship between side medicine-ball throw performance and physical ability for male and female athletes. *European Journal of Applied Physiology*, *99*(1), 47–55. https://doi.org/10.1007/s00421-006-0316-4

Ingebrigtsen, J., Jeffreys, I., & Rodahl, S. (2013). Physical characteristics and abilities of junior elite male and female handball players. *The Journal of Strength & Conditioning Research*, *27*(2), 302–309. https://doi.org/10.1519/JSC.0b013e318254899f

Innes, E. (1999). Handgrip strength testing: A review of the literature. *Australian Occupational Therapy Journal*, *46*(3), 120–140. https://doi.org/10.1046/j.1440-1630.1999.00182.x

International Handball Federation. (2016). *Rules of the game* (pp. 1–98). International Handball Federation. https://www.ihf.info/sites/default/files/2019-07/New-Rules%20of%20the%20Game_GB.pdf

Jadach, A., & Ciepliňski, J. (2008). Level of physical preparation and its influence on selection of game concepts for the polish national handball female team. *Polish Journal of Sport & Tourism*, *15*(1), 17–28.

Jensen, J., Jacobsen, S. T., & Tveit, P. (1997). Effect of combined endurance, strength and sprint training on maximal oxygen uptake, isometric strength and sprint performance in female elite handball players during a season. *International Journal of Sports Medicine*, *18*(5), 354–358. https://doi.org/10.1055/s-2007-972645

Jensen, K., Johansen, L., & Secher, N. H. (2001). Influence of body mass on maximal oxygen uptake: Effect of sample size. *European Journal of Applied Physiology*, *84*(3), 201–205. https://doi.org/10.1007/s004210170005

Karcher, C., & Buchheit, M. (2017). Shooting performance and fly time in highly trained wing handball players: Not everything is as it seems. *International Journal of Sports Physiology and Performance*, *12*(3), 322–328. https://doi.org/10.1123/ijspp.2016-0055

Karpan, G., Škof, B., Bon, M., & Šibila, M. (2015). Analysis of female handball players' effort in different playing positions during official matches. *Kinesiology*, *47*(1), 100–107.

Keys, A., & Brožek, J. (1953). Body fat in adult man. *Physiological Reviews*, *33*(3), 245–325. https://doi.org/10.1152/physrev.1953.33.3.245

Kilic-Toprak, E., Yapici, A., Kilic-Erkek, O., Koklu, Y., Tekin, V., Alemdaroglu, U., & Bor-Kucukatay, M. (2015). Acute effects of Yo-Yo intermittent recovery test level 1 (Yo-YoIR1) on hemorheological parameters in female volleyball players. *Clinical Hemorheology and Microcirculation*, *60*(2), 191–199. https://doi.org/10.3233/CH-141844

Kirkendall, D. T. (2007). Issues in training the female player. *British Journal of Sports Medicine*, *41*(1), 64–67. https://doi.org/10.1136/bjsm.2007.036970

Krüger, K., Pilat, C., Ückert, K., Frech, T., & Mooren, F. C. (2014). Physical performance profile of handball players is related to playing position and playing class. *Journal of Strength and Conditioning Research*, *28*(1), 117–125. https://doi.org/10.1519/JSC.0b013e318291b713

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J. M., Steensberg, A., Pedersen, P. K., & Bangsbo, J. (2003). The Yo-Yo intermittent recovery test: Physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise*, *35*(4), 697–705. https://doi.org/10.1249/01.mss.0000058441.94520.32

Krustrup, P., Mohr, M., Nybo, L., Jensen, J. M., Nielsen, J. J., & Bangsbo, J. (2006). The Yo-Yo IR2 test: Physiological response, reliability, and application to elite soccer. *Medicine and Science in Sports and Exercise*, *38*(9), 1666–1673. https://doi.org/10.1249/01.mss.0000227538.20799.08

Kvorning, T., Hansen, M. R. B., & Jensen, K. (2017). Strength and conditioning training by the Danish national handball team before an Olympic tournament. *The Journal of Strength & Conditioning Research*, *31*(7), 1759–1765. https://doi.org/10.1519/JSC.0000000000001927

Lage, G. M., Gallo, L. G., Cassiano, J. M., Lobo, I. B., Vieira, M. V., Salgado, J. V., Fuentes, D., & Malloy-Diniz, L. F. (2011). Correlations between impulsivity and technical performance in handball female athletes. *Scientific Research*, *2*(7), 721–726.

Larry, K., W., Jack, W., & David, C. (2015). *Physiology of sport and exercise* (6th ed.). Champaign, IL: Human Kinetics.

Leite, M. A. F., Sasaki, J. E., Lourenço, C. L. M., Zanetti, H. R., Cruz, L. G., Mota, G. R., & Mendes, E. L. (2016). Medicine ball throw test predicts arm power in rugby sevens players. *Brazilian Journal of Kinanthropometry and Human Performance*, *18*(2), 166–176. https://doi.org/10.5007/1980-0037.2016v18n2p166

Leyk, D., Gorges, W., Ridder, D., Wunderlich, M., Rüther, T., Sievert, A., & Essfeld, D. (2007). Hand-grip strength of young men, women and highly trained female athletes. *European Journal of Applied Physiology*, *99*(4), 415–421. https://doi.org/10.1007/s00421-006-0351-1

Lidor, R., Falk, B., Arnon, M., Cohen, Y., Segal, G., & Lander, Y. (2005). Measurement of talent in team handball: The questionable use of motor and physical tests. *Journal of Strength and Conditioning Research*, *19*(2), 318–325. http://dx.doi.org/10.1519/00124278-200505000-00014

Lidor, R., & Ziv, G. (2018). Physical characteristics of the handball player. In L. Laver, P. Landreau, R. Seil, & N. Popovic (Eds.), *Handball Sports Medicine* (pp. 3–14). Springer. https://doi.org/10.1007/978-3-662-55892-8_1

Lúðvíksson, S. J. (2012). *Handknattleiksbókin: Saga handknattleiksins á Íslandi 1920-2010*. Reykjavík: Bókaútgáfan Hólar.

Manchado, C., Pers, J., Navarro, F., Han, A., Sung, E., & Platen, P. (2013). Time-motion analysis in women's team handball: Importance of aerobic performance. *Journal of Human Sport and Exercise*, *8*(2), 376–390. https://doi.org/10.4100/jhse.2012.82.06

Manchado, C., Tortosa-Martínez, J., Vila, H., Ferragut, C., & Platen, P. (2013). Performance factors in women's team handball: Physical and physiological aspects - A review. *The Journal of Strength & Conditioning Research*, *27*(6), 1–34. https://doi.org/10.1519/JSC.0b013e3182891535

Marques, M. A. C., & González-Badillo, J. J. (2006). In-season resistance training and detraining in professional team handball players. *Journal of Strength and Conditioning Research*, *20*(3), 563–571. http://dx.doi.org/10.1519/00124278-200608000-00017

Martin Acero, R. M., Sánchez, J. A., & Fernández-del-Olmo, M. (2012). Tests of vertical jump: Countermovement jump with arm swing and reaction jump with arm swing. *Strength & Conditioning Journal*, *34*(6), 87–93. https://doi.org/10.1519/SSC.0b013e318276c353

Massuça, L. M., Fragoso, I., & Teles, J. (2014). Attributes of top elite team-handball players. *The Journal of Strength & Conditioning Research*, *28*(1), 178–186. https://doi.org/10.1519/JSC.0b013e318295d50e

Massy-Westropp, N., Gill, T. K., Taylor, A. W., Bohannon, R. W., & Hill, C. L. (2011). Hand grip strength: Age and gender stratified normative data in a population-based study. *BMC Research Notes*, *4*(1), 127-132. https://doi.org/10.1186/1756-0500-4-127

Matthys, S. P. J., Fransen, J., Vaeyens, R., Lenoir, M., & Philippaerts, R. (2013). Differences in biological maturation, anthropometry and physical performance between playing positions in youth team handball. *Journal of Sports Sciences*, *31*(12), 1344–1352. https://doi.org/10.1080/02640414.2013.781663

Matthys, S. P. J., Vaeyens, R., Coelho-e-Silva, M. J., Lenoir, M., & Philippaerts, R. (2012). The contribution of growth and maturation in the functional capacity and skill performance of male adolescent handball players. *International Journal of Sports Medicine*, *33*(7), 543–549. http://dx.doi.org/ 10.1055/s-0031-1298000

Matthys, S. P. J., Vaeyens, R., Fransen, J., Deprez, D., Pion, J., Vandendrissche, J., Vandorpe, B., Lenoir, M., & Philippaerts, R. (2013). A longitudinal study of multidimensional performance characteristics related to physical capacities is youth handball. *Journal of Sport Sciences*, *31*(3), 325–334.

Matthys, S. P. J., Vaeyens, R., Vandendrissche, J., Pion, J., Coutts, A. J., Lenoir, M., & Philipparets, R. M. (2011). A multidisciplinary identification model for youth handball. *European Journal of Sport Science*, *11*(5), 355–363.

Matthys, S. P. J., Vaeyens, R., Vandendrissche, J., Vandorpe, B., Pion, J., Coutts, A. J., Lenoir, M., & Philipparets, R. M. (2011). A multidisciplinary identification model for youth handball. *European Journal of Sport Science*, *11*(5), 355–363.

Michalsik, L., Aagaard, P., & Madsen, K. (2013). Locomotion characteristics and match-induced impairments in physical performance in male elite team handball players. *International Journal of Sports Medicine*, *34*(7), 590–599. https://doi.org/10.1055/s-0032-1329989

Michalsik, L. B. (2018). On-court physical demands and physiological aspects in elite team handball. In L. Laver, P. Landreau, R. Seil, & N. Popovic (Eds.), *Handball Sports Medicine* (pp. 15–33). Springer. https://doi.org/10.1007/978-3-662-55892-8_2

Michalsik, L. B., & Aagaard, P. (2015). Physical demands in elite team handball: Comparisons between male and female players. *The Journal of Sports Medicine and Physical Fitness*, *55*(9), 878–891.

Michalsik, L. B., Madsen, K., & Aagaard, P. (2014). Match Performance and physiological capacity of female elite team handball players. *International Journal of Sports Medicine*, *35*(7), 595–607. https://doi.org/10.1055/s-0033-1358713

Michalsik, L. B., Madsen, K., & Aagaard, P. (2015a). Physiological capacity and physical testing in male elite team handball. *The Journal of Sports Medicine and Physical Fitness*, *55*(5), 415–429.

Michalsik, L. B., Madsen, K., & Aagaard, P. (2015b). Technical match characteristics and influence of body anthropometry on playing performance in male elite team handball. *The Journal of Strength & Conditioning Research*, *29*(2), 416–428. https://doi.org/10.1519/JSC.0000000000000595

Milanese, C., Piscitelli, F., Lampis, C., & Zancanaro, C. (2012). Effect of a competitive season on anthropometry and three compartment body composition in female handball players. *Biology of Sport*, *29*(1), 199–204. https://doi.org/10.5604/20831862.1003443

Mohamed, H., Vaeyens, R., Matthys, S., Multael, M., Lefevre, J., Lenoir, M., & Philippaerts, R. (2009). Anthropometric and performance measures for the development of a talent detection and identification model in youth handball. *Journal of Sports Sciences*, *27*(3), 257–266. https://doi.org/10.1080/02640410802482417

Moss, S. (2014). *The physical, physiological and performance characteristics of English youth team handball players* [Thesis, University of Chester]. http://hdl.handle.net/10034/550901

Moss, S. L., McWhannell, N., Michalsik, L. B., & Twist, C. (2015). Anthropometric and physical performance characteristics of top-elite, elite and non-elite youth female team handball players. *Journal of Sports Sciences*, *33*(17), 1780–1789. https://doi.org/10.1080/02640414.2015.1012099

Muratovic, A., Vujovic, D., & Hadzic, R. (2014). Comparative study of anthropometric measurement and body composition between elite handball and basketball players. *Montenegrin Journal of Sports Science and Medicine*, *3*(2), 19–22.

Newton, R. U., & Dugan, E. (2002). Application of strength diagnosis. *Strength and Conditioning Journal*, *24*(5), 50–59.

Neyzi, O., Bundak, R., Gökçay, G., Günöz, H., Furman, A., Darendeliler, F., & Baş, F. (2015). Reference values for weight, height, head circumference, and body mass index in turkish children. *Journal of Clinical Research in Pediatric Endocrinology*, *7*(4), 280–293. https://doi.org/10.4274/jcrpe.2183

Nikolaidis, P. T., Chtourou, H., Torres-Luque, G., Rosemann, T., & Knechtle, B. (2019). The relationship of age and BMI with physical fitness in futsal players. *Sports*, *87*(7), 1–10. https://doi.org/10.3390/sports7040087

Norweigian handball federation. (2017). *Norges Håndballforbund*. www.handball.no

Ortega-Becerra, M., Pareja-Blanco, F., Jiménez-Reyes, P., Cuadrado-Peñafiel, V., & González-Badillo, J. J. (2018). Determinant factors of physical performance and specific throwing in handball players of different ages. *Journal of Strength and Conditioning Research*, *32*(6), 1778–1786. https://doi.org/10.1519/JSC.0000000000002050

Pastuszak, A., Górski, M., Gajewski, J., & Buśko, K. (2018). Anthropometric profile of female handball players is related to bone mineral density. *Anthropological Review*, *81*(3), 298–306. https://doi.org/10.2478/anre-2018-0024

Peña, J., Moreno-Doutres, D., Coma, J., Cook, M., & Buscà, B. (2018). Anthropometric and fitness profile of high-level basketball, handball and volleyball players. *Revista Andaluza de Medicina Del Deporte*, *11*(1), 30–35. https://doi.org/10.1016/j.ramd.2016.03.002

Picerno, P., Camomilla, V., & Capranica, L. (2011). Countermovement jump performance assessment using a wearable 3D inertial measurement unit. *Journal of Sports Sciences*, *29*(2), 139–146. https://doi.org/10.1080/02640414.2010.523089

Póvoas, S. C., Seabra, A. F., Ascensão, A. A., Magalhães, J., Soares, J. M., & Rebelo, A. N. (2012). Physical and physiological demands of elite team handball. *Journal of Strength and Conditioning Research*, *26*(12), 3365–3375. https://doi.org/10.1519/JSC.0b013e318248aeee

Reilly, T. (2001). Assessment of sports performance with particular reference to field games. *European Journal of Sport Science*, *1*(3), 1–12. https://doi.org/10.1080/17461390100071306

Rivilla-García, J., Martínez, I., Grande, I., & Sampedro-Molinuevo, J. (2011). Relation between general throwing tests with a medicine ball and specific tests to evaluate throwing velocity with and without opposition in handball. *Journal of Human Sport and Exercise*, *6*(2), 414–426. https://doi.org/10.4100/jhse.2011.62.22

Rogulj, N., Vuleta, D., Cavala, M., & Foretic, N. (2011). The efficiency of elements of collective attack tactics in handball. *Kinesiologia Slovenica*, *17*(1), 5–14.

Saavedra, J. M., Halldórsson, K., Kristjánsdóttir, H., Þorgeirsson, S., & Sveinsson, G. (2019). Anthropometric characteristics, physical fitness and the prediction of throwing velocity in young men handball players. *Kinesiology : International Journal of Fundamental and Applied Kinesiology*, *51*(2), 253–260. https://doi.org/10.26582/k.51.2.14

Saavedra, J. M., Halldórsson, K., Þorgeirsson, S., Einarsson, I. Þ., & Guðmundsdóttir, M. L. (2020). *Prediction of handball players' performance on the basis of kinanthropometric variables, conditioning abilities, and handball skills*. *73*(1), 131–141. https://doi.org/10.2478/hukin-2019-0147

Saavedra, J. M., Kristjánsdóttir, H., Einarsson, I. Þ., Guðmundsdóttir, M. L., Þorgeirsson, S., & Stefansson, A. (2018). Anthropometric characteristics, physical fitness, and throwing velocity in elite women's handball teams. *The Journal of Strength & Conditioning Research*, *32*(8), 2294–2301. https://doi.org/10.1519/JSC.0000000000002412

Saavedra, J. M., Þorgeirsson, S., Kristjansdottir, H., Halldorsson, K., Guðmundsdottir, M. L., & Einarsson, I. Þ. (2018). Comparison of training volumes in different elite sportspersons according to sex, age, and sport practised. *Montenegrin Journal of Sports Science and Medicine*, *7*(2), 37–42. https://doi.org/10.26773/mjssm.180906

Saavedra, Y., & Saavedra, J. M. (2019). The association between relative age effect, goals scored, shooting effectiveness and the player's position, and her team's final classificationin international level women's youth handball. *Montenegrin Journal of Sports Science and Medicine*, *9*(1), 1–7. https://doi.org/10.26773/mjssm. 200303

Sabido, R., Hernámdez-Davó, J. L., Botella, J., & Moya, M. (2016). Effect of 4-week training intervention with unknown loads on power output performance and throwing velocity in junior team handball players. *PLOS ONE*, *11*(6), 1–12. https://doi.org/10.1371/journal.pone.0157648

Schmitz, B., Pfeifer, C., Kreitz, K., Borowski, M., Faldum, A., & Brand, S. M. (2018). The Yo-Yo intermittent tests: A systematic review and structured compendium of test results. *Frontiers in Physiology*, *9*(870), 1–16. https://doi.org/10.3389/fphys.2018.00870

Schwesig, R., Hermassi, S., Fieseler, G., Irlenbusch, L., Noack, F., Delank, K. S., Shephard, R. J., & Chelly, M. S. (2017). Anthropometric and physical performance characteristics of professional handball players: Influence of playing position. *The Journal of Sports Medicine and Physical Fitness*, *57*(11), 1471–1478.

Schwesig, R., Koke, A., Fischer, D., Fieseler, G., Jungermann, P., Delank, K. S., & Hermassi, S. (2016). Validity and reliability of the new handball-specific complex test. *The Journal of Strength & Conditioning Research*, *30*(2), 476–486. https://doi.org/10.1519/JSC.0000000000001061

Sharrock, C., Cropper, J., Mostad, J., Johnson, M., & Malone, T. (2011). A pilot study of core stability and athletic performance: Is there a relationship? *International Journal of Sports Physical Therapy*, *6*(2), 63–74.

Šibila, M., Vuleta, D., & Pori, P. (2004). Position-related differences in volume and intensity of large-scale cyclic movements of male players in handball. *Kinesiology*, *36*(1), 58–68.

Sporis, G., Vuleta, D., Vuleta, D. Jr., & Milanovic, D. (2010). Fitness profiling in handball: Physical and physiological characteristics of elite players. *Collegium Antropologicum*, *34*(3), 1009–1014.

Srhoj, V., Rogulj, N., Zagorac, N., & Katic, R. (2006). A new model of selection in women's handball. *Collegium Antropologicum*, *30*(3), 601–605.

Stockbrugger, B. A., & Haennel, R. G. (2001). Validity and reliability of medicine ball explosive power test. *Journal of Strength and Conditioning Research*, *15*(4), 431–438.

Stockbrugger, B. A., & Haennel, R. G. (2003). Contributing factors ro performance of a medicine ball explosive power test: A comparison between jump and nonjump athletes. *Journal of Strength and Conditioning Research*, *17*(4), 768–774.

Szymanski, D. J., Szymanski, J. M., Bradford, T. J., Schade, R. L., & Pascoe, D. D. (2007). Effect of twelve weeks of medicine ball training on high school baseball players. *Journal of Strength and Conditioning Research*, *21*(3), 894–901.

The National Olympic and Sports Association of Iceland. (2019, April 15). *Iðkendur 2018 eftir íþróttagreinum* [Isi.is]. Tölfræðirit. http://isi.is/um-isi/utgafa/tolfraedi/

Toyoshima, S., Hoshikawa, T., Miyashita, M., & Oguri, T. (1974). Contribution of the body parts to throwing performance. In *Biomechanics IV* (pp. 169–174). University Park Press. https://doi.org/10.1007/978-1-349-02612-8_24

Van den Tillaar, R., & Ettema, G. (2004). Effect of body size and gender in overarm throwing performance. *European Journal of Applied Physiology*, *91*(1), 413–418.

Van den Tillaar, R., & Ettema, G. (2006). A comparison between novices and experts of the velocity-accuracy trade-off in overarm throwing. *Perceptual and Motor Skills*, *103*(2), 503–514. https://doi.org/10.2466/pms.103.2.503-514

Vila, H., Manchado, C., Rodriguez, N., Abraldes, J. A., Alcaraz, P. E., & Ferragut, C. (2012). Anthropometric profile, vertical jump, and throwing velocity in elite female handball players by playing positions. *The Journal of Strength & Conditioning Research*, *26*(8), 2146–2155. https://doi.org/10.1519/JSC.0b013e31823b0a46

Visnapuu, M., & Jürimäe, T. (2007). Handgrip strength and hand dimensions in young handball and basketball players. *Journal of Strength and Conditioning Research*, *21*(3), 923–929.

Visnapuu, M., & Jürimäe, T. (2009). Relations of anthropometric parameters with scores on basic and specific motor tasks in young handball players. *Perceptual and Motor Skills*, *108*(3), 670–676. https://doi.org/10.2466/pms.108.3.670-676

Wagner, H., Buchecker, M., von Duvillard, S. P., & Müller, E. (2010). Kinematic description of elite vs. Low level players in team-handball jump throw. *Journal of Sports Science & Medicine*, *9*(1), 15–23.

Wagner, H., Finkenzeller, T., Würth, S., & von Duvillard, S. P. (2014). Individual and team performance in team-handball: A review. *Journal of Sports Science & Medicine*, *13*(1), 808–816.

Wagner, H., Fuchs, P., & Duvillard, S. P. (2017). Specific physiological and biomechanical performance in elite, sub-elite and in non-elite male team handball players. *The Journal of Sports Medicine and Physical Fitness*, *58*(1–2), 73–81. https://doi.org/10.23736/S0022-4707.16.06758-X

Wagner, H., & Müller, E. (2008). The effects of differential and variable training on the quality parameters of a handball throw. *Sports Biomechanics*, *7*(1), 54–71. https://doi.org/10.1080/14763140701689822

Wagner, H., Pfusterschmied, J., von Duvillard, S. P., & Müller, E. (2011). Performance and kinematics of various throwing techniques in team-handball. *Journal of Sports Science & Medicine*, *10*(1), 73–80.

Wallace, M. B., & Cardinale, M. (1997). Conditioning for team handball. *Strength and Conditioning Journal*, *19*(6), 7–12.

Zapartidis, I., Gouvali, M., Bayios, I., & Boudolos, K. (2007). Throwing effectiveness and rotational strength of the shoulder in team handball. *Journal of Sports Medicine and Physical Fitness*, *47*(2), 169–178.

Zapartidis, I., Palamas, A., Papa, M., Tsakalou, L., & Kotsampouikidou, Z. (2016). Relationship among anthropometric characteristics, handgrip strength and throwing velocity in adolecent handball players. *Journal of Physical Education and Sports Management*, *3*(2), 127–139. https://doi.org/10.15640/jpesm.v3n1a9

Zapartidis, I., Toganidis, T., Vareltzis, I., Chrisodoulidis, T., Kororos, P., & Skoufas, D. (2009). Profile of young female handball players by playing position. *Serbian Journal of Sports Sciences*, *3*(1–4), 53–60.

Zapartidis, I., Vareltzis, I., Gouvali, M., & Kororos, P. (2009). Physical fitness and anthropometric characteristics in different levels of young team handball players. *The Open Sports Sciences Journal*, *2*(1), 22–28.

Ziv, G., & Lidor, R. (2009). Physical characteristics, physiological attributes, and on-court performances of handball players: A review. *European Journal of Sport Science*, *9*(6), 375–386.