Anthropometric and physical characteristics of elite, sub-elite and recreational Icelandic badminton players

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Thesis of 45 ECTS credits
Master of Science in Exercise Science and Coaching
December 2017
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Thesis of 45 ECTS credits submitted to the school of Science and Engineering at Reykjavík University in partial fulfillment of the requirements for the degree of

Master of Science in Exercise Science and Coaching

December 2017

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1. Abstract

Badminton is a fast, interceptive, racquet sport and characterized by high-intensity intermittent actions. This work aimed to (i) analyze the anthropometric and physical fitness in Icelandic badminton players of different levels, (ii) develop a multidimensional test battery explaining from a multivariate perspective badminton performance (iii) and to examine the relationship of anthropometric and physical fitness variables and performance in badminton players. Thirty-five Icelandic badminton players (18.83 ± 2.04 years old; males, n=19; females, n=16) participated in this study. The badminton players were grouped in three groups in accordance with their playing level: elite (n=10), sub-elite (n=11) and recreational players (n=14). A multidimensional test battery was conducted where different parameters were measured and tested: height, weight, BMI, arm span, CMJ, medicine ball throw, grip strength, 505 test, reactive agility, shoulder flexibility and estimated VO$_{2\text{max}}$. One-way ANOVA were carried out with LSD Post-hoc tests to know the differences between groups. A discriminant analysis was recorded to know which variables could predict badminton performance and, finally, Spearman’s rho correlations were performed to identify the relationship between variables. The results show that elite players have superior results ($p<0.05$) in four physical tests; CMJ, 505 test, grip strength test and estimated VO$_{2\text{max}}$. No difference was detected between groups in shoulder flexibility, reactive agility or medicine ball throw. The predictive model classified 61.1% of male players correctly and 66.7% of female players correctly using only the VO$_{2\text{max}}$ results. A moderate ($r_c=-0.47$) to very strong ($r_c=-0.83$) correlation existed between four out of thirteen variables and badminton performance in males; medicine ball throw, CMJ, 505 test and estimated VO$_{2\text{max}}$. For females, a moderate ($r_c=-0.51$) to very strong ($r_c=-0.86$) correlation existed between six out of thirteen variables and badminton performance; height, medicine ball throw, CMJ, grip strength, 505 test, and estimated VO$_{2\text{max}}$. This study can give coaches helpful information regarding the anthropometric and physical characteristics of Icelandic badminton players which can assist them in training process of their athletes.
Víkingsport og líkamlegt hreysti íslenskra badmintonspilara: Samanburður á afreks-, keppnis- og áhugamönnum

1.1. Útdráttur

Badminton er hröð íþrótt sem einkennist af miklum átökum með stuttri hvíld. Markmið þessarar rannsóknar var að (i) greina líkamsgerð og líkamlegt hreysti íslenskra badmintonspilara á mismunandi getustigum, (ii) þróa fjölpætt mælitæki sem geti greint frammistöðu í badminton á mörgum sviðum (iii) og skoða tengslin á milli líkamsgerðar og líkamlegs hreystis á frammistöðu badmintonspilara. Þráttu og fimm íslenskir badmintonspilarar (18.83 ± 2.04 ára; karlar, n=19; konur, n=16) tóku þátt í þessari rannsókn. Badmintonspilurunum var getuskipt í þrjá hópa: afreks- (n=10), keppnis- (n=11) og áhugamannaspilarar (n=14). Fjölpætt mælitekið innihélt eftirfarandi breytur: hæð, þyngd, líkamssamsetningu, faðmlengd, lóðréttan stökkkraft (CMJ), kast með 2kg bolta, gripstyrk, 505 prófi, viðbragðssnerpu og áætluð VO$_{2\text{max}}$. Einhliða dreifigreining var framkvæmd með LSD (e. least significant difference) eftir á prófunum til að kanna hvort það væri munur á milli hópa. Aðgerðargreining var gerð til að kanna hvaða breytur geti spáð fyrir um frammistöðu í badminton og að lokum var stikalaus fylgnigreining framkvæmd til að kanna tengslin á milli breytanna. Niðurstöðurnar sýna að afreksspilarararnir eru að skora hærra (p<0.05) í fjórum líkamlegum mælingum; CMJ, 505 prófi, gripstyrk og áætluðum VO$_{2\text{max}}$. Enginn munur fannst á milli hópanna í axlarliðleika, viðbragðssnerpu eða kasti með 2kg bolta. Spálíkandi raðaði 61.1% karla og 66.7% kvenna rétt í hópa með því að styðjast aðeins við niðurstöður úr VO$_{2\text{max}}$ prófinu. Hjá körlunum voru meðal (r$_c$=-0.47) til mjög sterk (r$_c$=-0.83) tengsl milli fjögurra af þrettan breytmum og frammistöðu í badminton; kasti með 2kg bolta, CMJ, 505 próf og áætluðum VO$_{2\text{max}}$. Hjá konunum voru meðal (r$_c$=-0.51) til mjög sterk (r$_c$=-0.86) tengsl á milli sex af þrettan breytmum og frammistöðu í badminton; heð, kasti með 2kg bolta, CMJ, gripstyrk, 505 próf og áætluðum VO$_{2\text{max}}$. Þessi rannsókn getur gefið þjálfurum gagnlegar upplýsingar er varða líkamsgerð og líkamshreysti íslenskra badmintonspilara sem getur nýst við þjálfun og skipulagningu.
## List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>BH</td>
<td>Badmintonfélag Hafnafjarðar</td>
</tr>
<tr>
<td>BWF</td>
<td>Badminton World Federation</td>
</tr>
<tr>
<td>BMI</td>
<td>Body Mass Index</td>
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<tr>
<td>BRIT</td>
<td>Badminton Reaction Inhibition Test</td>
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<td>BSAT</td>
<td>Badminton Specific Agility Test</td>
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<tr>
<td>CMJ</td>
<td>Counter Movement Jump</td>
</tr>
<tr>
<td>COD</td>
<td>Change of Direction</td>
</tr>
<tr>
<td>Est.</td>
<td>Estimated</td>
</tr>
<tr>
<td>h</td>
<td>Hour</td>
</tr>
<tr>
<td>HR</td>
<td>Heart Rate</td>
</tr>
<tr>
<td>Kg</td>
<td>Kilogram</td>
</tr>
<tr>
<td>kg/m²</td>
<td>Kilogram per Square Meter</td>
</tr>
<tr>
<td>LSD</td>
<td>Least Significant Difference</td>
</tr>
<tr>
<td>M</td>
<td>Mean</td>
</tr>
<tr>
<td>mL/min/kg</td>
<td>Milliliters per Minute per Kilogram</td>
</tr>
<tr>
<td>N</td>
<td>Newton</td>
</tr>
<tr>
<td>n</td>
<td>Number</td>
</tr>
<tr>
<td>OG</td>
<td>Olympic Games</td>
</tr>
<tr>
<td>ROM</td>
<td>Range of Motion</td>
</tr>
<tr>
<td>SD</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>th.</td>
<td>Throw</td>
</tr>
<tr>
<td>VO₂max</td>
<td>Maximum Volume of Oxygen uptake</td>
</tr>
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</table>
2. Introduction

2.0. General introduction to badminton

Badminton is one of the fastest sports in the world with the fastest badminton smash recorded in competition (male) at 408 km/h (Guinness World Records, 2015). Originating in China and created in England it is one of the most popular sports in the world with over 200 million participants (Phomsoupha and Laffaye, 2015). Badminton is characterized as a fast, interceptive, racquet sport, with high-intensity intermittent actions (Manrique and González-Badillo, 2003; Phomsoupha and Laffaye, 2015; Water et al., 2017). In 2006 the Badminton World Federation (BWF) introduced a new scoring system; a badminton match consists of the best of three games of 21 points and for every serve - there is a point scored (BWF, 2015). Players try to place the shuttle into the opponents’ court and out of their reach by, e.g., using high-speed strikes which results in completion of about one shot every two seconds (Manrique and González-Badillo, 2003; Faude et al., 2007; Loureiro and Freitas, 2016). With two or four players on the court, badminton has three events; singles, doubles and mixed doubles, each of the disciplines requires specific physiological demands and tactical strategies (Kwan, Cheng, and Tang, 2010; Phomsoupha and Laffaye, 2015). Most players specialize in either singles or doubles/mixed doubles. International single matches vary in length from fifteen to ninety minutes dependent on how players match up, how equal they are in playing ability (Manrique and González-Badillo, 2003; Walkate et al., 2009). Badminton matches are usually played in tournaments with one to three matches over the course of four or five days (Phomsoupha and Laffaye, 2015). Elite players playing at top level compete at World Super Series Tournaments consisting of twelve tournaments per season with 32-80 entries in each discipline competing at each tournament (BWF, 2017b). The competition season is from the beginning of March until the middle of December with the World Super series Finals in December (BWF, 2017b).

2.1. Anthropometry of badminton players

In recent review article anthropometric measurements sometimes revealed a correlation between body structure, bone mass, physical characteristics and performance in sport (Phomsoupha and Laffaye, 2015). These results suggest the possibility of assessing performance on the basis of anthropometric and physical characteristics (Nordström, Högström and Nordström, 2008). Badminton players height and body weight have been recorded in several studies (Aydogmus, Arslanoglu, and Senel, 2014; Faude et al., 2007; Jeyaraman and Kalidasan, 2012; Ooi et al., 2009; Raschka and Schmidt, 2013). Aydogmus et al., (2014)
gathered data from the official website of London Olympics were the mean height and weight of 80 female players was; 169.12 ± 6.12cm, 61.25 ± 5.18kg and the mean height and weight of 90 male players was; 179.29 ± 6.47cm, 72.78 ± 7.16kg. Similar values was recorded in internationally ranked males and females (Faude et al., 2007) and in German females (Raschka and Schmidt, 2013). However the values were higher in the German males, 182.0 ± 4.6cm, 77.5 ± 5.9kg (Raschka and Schmidt, 2013) but lower in Indian males (Jeyaraman and Kalidasan, 2012). Ooi et al., (2009) recorded the mean height and weight of twenty-four male Malasian players. They were divided into two equally large groups; elite and sub – elite. The mean height and weight of the elite males was: 176 ± 7 cm, 73.2 ± 7.6kg and for the sub- elite; 171 ± 5cm, 62.7 ± 4.2kg.

It has been suggested that being taller is an advantage in badminton considering the increasing rate of situations where the taller players can perform an attack shot during a rally (Phomsoupha and Laffaye, 2015). Few studies have also examined the length and circumference of the arm and the legs of badminton players and suggests that having longer limbs will enhance player’s ability to cover the court and is considered to positively affect the playing ability of badminton players (Jeyaraman and Kalidasan, 2012; Raschka and Schmidt, 2013; Yasin et al., 2010). Raschka and Schmidt, (2013) recorded the mean armspan of twenty males as; 184.8 ± 5.8cm and of twenty females as; 168.0 ± 6.2cm. Most studies of anthropometry among badminton players are unable to identify between singles players from doubles players suggesting that general anthropometric characteristics are not crucial for understanding differences between these events (Phomsoupha and Laffaye, 2015).

2.2. Physical characteristics of badminton players

Studies have pointed out the importance of different traits or characteristics for various sports (Bandyopadhyay, 2007; Duncan, Woodfield, and Al-Nakeeb, 2006; Gabbett et al., 2009) and growing number of studies have aimed at determining the physical and physiological attributes of badminton players (Manrique and González-Badillo, 2003; Campos et al., 2009; Faude et al., 2007; Gucluover et al., 2012; Heller, 2010; Jaworski and Zak, 2015; Jeyaraman and Kalidasan, 2012; Ooi et a., 2009; Raman and Nageswaran, 2013; Singh, Raza and Mohammad, 2011). Due to the nature of the sport, players are required to perform movements which are unique compared to any other sport, such as jumps, lunges, quick directional changes, and rapid arm movements from a wide variety of postural positions (Kwan et al., 2010; Chin et
al., 1995; Hu et al., 2015; Raman and Nageswaran, 2013). The relatively small size of the badminton court (13 x 6 m) demand players to constantly change their speed and direction on court during a rally (Kusuma, Raharjo and Taathadi, 2015; Phomsoupha and Laffaye, 2015). Proper footwork is therefore important as it allows the player to reach the shuttle as quickly as possible with control and minimum effort (Lin et al., 2007). In contrast to the cyclic movements of the lower limbs during running, badminton footwork requires players to perform forward and backward braking, push-off, gliding, lunging and jumping at various speeds (Kusuma et al., 2015; Lin et al., 2007). Competitive badminton players need to be able to produce high levels of muscular power to respond to the opponents strike with explosive movements (Kusuma et al., 2015). They need to perform different kinds of shots per rally which gives an opportunity for numerous tactical choices where players’ attention should be focused on the shuttle and their opponents to anticipate the placement of the next shot (Laffaye et al., 2015; Phomsoupha and Laffaye, 2015). Flexibility and range of motion (ROM) is also an important component for badminton players as ROM is the ability to move the body and its parts without undue strain on the joints and muscle attachments (Singh, Singh and Singh, 2011) and allows players to produce the power needed for certain strokes (i.e. clear and smash) with minimum energy cost (Phomsoupha and Laffaye, 2015). A fast reaction time is thought to be a crucial component in fast-paced sports such as badminton (Loureiro and Freitas, 2012) and in reviews by Mann et al. (2007) and Voss et al. (2010) a fast reaction time was an important factor for elite performance, especially in interceptive sports like badminton. A reactive agility test is considered a better indicator of players’ performance than a change of direction speed tests (COD) where the movement sequence is already known beforehand (Gabbett et al., 2009). Therefore speed, strength, flexibility, explosive power, and agility are all necessary physical components to perform efficiently in badminton (Chin et al., 1995; Kusuma et al., 2015; Raman and Nageswaran, 2013).

Since badminton became an Olympic sport in 1992 researchers took an interest in looking at the temporal structure of the game. In a longitudinal study through the Olympic Game (OG) finals from 1992 until 2012, an increase of 34.0% in shot frequency during a match was noticed from the first OG final until the last one. Rest time between rallies increased as well due to the increase in the intensity during the game (Laffaye, Phomsoupha and Dor, 2015). Manrique and González-Badillo (2003) analyzed the characteristics of competitive badminton matches with motion analysis and recorded that during a typical badminton match (players of international experience) points range in duration between 1 and 40 seconds (s), with the average point lasting 6.8s and the rest time between rallies is 5 to 10s. Similar findings were
revealed by Faude et al., (2007). In a temporal and notational comparison study between women’s and men’s singles from 2003 the results showed that rally time, rest time and shots per rally were significantly higher in men’s singles that in women’s singles. Mean rally time for men was 9.0 ± 0.9s compared to women’s rally time of 7.8 ± 1.5s. Rest time was 24.1 ± 3.8s for men’s and 17.6 ± 2.4s for women’s. This research studied top level badminton players from the OG in 2008 and could explain the extended rest time between rallies (Abian-Vicen et al., 2013).

Temporal structure of badminton game has therefore changed a lot over the last couple of decades. Elite players rely on combination of the aerobic and anaerobic system (Jeyaraman and Kalidasan, 2012; Liddle, Murphy and Bleakley, 1996; Majumdar et al., 1997) with the anaerobic system working approximately 30% during a match due to the increase in high intensity rallies (Chin et al., 1995; Phomsoupha and Laffaye, 2015). Singles are considered more demanding than doubles, with approximately 80% of singles rallies lasting less than 10 seconds (Liddle et al., 1996).

Competitive badminton players need to have the high aerobic capacity as most matches last forty minutes to one hour, and the average heart rate (HR) during competitive matches is over 90% of the player’s maximal HR (Hu et al., 2015; Phomsoupha and Laffaye, 2015). VO$_{2\text{max}}$ values for racket sports players have never the less been found to be relatively low, compared to those demonstrated by athletes in endurance events (Wonisch et al., 2003). However a few studies have promoted the aerobic profile of badminton, with a high VO$_{2\text{max}}$ value; mean range from 56.9 – 63.2 mL/min/kg in international and elite men (Faude et al., 2007; Heller, 2010; Ooi et al., 2009) and 55.2 ± 2.6 mL/min/kg in elite women (Heller, 2010).

Several studies have addressed the validity of a limited range of specific tests to determine the physiological capacity and performance of elite badminton players (Chin et al., 1995; Hughes and Fullerton, 1995; Wonisch et al., 2003). Few studies have aimed at developing a test which evaluates badminton specific aerobic performance (Chin et al., 1995; Hughes and Fullerton, 1995; Wonisch et al., 2003). Wonisch et al., (2003) developed a badminton specific incremental test were seventeen subjects, national and international badminton players, all performed an incremental field test using the modified Conconi test (Conconi et al., 1982) in one half of a badminton court to assess the heart rate (HR) performance curve. Signals were given from a pacer and subjects had to move around the court towards three targets. The test was performed continuously until voluntary exhaustion. HR was measured continuously, and capillary blood samples were taken from the earlobe at the beginning and within one minute of the end of the exercise for determination of blood lactate concentration. In comparison, a lactate
steady state test was then performed after a rest period (24h) were the players performed one steady-state test of twenty minutes duration.

Other studies have tried to evaluate badminton specific movements and agility (Chin et al., 1995; Kusuma et al., 2015; Lin et al., 2007; Loureiro and Freitas, 2016; Madsen, Karlsen and Nybo 2015; Water et al., 2017). Chin et al., (1995) performed a field test on twelve top-level badminton players from Hong Kong. The field test was executed in one half of a badminton court. Six light bulbs were placed on posts, with one shuttle at the top end of each post. The lights were connected to a programming device, and when the light lit up the players should run towards that post and strike the shuttle. The test consisted of successive three-minute periods of exercise and it was not stated whether the sequence was fixed or in a randomized order. In the recent study by Madsen et al., (2015) a badminton speed test was performed on sixty male subjects (elite, skilled and non-badminton players) in a similar manner as the study by Chin et al. However the duration of the test was shorter (32.3 ± 1.1s), the light targets were four instead of six and lit up in a randomized order to imitate a real game.
3. Objectives

The aims of this study were to:

i. Analyze the anthropometric and physical fitness in Icelandic badminton players of different levels.

ii. Develop a multidimensional test battery explaining badminton performance from a multivariate perspective.

iii. Examine the relationship of anthropometric and physical fitness variables and performance in Icelandic badminton players.
4. Methods

4.1. Subjects

Forty Icelandic badminton players were recruited for this study and thirty-five agreed participation (figure 1). Subjects, the age of 18.83 ± 2.04 years (range 18-25 years), were recruited for this study with the help from the assistant national coach, the head coach of the badminton club in Hafnafjörður (BH) and the teacher in the upper secondary level comprehensive school. Subjects were divided into three groups in accordance with their playing level: elite, sub-elite and recreational players. The elite group consisted of players selected by the National Coach and were in the national team of Iceland at the time. In an international context, Icelandic players are far behind the best players in the world. In women’s single, the Icelandic best player was ranked in the 269th place and in men’s single the Icelandic best player was ranked in the 731st place according to Badminton World Federation, World Rankings (BWF, 2017a). The sub-elite group are players who were part of the national training group but were not part of the team. The recreational group trained approximately three times a week for recreational purposes and were not competing in tournaments. The ranking of the badminton players of elite and sub-elite participants was conducted by three coaches including the assistant national coach. Ranking of the recreational participants was done by an evaluation of their respective badminton coach. Subjects were ranked by their performance ability in singles matches.

Figure 1. Overview of subjects recruited.
4.2. Procedures

The study was conducted in compliance with the Declaration of Helsinki and approved preliminarily by the Ethics committee of Reykjavík University. Subjects gave their written informed consent (appendix 1) before participating in this study. Written consent was obtained from parents or guardian of subjects younger than eighteen years old. Background questions (training experience, training time and length of training) (appendix 2) were handed out and filled out by twenty-nine subjects. The physical tests were performed in one evening on the 21st of March 2017 (in competition phase) and then twelve days later for those who could not attend the first scheduled appointment. Test dates were selected after reviewing the schedule of the annual competitions of the Icelandic Badminton Association (Badmintsamband Íslands, n.d.) in cooperation with the coaches.

The measurements took place in an indoor sports hall and subjects were advised to eat properly and not to engage in strenuous activity 24 hours (h) before testing. To ensure safety during the measurements proper lighting and good grip on the floor was ensured. Subjects were told to wear their usual badminton shoes and clothes. Each test was explained in detail to the subjects. A multidimensional test battery was used, including general as well as badminton-specific test. The anthropometric assessments were conducted before a fifteen-minute guided warm-up including; running, arm swing, jumping, dynamic stretch exercises and acceleration sprints. Following the warm up, the physical performance tests were completed. The athletes were encouraged to perform with maximum effort throughout the tests.

4.3. Measurements

4.3.1. Basic Anthropometry

Standing height and weight was measured using a SECA scale, measured to within 0.1 cm and to a 100g. Participants were instructed to remove their shoes and to stand tall with heels together and arms relaxed (Hoffman, 2006; Ross and Marfell-Jones, 1982). Body Mass Index (BMI) was calculated in Excel using the following formula: \[ \text{BMI} = \frac{\text{weight (kg)}}{\text{height}^2 \text{ (m)}} \] to evaluate the relationship between height and weight (Keys and Brozek, 1953). Arm span was measured, using measuring tape, as the distance in cm between the tips of the middle finger of each hand when both arms were extended sideways at ninety-degree angle. The subjects had their back against the wall and the palms facing forward (Lohman, Roche, and Martorell, 1988; Ross and Marfell-Jones, 1982).
4.3.2. Physical Fitness

The physical measurements consisted of seven tests. Following the guided warm up subjects underwent physical tests which assessed upper and lower body power, strength, change of direction speed, reactive agility, flexibility in shoulder and endurance capacity. In each test subjects had to perform twice, except in the flexibility and the endurance test where they performed once, and the superior score was registered in all the measurements.

4.3.2.1. Muscular Power and Strength

a) Counter Movement Jump (CMJ) (figure 2).

- Objective: To evaluate the muscular power of extensors of the knee and hip.
- Brief description: The subjects stood upright with their weight evenly distributed over both feet. Hands placed on their hips and stayed there throughout the test to diminish upper body movement and to standardize the movement pattern (Ooi et al., 2009). The subjects’ squatted down until the knees were bent at ninety degrees then immediately jumped vertically as high as possible, landing back on the floor on both feet at the same time.
- Equipment: High-speed video camera, portable light, reference labels (sticking plaster and bar), Kinovea software [version 0.8.15].
- Score: height (cm) (Bosco, Mognoni and Luhtanen, 1983; Markovic et al., 2004).

Figure 2. CMJ.
b) Kneeling Medicine Ball Throw (figure 3).

- Objective: To measure upper body muscular power.
- Brief description: The subjects threw a 2kg medicine ball overhead vigorously as far straightforward as they could with both hands while resting one knee on the floor the whole time.
- Equipment: Medicine ball (2kg), measuring tape, radar gun (Sports Radar).
- Score: distance (m), speed (km/h) (Laffaye, 2011).

![Figure 3. Kneeling Medicine Ball Throw.](image)

c) Maximal Grip Strength (figure 4).

- Objective: To evaluate the maximal isometric strength of flexors of wrist and fingers.
- Brief description: The subjects’ sits on a chair, back against the backrest, elbow ninety degrees flexed. Subjects hold the dynamometer with his/her dominant hand (racquet hand). In this position, the subject is asked to exert maximal grip strength without arm or wrist movement.
- Equipment: Hand dynamometer [Vernier], laptop, Logger Lite software.
- Score: Newton (Mathiowetz, 1984).
4.3.3. Change of Direction Speed

*d) 505 Agility Test* (figure 5).

- Objective: To evaluate the subjects’ speed and 180 degrees turning ability.
- Brief description: The subjects start the test 10m from the timing gates. Subjects were instructed to accelerate as quickly as possible through the timing gates, pivot 180 degrees on the turning point and run back as quickly as possible.
- Equipment: Two time gates [Brower system], cones.
- Score: $s$ (Draper and Lancaster, 1985).
4.3.4. Reactive Agility

e) Badminton – Specific Agility Test (BSAT), (figure 6, 7).

- Objective: To evaluate the subjects’ reactive agility.
- Brief description: The subjects were positioned at central base in one half of a badminton court and assumed their badminton playing ready position facing the net. Four targets were positioned on the badminton court (Figure 5) and subjects were to deactivate the targets using a badminton racquet to resemble badminton match play. The main task was to deactivate the correct target as fast as possible as soon as it lit up. The targets have an inbuilt sensor which reacts to proximity or touch that deactivates the light. The system was programmed for random sequences of light activation and responded to the deactivation of the lights, while the timing was recorded by the tablet controller. Subjects had to deactivate twelve targets.
- Equipment: FitLight TrainerTM system, tablet controller, four fit lights, badminton racquet, badminton court.
- Score: s (Loureiro and Freitas, 2016; Water et al., 2017).

Figure 6. BSAT set up. Four FitLights were placed on the badminton court, two lights were placed on poles (placed 5cm behind the net at the same height as the net and 40cm from the single sideline) and two lights on the floor (105cm behind the service line and 10cm from the single sideline). Target diameter: 10cm.
4.3.5. Flexibility

f) Shoulder Flexibility (figure 8).

- Objective: To evaluate the subjects’ flexibility and range of motion in their dominant shoulder (racquet arm).
- Brief description: Subjects formed fists with both hands and placed their racquet hand down behind their back and reached their other hand over the head and tried to make the fists meet. The distance between the fists was then recorded.
- Equipment: measuring tape.
- Score: cm (Couppé et al., 2012; Hoffman, 2006).
4.3.6. Maximal Aerobic Power

g) The Yo-Yo Intermittent Recovery Test - Level 1 (figure 9).

- Objective: To evaluate maximal aerobic power.
- Brief description: Subjects performed continues running at progressively increasing speed, interspersed with 10 seconds active rest periods and continued until they were exhausted and failed twice to reach the finishing line in time.
- Equipment: Audio system, CD, measuring tape, cones.
- Score: distance (m), predicted VO$_{2\text{max}}$ (mL/min/kg) (Bangsbo, Iaia and Krstrup, 2008; Krstrup et al., 2003).

![Figure 9. The Yo-Yo Intermittent Recovery Test - Level 1.](image)

4.4 Statistical Analysis

Data are presented as means and standard deviations. One-way ANOVA was carried out with LSD Post-hoc tests to know the differences between groups. All test variables were checked for normality by using Kolmogorov–Smirnov test. Two variables failed to meet the assumption of normality in males (reactive agility total time and reaction time) and two in females (medicine ball throw and 505 test). For those variables a non-parametric test, Kruskal – Wallis test was carried out with Mann-Whitney test. A discriminant analysis was recorded to know which variables could predict badminton performance. Subjects were classified by the sample-splitting method in three, according to their performance level (i.e. elite, sub-elit and
recreational) using a stepwise selection procedure. The criterion used to determine whether or not a variable entered the model (i.e. discriminant function) was Wilks' lambda, which measures the deviations within each group with respect to the total deviations. The sample-splitting method included initially the variable that most minimized the value of Wilks' lambda, provided the value of F was greater than a certain critical value (i.e. F=3.84 to enter). The next step was pairwise combination of the variables with one of them being the variable included in the first step. Successive steps were performed in the same way, always with the condition that the F-value corresponding to the Wilks' lambda of the variable to select has to be greater than the aforementioned “entry” threshold. If this condition was not satisfied, the process was halted, and no further variables were selected in the process. Before including a new variable, an attempt was made to eliminate some of those already selected if the increase in the value of Wilks' lambda was minimal, and the corresponding F-value was below a critical value (i.e. F=2.71 to remove). Wilks’ lambda, canonical correlation index, and percentage of subjects correctly classified for the whole sample and for each group were computed as indicators of performance predictive capacity. Finally, a Spearman’s rho correlations were performed to identify the relationship between variables. Statistical significance was set at \( p<0.05 \) and all the analyses were computed using IBM SPSS 24 for Windows.
5. Results

5.1. Training experience, hours training badminton and length of each training

Table 1 presents the training experience, hours training badminton per week and length of each training session for males. A difference was found between groups in these variables.

<table>
<thead>
<tr>
<th></th>
<th>Elite (E) n=4</th>
<th>Sub-elite (S) n=8</th>
<th>Recreational (R) n=4</th>
<th>F</th>
<th>p</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training experience (years)</td>
<td>12.00 ± 2.71</td>
<td>9.06 ± 3.21</td>
<td>0.63 ± 0.95</td>
<td>19.39</td>
<td>0.001</td>
<td>E,S&gt;R</td>
</tr>
<tr>
<td>Training time (h/week)</td>
<td>11.00 ± 2.16</td>
<td>9.00 ± 2.79</td>
<td>2.38 ± 1.70</td>
<td>14.33</td>
<td>&lt;0.001</td>
<td>E,S&gt;R</td>
</tr>
<tr>
<td>Length training (h/session)</td>
<td>1.78 ± 0.26</td>
<td>1.65 ± 0.35</td>
<td>0.75 ± 0.50</td>
<td>9.77</td>
<td>0.003</td>
<td>E,S&gt;R</td>
</tr>
</tbody>
</table>

h, hours

Table 2 presents the training experience, hours training badminton per week and length of each training session for females. The elite group had more training experience than the recreational group, and both elite and sub-elite group train more hours per week than the recreational group.

<table>
<thead>
<tr>
<th></th>
<th>Elite (E) n=5</th>
<th>Sub-elite (S) n=3</th>
<th>Recreational (R) n=5</th>
<th>F</th>
<th>p</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training experience (years)</td>
<td>11.10 ± 4.67</td>
<td>7.00 ± 2.65</td>
<td>2.80 ± 3.03</td>
<td>6.24</td>
<td>0.017</td>
<td>E &gt; R</td>
</tr>
<tr>
<td>Training time (h/week)</td>
<td>9.70 ± 1.79</td>
<td>7.33 ± 2.31</td>
<td>3.10 ± 1.14</td>
<td>19.35</td>
<td>&lt;0.001</td>
<td>E,S&gt;R</td>
</tr>
<tr>
<td>Length training (h/session)</td>
<td>2.04 ± 0.29</td>
<td>1.83 ± 0.29</td>
<td>1.40 ± 0.96</td>
<td>1.26</td>
<td>0.326</td>
<td></td>
</tr>
</tbody>
</table>

h, hours
5.2. Anthropometric and physical parameters

The anthropometric and physical parameters for males are presented in table 3. Most of the anthropometric and physical parameter test showed no differences between groups. Elite group was older and showed superior results from the estimated \( \text{VO}_{2\text{max}} \) test. Elite and sub-elite group outscored the recreational group in CMJ and 505 test.

<table>
<thead>
<tr>
<th>Table 3. Anthropometric and physical parameters in males according to performance level. F value, P-value of ANOVA and differences (post hoc LSD test).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>21.64 ± 2.32</td>
</tr>
<tr>
<td>Anthropometric</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Weight (kg)</td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
</tr>
<tr>
<td>Arm span (cm)</td>
</tr>
<tr>
<td>Muscular power</td>
</tr>
<tr>
<td>CMJ (cm)</td>
</tr>
<tr>
<td>Medicine ball th. (m)</td>
</tr>
<tr>
<td>Medicine ball th. (km/h)</td>
</tr>
<tr>
<td>Isometric strength</td>
</tr>
<tr>
<td>Grip strength (N)</td>
</tr>
<tr>
<td>Change of direction speed</td>
</tr>
<tr>
<td>505 test (s)</td>
</tr>
<tr>
<td>Reactive agility</td>
</tr>
<tr>
<td>*BSAT total time (s)</td>
</tr>
<tr>
<td>*BSAT reaction time (s)</td>
</tr>
<tr>
<td>Range of Motion</td>
</tr>
<tr>
<td>Shoulder flexibility (cm)</td>
</tr>
<tr>
<td>Maximal Aerobic Power</td>
</tr>
<tr>
<td>Level (number)</td>
</tr>
<tr>
<td>Total distance (m)</td>
</tr>
<tr>
<td>Est. ( \text{VO}_{2\text{max}} ) (mL/kg/min)</td>
</tr>
</tbody>
</table>

BMI, Body Mass Index; CMJ, Countermovement Jump; Medicine ball th., Medicine ball throw; Est, estimated; BSAT, Badminton Specific Agility Test; * Chi-square, P-value of Kruskal-Wallis test and differences (Mann-Whitney test).
The anthropometric and physical parameters for females are presented in table 4. A difference was found in age, height and in four physical parameters; CMJ, grip strength, 505 and estimated \( VO_{2\text{max}} \).

Table 4. Anthropometric and physical parameters in females according to performance level. F value, P-value of ANOVA and differences (post hoc LSD test).

<table>
<thead>
<tr>
<th></th>
<th>Elite (E)</th>
<th>Sub-elite (S)</th>
<th>Recreational (R)</th>
<th>F</th>
<th>p</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>19.70 ± 2.04</td>
<td>16.88 ± 1.18</td>
<td>17.63 ± 0.70</td>
<td>5.70</td>
<td>0.017</td>
<td>E&gt;S</td>
</tr>
<tr>
<td>Anthropometric</td>
<td>n=5</td>
<td>n=5</td>
<td>n=6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>172.74 ± 5.13</td>
<td>166.56 ± 3.17</td>
<td>164.43 ± 5.77</td>
<td>4.12</td>
<td>0.041</td>
<td>E&gt;R</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>67.82 ± 6.59</td>
<td>58.36 ± 1.72</td>
<td>62.90 ± 7.91</td>
<td>2.92</td>
<td>0.090</td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
<td>22.75 ± 2.15</td>
<td>21.06 ± 1.14</td>
<td>23.25 ± 2.58</td>
<td>1.59</td>
<td>0.241</td>
<td></td>
</tr>
<tr>
<td>Arm span (cm)</td>
<td>170.54 ± 5.26</td>
<td>166.80 ± 5.13</td>
<td>164.00 ± 6.68</td>
<td>1.73</td>
<td>0.216</td>
<td></td>
</tr>
<tr>
<td>Muscular power</td>
<td>n=5</td>
<td>n=5</td>
<td>n=6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>38.08 ± 1.42</td>
<td>37.76 ± 5.04</td>
<td>30.43 ± 6.47</td>
<td>4.30</td>
<td>0.037</td>
<td>E,S&gt;R</td>
</tr>
<tr>
<td>Medicine ball th. (m)</td>
<td>6.30 ± 0.35</td>
<td>5.73 ± 0.72</td>
<td>5.40 ± 1.34</td>
<td>1.26</td>
<td>0.317</td>
<td></td>
</tr>
<tr>
<td>*Medicine ball th. (km/h)</td>
<td>25.40 ± 1.34</td>
<td>23.20 ± 2.49</td>
<td>23.33 ± 3.14</td>
<td>4.184</td>
<td>0.123</td>
<td></td>
</tr>
<tr>
<td>Isometric strength</td>
<td>n=5</td>
<td>n=5</td>
<td>n=6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grip strength (N)</td>
<td>297.64 ± 28.53</td>
<td>250.08 ± 45.64</td>
<td>213.80 ± 27.21</td>
<td>8.15</td>
<td>0.005</td>
<td>E&gt;R</td>
</tr>
<tr>
<td>Change of direction speed</td>
<td>n=5</td>
<td>n=5</td>
<td>n=6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*505 test (s)</td>
<td>2.40 ± 0.09</td>
<td>2.37 ± 0.09</td>
<td>2.88 ± 0.33</td>
<td>10.804</td>
<td>0.005</td>
<td>E,S&gt;R</td>
</tr>
<tr>
<td>Reactive agility</td>
<td>n=3</td>
<td>n=3</td>
<td>n=6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BSAT total time (s)</td>
<td>17.25 ± 1.22</td>
<td>16.67 ± 1.32</td>
<td>17.38 ± 1.96</td>
<td>0.18</td>
<td>0.838</td>
<td></td>
</tr>
<tr>
<td>BSAT reaction time (s)</td>
<td>1.37 ± 0.11</td>
<td>1.32 ± 0.11</td>
<td>1.38 ± 0.17</td>
<td>0.18</td>
<td>0.838</td>
<td></td>
</tr>
<tr>
<td>Range of Motion</td>
<td>n=5</td>
<td>n=5</td>
<td>n=6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder flexibility (cm)</td>
<td>10.82 ± 3.47</td>
<td>9.26 ± 10.91</td>
<td>12.80 ± 6.60</td>
<td>0.30</td>
<td>0.744</td>
<td></td>
</tr>
<tr>
<td>Maximal Aerobic Power</td>
<td>n=4</td>
<td>n=5</td>
<td>n=6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level</td>
<td>25.50 ± 6.81</td>
<td>21.80 ± 5.68</td>
<td>8.50 ± 2.74</td>
<td>16.40</td>
<td>&lt;0.001</td>
<td>E,S&gt;R</td>
</tr>
<tr>
<td>Total distance (m)</td>
<td>1020 ± 272</td>
<td>872 ± 227</td>
<td>340 ± 110</td>
<td>16.40</td>
<td>&lt;0.001</td>
<td>E,S&gt;R</td>
</tr>
<tr>
<td>Est. ( VO_{2\text{max}} ) (mL/kg/min)</td>
<td>44.97 ± 2.29</td>
<td>43.72 ± 1.90</td>
<td>39.26 ± 0.92</td>
<td>16.42</td>
<td>&lt;0.001</td>
<td>E,S&gt;R</td>
</tr>
</tbody>
</table>

BMI, Body Mass Index; CMJ, Countermovement Jump; Medicine ball th., Medicine ball throw; Est, estimated; BSAT, Badminton Specific Agility Test; *Chi-square, P-value of Kruskal-Wallis test and differences (Mann-Whitney test).
5.3. Discriminant analysis for different parameters

The predictive model classified 61.1% of male players correctly and 66.7% of female players correctly using the VO$_{2\text{max}}$ variable (Table 5).

<table>
<thead>
<tr>
<th>Group</th>
<th>Males (n=18)</th>
<th>Females (n=12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elite</td>
<td>80.0%</td>
<td>50%</td>
</tr>
<tr>
<td>Sub-elite</td>
<td>40.0%</td>
<td>40%</td>
</tr>
<tr>
<td>Recreational</td>
<td>62.5%</td>
<td>100%</td>
</tr>
<tr>
<td>Whole sample</td>
<td>61.1%</td>
<td>66.7%</td>
</tr>
<tr>
<td>Wilks’ $\lambda$</td>
<td>0.405</td>
<td>0.252</td>
</tr>
<tr>
<td>Canonical correlation index</td>
<td>0.771</td>
<td>0.865</td>
</tr>
<tr>
<td>Variable included in the model</td>
<td>VO$_{2\text{max}}$</td>
<td>VO$_{2\text{max}}$</td>
</tr>
</tbody>
</table>

5.4. Correlation of anthropometric and physical fitness variables and performance in badminton

Table 6 displays Spearman’s rho correlation coefficient of anthropometric and physical fitness variables and performance in male badminton players. A moderate ($r_c= -0.47$) to very strong ($r_c= -0.83$) correlation existed between four variables and badminton performance.

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>$r_c$</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>19</td>
<td>0.21</td>
<td>0.387</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>19</td>
<td>-0.28</td>
<td>0.249</td>
</tr>
<tr>
<td>Arm span (cm)</td>
<td>19</td>
<td>0.18</td>
<td>0.475</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>19</td>
<td>-0.39</td>
<td>0.103</td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>19</td>
<td>-0.74</td>
<td>0.000</td>
</tr>
<tr>
<td>Grip Strength (N)</td>
<td>19</td>
<td>-0.17</td>
<td>0.495</td>
</tr>
<tr>
<td>505 (s)</td>
<td>19</td>
<td>0.76</td>
<td>0.000</td>
</tr>
<tr>
<td>Shoulder Flexibility</td>
<td>19</td>
<td>-0.16</td>
<td>0.528</td>
</tr>
<tr>
<td>Medicine ball th. (m)</td>
<td>19</td>
<td>-0.47</td>
<td>0.045</td>
</tr>
<tr>
<td>Medicine ball th. (km/h)</td>
<td>19</td>
<td>-0.24</td>
<td>0.319</td>
</tr>
<tr>
<td>FitLight total time (s)</td>
<td>18</td>
<td>0.28</td>
<td>0.257</td>
</tr>
<tr>
<td>FitLight reaction time (s)</td>
<td>18</td>
<td>0.28</td>
<td>0.259</td>
</tr>
<tr>
<td>Estimated VO$_{2\text{max}}$ (mL/kg/min)</td>
<td>18</td>
<td>-0.83</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Rc= Correlation coefficient
Table 7 displays Spearman’s rho correlation coefficient of anthropometric and physical fitness variables and performance in female badminton players. A moderate ($r_c=-0.51$) to very strong ($r_c=-0.86$) correlation existed between five variables and badminton performance.

<table>
<thead>
<tr>
<th>Variable</th>
<th>$n$</th>
<th>$r_c$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>16</td>
<td>-0.51</td>
<td>0.042</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>16</td>
<td>-0.31</td>
<td>0.244</td>
</tr>
<tr>
<td>Arm span (cm)</td>
<td>16</td>
<td>-0.42</td>
<td>0.104</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>16</td>
<td>-0.24</td>
<td>0.931</td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>16</td>
<td>-0.61</td>
<td>0.012</td>
</tr>
<tr>
<td>Grip Strength (N)</td>
<td>16</td>
<td>-0.73</td>
<td>0.001</td>
</tr>
<tr>
<td>505 (s)</td>
<td>16</td>
<td>0.74</td>
<td>0.001</td>
</tr>
<tr>
<td>Shoulder Flexibility</td>
<td>16</td>
<td>-0.12</td>
<td>0.664</td>
</tr>
<tr>
<td>Medicine ball th. (m)</td>
<td>16</td>
<td>-0.52</td>
<td>0.038</td>
</tr>
<tr>
<td>Medicine ball th. (km/h)</td>
<td>16</td>
<td>-0.33</td>
<td>0.211</td>
</tr>
<tr>
<td>FitLight total time (s)</td>
<td>12</td>
<td>0.10</td>
<td>0.753</td>
</tr>
<tr>
<td>FitLight reaction time (s)</td>
<td>12</td>
<td>0.11</td>
<td>0.745</td>
</tr>
<tr>
<td>Estimated VO$_{2\text{max}}$ (mL/kg/min)</td>
<td>15</td>
<td>-0.86</td>
<td>0.000</td>
</tr>
</tbody>
</table>

R$_c$ = Correlation coefficient
6. Discussion

This study presented the anthropometric and physical characteristics of elite, sub-elite and recreational Icelandic badminton players. This is the first study of this kind done around badminton in Iceland. The elite and sub-elite groups were homogenous in training experience, training hours per week, for how long they trained for each session, and in the anthropometric and physical measurements. The elite females were taller than the recreational female players; other anthropometrical differences were not found between groups in either males or females. Differences in several physical measurements were detected between elite groups (males and females) compared to recreational groups (males and females), but no difference was detected between the elite and sub-elite group in any of the physical measurements. This multidimensional test battery, therefore, did not discriminate between elite and sub-elite players. A moderate to very strong correlation existed between four physical fitness variables and performance in male badminton players and five physical fitness variables and one anthropometrical variable in female badminton players.

6.1. Training experience, hours training badminton, and length of each training

A difference was found between male groups in all the variables were the elite and sub-elite males scored higher than the recreational males. Elite and sub-elite males had more training experience (F=19.39; p= 0.001), trained more hours per week (F= 14.33; p= 0.001) and had longer training sessions (F=9.77; p=0.003) than the recreational males. No difference was detected between the elite and sub-elite males and could potentially be explained by the fact that those groups of players usually train together. Elite females had more training experience (F= 6.24; p= 0.017) than the recreational females, but no significant difference was detected between the training experience of the sub-elite females with either elite or the recreational females. Both elite and sub-elite females had more training hours per week (F= 19.35; p<0.001), but no significant difference was in the length of each training sessions between groups. Icelandic elite males train on average 11.00 ± 2.16 hours per week and Icelandic elite females 9.70 ± 1.79 hours per week. Compared to Chinese badminton players who trained four hours per day, six days per week, for total of 24 hours per week, and have been the world dominant nation in badminton (Chin et al., 1995). These findings regarding training hours per week could partially explain why Icelandic badminton players are far behind their international colleagues.
6.2. Anthropometric and physical parameters

The results revealed no differences between the male groups in anthropometric measurements. No difference was detected in height between elite or the other two groups which is not in harmony with Ooi et al., (2009) where their results showed that elite males were taller than sub-elite males. The mean height and weight of the Icelandic male players (the whole sample) was; 182 ± 10cm and 75.26 ± 6.90kg which is very close to the results from Raschka and Schmidt (2013) where they recorded the mean height and weight of twenty German badminton males; 182.0 ± 4.6cm, 77.5 ± 5.9kg. Other studies that have recorded the mean height and weight of male badminton players show that the Icelandic male players are on average about 3-11cm taller and 3-15kg heavier (Aydogmus, Arslanoglu, and Senel, 2014; Faude et al., 2007; Jeyaraman and Kalidasan, 2012; Ooi et al., 2009). This wide range in height and weight could be explained by the fact that country of origin plays an important role as Nigerian, Malaysian, Indonesian, Turkish and Spanish players are shorter compared with Danish, Czech Republic, South African and German players, and white population had the highest values in weight comparing to the Asian population who had the lowest values (Phomsoupha and Laffaye, 2015). The mean arm span of the Icelandic players (males; 183.63 ± 7.99cm and females; 166.92 ± 6.09cm) were very similar to the results from Raschka and Schmidt, (2013).

Difference was found between female groups in height (F= 4.12; p= 0.041) in this current study where the elite females were taller than the recreational females which is consistent with previous studies (Ooi et al., 2009) and review article (Phomsoupha and Laffaye, 2015). The Icelandic female players (the whole sample) had a mean height of 167.69 ± 5.83cm and weight of 63.02 ± 6.94kg which is very similar to other findings (Aydogmus et al., 2014; Faude et al., 2007; Raschka and Schmidt, 2013) however when considering only the elite group, the Icelandic elite female players were on average about 4-6 cm taller and 2-8kg heavier than the average of other female players (Aydogmus et al., 2014; Faude et al., 2007; Raschka and Schmidt, 2013).

Results from the physical tests revealed that difference was detected in three out of the seven physical tests between male groups and in four out of seven tests between female groups. Three of the same physical tests had a significant difference between the elite and recreational group in both males and females; **CMJ, 505 and estimated VO2max**, which could be an indicator that those tests are more relevant to badminton performance in Icelandic players than the others. The difference in **handgrip strength** was detected between elite and recreational females where the elite had a higher score (F= 8.15; p=0.005). These findings are consistent with previous studies of elite and sub-elite badminton players where the difference between groups was found
in grip strength test, CMJ and agility tests (Gucluover et al., 2012; Jeyaraman and Kalidasan, 2012). The elite and sub-elite males in this study had similar and even superior results from the CMJ and 505 test compared to other studies on elite and sub-elite badminton players (Gucluover et al., 2012; Ooi et al., 2009). The superior results from the Icelandic players could be explained by the difference in age of the subjects. The Icelandic elite players were about five years older (21.64 ± 2.32 years) than the Turkish elite players (16.8 ±1.5 years) (Gucluover et al., 2012). The results from the CMJ may reflect the differences in method and protocols used to measure CMJ. In this present study, CMJ was measured with high-speed camera, whereas in the study by Ooi et al., (2009) they used a contact timing mat system (Swift Performance Equipment, Australia) and in the study by Jeyaraman and Kalidasan (2012) they used vertical jump to assess leg explosive power but did not explain the protocol any further. No information were given on when in the annual periodization plan of the players these tests were performed, which could have affected their results as well. The subjects performance in 505 test in this current study was measured via two time gates, however Gucluover et al., (2012) did not specify with which equipment they measured their subjects performance in 505, and therefore are those results to be taken with precaution.

Unlike other studies no difference was detected between the groups in either males or females in BSAT. The BSAT was the most sport specific test in this current study and previous studies have already depicted differences between elite, sub-elite and non-skilled players (Madsen et al., 2015; Water et al., 2017). Two reviews (Mann et al., 2007; Voss et al., 2010) show that a fast reaction time is essential for elite performance in interceptive sports like badminton. BSAT used in this study was adopted and modified from the Badcamp agility test described by Loureiro and Freitas (2016) and the Badminton Reaction Inhibition Test (BRIT) Water et al., (2017). By intention no instructions were given on how the subjects should move around the court, and therefore it was expected that the elite and sub-elite players would benefit from more training experience with better and more efficient footwork on the court (Kusuma et al., 2015). It could also be argued that the test should have been made longer in duration by increasing the repetitions the subjects were to complete to find a difference as Madsen et al., (2015) did. The reason why twelve repetitions were decided upon for this test is that the literature states that an average badminton rally is about 9.0 ± 0.9 s for men and 7.8 ± 1.5 s for women (Abian-Vicen et al., 2013). The duration of BSAT with twelve repetitions took on average 15.98 ± 1.49s for men and 17.17 ± 1.56s for women in this study. Subjects participating in the BSAT were perhaps too few to detect a difference; eighteen males and twelve females, especially in female elite group (n=3) and sub-elite group (n=3). Other possible explanation of
why no difference was detected between groups in this test is that reactive agility is complex and incorporates neuropsychological factors such as anticipation, intuition, sensory processing, and decision making (Veale, Pearce and Carlson, 2010). Therefore it would be better if the test would incorporate anticipatory and decision making factors (Farrow, Young and Bruce, 2005; Gabbett et al., 2009; Veale et al., 2010). Agility tests using lights or other types of visual stimuli do not provide information about the opponent’s movement pattern, but expert players are better in extracting visual information from the opponent’s body and racket motion than non-expert players and have therefore a faster response time (Loureiro and Freitas, 2016).

Researchers are still debating on which tests should be used to determine physiological characteristics of elite badminton players even though a number of studies (Chin et al., 1995; Hughes and Fullerton, 1995; Wonisch et al., 2003) have addressed the validity of certain tests. Based on previous evidence (Gabbett, 2009; Gucluover et al., 2012) it was expected that the elite group would have superior results from the anthropometric and physical measurements than the other two groups. No significant difference was detected between the elite and the sub-elite group in any of the anthropometrical tests nor the physical tests which could suggest that the elite and sub-elite groups were too homogeneous, especially the males, and/or that other factors such as technical, tactical or psychological parameters could have discriminated between those two groups. Other explanation could be that due to the small size of the Icelandic badminton community there is perhaps not enough players that are competing for selection on the Icelandic national team. Physical and anthropometric factors that would likely discriminate between the elite and sub-elite players elsewhere in the world, where the competition is higher, is currently not represented in this sample of Icelandic players.

6.3. Discriminant analysis for different parameters

Discriminant analysis showed that one variable estimated $VO_{2\text{max}}$ classified 61.1% of male players and 66.7% of female players correctly in groups which suggests that a $VO_{2\text{max}}$ Value of the player is a very important component in relation to badminton performance in Icelandic players. In a recent review article (Phomsoupha and Laffaye, 2015) eighteen studies examined the estimated $VO_{2\text{max}}$ of badminton players. The average estimated $VO_{2\text{max}}$ of elite males was 56.3 mL/kg/min and 48.1 mL/kg/min for elite women. Results from the current study revealed that the elite males scored a mean of $51.72 \pm 2.01$ mL/kg/min and the elite females scored a mean of $44.97 \pm 2.29$ mL/kg/min. This suggests that Icelandic elite players, both men and women, are somewhat behind elite badminton players worldwide in relation to maximal aerobic power. However, consideration must be made on the possibility of differences in methods and
protocols used to measure VO$_{2\text{max}}$ across those studies. In this current study, the VO$_{2\text{max}}$ of the players was estimated from the performance on a Level-1 Yo-Yo Intermittent Recovery Test, whereas in the studies from the review article (Phomsoupha and Laffaye, 2015) some researchers used an incremental maximum treadmill exercise test while others used incremental field test on the badminton court.

6.4. **Correlation of anthropometric and physical fitness variables and performance in badminton**

It was expected that height and arm span would positively correlate with badminton performance (Jeyaraman and Kalidasan, 2012; Phomsoupha and Laffaye, 2015; Raschka and Schmidt, 2013; Yasin et al., 2010) however results from the Spearman’s rho correlation coefficient analysis revealed that only one anthropometrical variable correlated in the current study with performance; *height* in females ($p=0.042$; $r_c = -0.51$).

A moderate to very strong correlation existed between four variables from the physical tests and badminton performance in males and between five physical fitness variables in females. For males the variables were; estimated VO$_{2\text{max}}$ ($p=0.000$; $r_c = -0.83$), CMJ ($p=0.000$; $r_c = -0.74$), test ($p=0.000$; $r_c = -0.76$), and Kneeling Medicine Ball Throw ($p=0.045$; $r_c = -0.47$). For females the variables were; estimated VO$_{2\text{max}}$ ($p = 0.000$; $r_c = -0.86$), CMJ ($p=0.012$; $r_c = -0.61$), 505 test ($p=0.001$; $r_c = -0.74$), Grip Strength ($p=0.001$; $r_c = -0.73$), and Kneeling Medicine Ball Throw ($p=0.038$; $r_c = -0.52$). These findings are in accordance with other studies intended to analyze the correlation between different physical characteristics and playing ability (Jeyaraman and Kalidasan, 2012). The strongest correlation in both males and females were in estimated VO$_{2\text{max}}$ ($r_c > -0.80$) and 505 test ($r_c > -0.70$) which indicates that change of direction speed and endurance was the most beneficial physical attributes of Icelandic players in relation to badminton performance. Grip Strength played an important role in females with a strong correlation to their badminton performance and is consistent with previous study (Singh et al., 2011) however no significant correlation was detected in grip strength test in males. These results suggest that coaches should emphasize the development of change of direction speed, explosive power in upper and lower body, and on maximal aerobic power. The uniqueness of this study was that no estimation in the ranking of the subjects had to be made. We were able to rank all the players in precise right order as the Icelandic badminton community is small and coaches are very familiar with every players’ performance ability.
7. Limitations

The multivariate model could not discriminate between elite and sub-elite players. Subjects might have been too few and due to technical problem with the FitLight system on the second day of measurements one male and four females could not finish the BSAT test. Many different factors need to be taken into consideration when trying to explain badminton performance beside the physical and anthropometrical characteristics of the players. Measurements and analysis of psychological, tactical and technical skills could potentially aid in discriminating between those two groups.
8. Conclusion

This study analyzed the anthropometric and physical fitness in badminton players of different levels in Iceland. Reporting differences in those parameters give helpful information on the physical qualities that are important for badminton performance. The main conclusions were:

i. Icelandic elite females are taller than recreational female players. Other anthropometrical differences were not found between groups in either males or females. Differences in several physical measurements were detected between elite groups (males and females) compared to recreational groups (males and females), but no difference was detected between the elite and sub-elite group in any of the physical measurements.

ii. This multivariate model, therefore, did not allow us to discriminate between elite and sub-elite players, suggesting that the multivariate model either did not test specific factors important to badminton performance, subjects were too homogeneous or that other factors such as psychological, tactics or technical skills are to be considered of more importance.

iii. A moderate to very strong correlation existed between four physical fitness variables and badminton performance in male players and five physical fitness variables and one anthropometrical variable in female badminton players.

These findings can help badminton coaches and players recognize which physical parameters are most important in benefitting them on the court, and therefore they can emphasize training those parameters especially.
9. Future Research

Future research should try to use a larger sample and to include psychological, tactical and technical skill in the chance to discriminate between elite and sub-elite groups. Other physiological factors such as measurements on body fat could also be beneficial. A notational analysis of matches could give useful information about technical and tactical skills of the players.

10. Acknowledgements

Gratitude’s goes out to numerous people for making this master thesis study achievable. I would like to thank all the players for their participation in this study, cooperation in filling out the questionnaires and willingness to perform their very best during the physical tests. Thanks to all the coaches who both helped me in recruiting the participants and were a tremendous help on the day of the physical testing and measurements. Thanks to Badmintonfélag Hafnafjarðar for lending me their FitLight trainer system as well as lending their indoor badminton facility during the two days of measurements. I would like to thank the University of Reykjavík for all the lecturers and courses through the years and with providing me with all the necessary testing equipment for this study. I would like to thank my better half Sveinn Þorgeirsson for review and support in writing this thesis. Special thanks goes to my supervisor Jose M. Saavedra for the great guidance and help all along the way.
11. References


national and amateur badminton players. *Journal of Physical Education and Sport Sciences, 6*(3), 244-250.


12. Appendices

Appendix 1. Informed consent

Kynningarbréf

Nafn þátttakenda: _________________________________________________________________

Heiti verkefnis: Fjölbátttagreining á frammistöðu badmintonspilara á Íslandi.

Rannsakandi: Anna Margrét Guðmundsdóttir, MSc. nemi í Íþróttaþjálfun og víslendum.

Leiðbeinandi: Professor Jose M. Saavedra.

HLUTI I: UPPLÝSINGAR

1. Kynning
Markmið þessarar rannsóknar er að gera fjölbátttagreiningu á frammistöðu badmintonspilara. Við viljum bjöða þér að vera með í þessari rannsókn og meðfylgjandi eru upplýsingar um markmið, snið og framkvæmd hennar. Þetta blæð skaltu lesa vandlega yfir og skrifa undir þegar þú mætir í mælingarnar. Æður en þú tekur ákvörðun er þér velkomið að tala við okkur og spyrja spurninga varðandi rannsóknina. Ef spurningar kunna að vakna síðar meir er þér einnig frjálst að hafa samband og spyrja.

2. Markmið rannsóknarinnar
Markmiðin með verkefni þessu eru að (i) greina frammistöðu í badminton út frá mörgum þáttum byggðum á mælingum sem við leggjum fyrir og (II) að ákvarða hvaða breytur (mælingar) geta spáð fyrir um frammistöðu í badminton.

3. Snið rannsóknarinnar
Í þessari rannsókn verða lagðir fyrir spurningalistar um hugarfararslega þætti og þátttöku í þráttum til dagsins í dag, ásamt líkamsgerðarmælingum, afkastamælingum og þæðilegum prófum.

4. Val á þátttakendum
Þátttakendur voru valdir af rannsakanda í samráði við landsliðs- og aðstoðarlandsliðsþjálfara Íslands í badminton ásamt þjálfurum Badmintondeildar Hafnafjarðar.

5. Þátttaka af eigin áhuga og vilja
Þátttaka þín i þessari rannsókn er í sjálfboðastarfi. Það er þín ákvörðun hvort þú tekur þátt eða ekki. Hvort sem þú velur að halda áfram eða ekki, mun þessi rannsókn fara fram.

6. Framkvæmd og ferlar
Þátttakafara í gegnum allar líkams- og afkastamælingar á staðnum (Strandgötu) og svara spurningalistum heima fyrir eða á staðnum eftir að mælingunum lýkur.

7. Áhætta
Engin heilsufarsleg áhætta fylgir þátttöku í rannsókninni.
8. Ávinningur
Takir þú þátt í rannsókninni eykst áreiðanleiki safnaðra gagna um hugarfarslega þætti, líkamlegar afkastamælingar, líkamsgerð og tæknifærni í badminton sem nota má til að bæta framhistöðu.

9. Greiðslur
Þú munt ekki fá greiðslur fyrir þátttöku í þessari rannsókn, hvorki peninga né önnur hlunnindi. Rannsakendur njóta ekki styrks til þess að verkefni heldur er áhuginn fyrst og fremst í þágu vísinda og frampróunum meistaranehenda.

10. Trúnaður
Við munum ekki deila þátttakendalista rannsóknarinnar neinsstaðar og upplýsingar sem safnast við vinnslu rannsóknarinnar mun verða trúnaðarupplýsingar. Pessar upplýsingar verða ekki rekjanlegar til einstaklinga beint heldur verða niðurstöðurnar dulköðaðar til persónuverndar og aðeins rannsakendur munu hafa aðgang að þeim.

11. Birting niðurstaðna
Sú þekking sem við öflum með þessari rannsókn mun verða sett fram í lokaverkefni rannsakanda en þar verða engin nöfn verða birt og trúnaðarupplýsingun verður ekki deilt. Landsliðs- og abstöðarlandsliðsþjálfari í badminton fá aðgang að niðurstöðum.

12. Rétturn til að hafna eða að draga þátttöku til baka
Þú þarft ekki að taka þátt í þessari rannsókn ef þú hefur ekki áhuga á því. Þú mátt hætta þátttöku á hvaða tímapunkti sem er og eins mætti hafna að taka þátt í stökkum þáttum verkefns. Kjósir þú að gera það mun það ekki hafa nein áhrif á þig, valið og rétturinn er þinn.

13. Tengiliðaupplýsingar
Ef þú hefur einhverjar spurningar máttu spyrja að þeim núna og jafnvel eftir að rannsókn lýkur.

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HLUTI II: YFIRLYSING

Ef þú ákveður að samþykkja þessa rannsókn, vinsamlega skilaðu þeirri afstöðu skriflega með því að undirrita eftirfarandi:
Þátttakandur yngri en 18 ára verða einnig að fá undirritun foreldra/ forráðamanns.

Undirritun íþróttamanns dagsetning
Undirritun foreldra eða forráðamanns dagsetning
Undirritun rannsakanda (móttekið) dagsetning
Appendix 2. Background questions

Bakgrunnspurningar

Merktu við það sem við á eða skrifaðu svörin á línurnar

1. Hvert er kyn þitt?
   ☐ KK
   ☐ KVK

2. Hvert er fæðingaár þitt?: __________________________
   Ertu í landslídshóp/-um? Mertu við það sem við á.
   ☐ Er ekki í landslídshóp í badminton
   ☐ U-17
   ☐ U-19
   ☐ A- höp
   ☐ Afrekshóp

3. Ertu örvhent/ur eða réthent/ur?
   ☐ Örvhent/ur
   ☐ Réthent/ur

4. Hvað hefur þú æft badminton í mörg ár?
   __________________________

5. Hversu marga daga æfir þú á viku badminton?
   __________________________

6. Hversu marga klukkutíma að jafnaði æfir þú á viku badminton með þínu félagi?
   ____________________________ (klst)

7. Hversu marga klukkutíma er hver badminton æfing að jafnaði hjá þér?
   ____________________________ (klst)
8. Hversu oft keppir þú á ári?
☐ ég keppi ekki á badmintonmó tum
☐ 3 sinnum eða sjaldnar
☐ 4-7 sinnum
☐ 8-12 sinnum
☐ oftar en 12 sinnum

9. Hvað varstu gamall/gömul þegar þú byrjaðir að æfa badminton?
____________ ára

10. Hvað varstu gömul/gamall þegar þú fórst að æfa reglulega með meistaraflokki?
____________ ára
☐ Æfi ekki með meistaraflokki

11. Hvað varstu gömul/gamall þegar þú varst valin/n í þitt fyrsta landsliöðsverkefni (unglinga- eða A- landsliöðsverkefni)?
____________ ára
☐ Hef ekki verið valin í landsliöðsverkefni

☐ Ég á engan landsleik fyrir Ís land, hvorki yngri landsleik né A-landsleik
☐ Ég á leik með yngri landsliöðum Ís lands en ekki A-landsliöði
☐ Ég á leiki með yngri landsliöðum Ís lands og A-landsliöði

13. Stundaðir þú (æfðir eða kepptir) aðrar íþróttagerirnar með íþróttafélögum sem barn/unglingur?
☐ Já
☐ Nei

14. Ef já, hvaða íþróttagerirnar stundaðir þú? (merktu við fleiri en eina grein ef það á við)
☐ Handbolta
☐ Körfubolta
☐ Fótbolta
☐ Fimleika
☐ Frjálsar íþróttir
☐ Annað

15. Hversu lengi æfðir þú viðkomandi íþrótt/ir? ______________________
**Styrkþjálfun**

Hér er spurt um styrkþjálfun. Þá er átt við skipulagðar styrkæfingar þar sem þú ert med þjálfaranum eða fylgir áætlun skipulagðri af þjalfrarunum.

16. **Hversu oft í viku stundar þú styrkþjálfun?**
   - Í og stunda ekki styrkþjálfun
   - 1–2 sinnum
   - 3–4 sinnum
   - 5 sinnum eða oftar

17. **Hversu lengi hefur þú stundað skipulagða styrkþjálfun?**
   _____________ ár

18. **Stundar þú styrkþjálfun aukalega utan hefðbundinna æfinga og styrkæfinga?**
   - Já, oft
   - Já, stundum
   - Nei

**Andleg þjálfun**

19. **Hefur þú leitað til íþróttasálfræðings, sálfræðings eða einhverskonar hugarþjálfa til þess að bæta frammistöðu þína í badminton?**
   - Já
   - Nei

20. **Hefur þú áhuga á að leita til íþróttasálfræðings, sálfræðings eða einhverskonar hugarþjálfa til þess að bæta frammistöðu þína í badminton.**
   - Já
   - Nei

SPURING ADEINS FYRIR PÁ SEM HAVA VERID VALDIR Í A-LANDSLÍÐ

21. **Hvað varstu gómul/gamall þegar þú varst valin/n í A-landslið?**
   _____________ ára