Relationship between resistance training-induced changes in Power, Change of Direction, Sprint, Jumping abilities and match-related handball performance in female players during season

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Structure of the present thesis

The present thesis is presented in two parts, followed by part 3: appendices.

Part 1 presents the theoretical framework, along with methods of the present study and a methodical discussion.

Part 2 entails the research paper, written according to the guidelines of “Scandinavian Journal of Science and Medicine in Sports”.

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Best regards,
Emil Martinovic

Abbreviations

IMU	Intertial Movement Unit
HIE	High-Intensity Event
Pmax	Maximal Power Output
CMJ	Counter Movement Jump
RFD	Rate of Force Development
CSA	Cross-Sectional Area
SSC	Stretch-Shortening Cycle
Vmax	Maximal Velocity Shortening
CoD	Change of Direction
GPS	Global Positioning System
LPS	Local Positioning System
RIR	Repetitions in Reserve
1RM	One-Repetition Maximum
N	Newton
M/s	Meters per second
W	Watt
CV	Coefficient of Variation
SWD	Smallest Worthwhile Change
Acc	Acceleration
Dec	Deceleration
IMA	Inertial Movement Analysis

Abstract

Purpose: The purpose of this study was to investigate the relationship between resistance training-induced changes in lower-body Power, sprint, change of direction, jumping abilities and changes in match-related handball performance during season in female handball players.

Methods: Twenty-five female handball players from the third highest level in Norway completed a 12-week strength- and power training intervention. Players were subsequently pooled into high-responders (n=7) and low-responders (n=18) based on pre-post changes in four tests; leg press power (pneumatic device), countermovement jump height (CMJ), sprint (30m) and change of direction (CoD) times (4x180° turns). High-responders were defined as players who improved in 3 of the 4 tests, surpassing both each test´s smallest worthwhile change and coefficient of variation. Match-related handball performance were measured as High-Intensity Events (HIE) proximally once a week during 6vs6 match-related sessions for 10min (5minx2).

Results: There were revealed no significant difference between groups in HIE-changes from pre-to post (high-responders: -3.44 ± 8.88 vs low-responders: -0.211 ± 9.22, p= 0.435). Furthermore, a correlation analysis on changes in performance measures (Power, CMJ, 30m sprint, CoD) and changes in HIE revealed no significant correlation between the variables (r=-0.127, p= 0.553).

Conclusion: Our findings suggest that resistance training-induced changes in performance measures does not correlate with changes in HIE among female handball players in-season.

KEYWORDS

Inertial movement units, Catapult System, handball, neuromuscular.

Sammendrag

Hensikt: Hensikten med dette studiet var å undersøke sammenhengen mellom styrketrenings-induserte endringer i ben-Power, sprint, retningsforandring, svikthopp-høyde og endring i kamprelatert data, hos kvinnelige håndballspillere i sesong.

Metode: Tjuefem kvinnelige håndballspillere fra tredje høyeste nivå i Norge fullførte en 12-ukers styrke- og powertrening intervensjon. Spillerne ble deretter gruppert i høy-respondere (n = 7) og lav-respondere (n = 18) basert på endringer fra pre-til post i fire tester; ben-Power (pneumatisk enhet), svikthopp-høyde (CMJ), sprint (30m) og retningsforandring (CoD) tider (4x180°). Høy-respondere ble definert som spillere som forbedret seg i 3 av de 4 testene, og overgikk både testens minste signifikante endring og variasjonskoeffisient. Kamprelatert ytelse ble målt som høy-intensive aksjoner (HIE) omtrent en gang i uken i løpet av 6vs6 kamprelaterte økter i 10 minutter (5minx2).

Resultater: Det ble vist ingen signifikant forskjell mellom gruppene i HIE-endringer fra pre-til post (høy-respondere: -3.44 ± 8.88 vs lav-respondere: -0.211 ± 9.22, $p = 0.435$). Videre viste en korrelasjonsanalyse på endringer i HIE og endringer i prestasjonsmål (Power, CMJ, 30m sprint, CoD) ingen signifikant sammenheng mellom variablene ($r = -0.127$, $p = 0.553$).

Konklusjon: Våre funn tyder på at endringer i prestasjonsmål ikke korrelerer med endringer i HIE blant kvinnelige håndballspillere under sesong.

NØKKELORD

Inertial movement units, Catapult System, håndball, neuromuskulær.

Part 1:

INTRODUCTION AND THEORETICAL BACKGROUND OF THE THESIS

TABLE OF CONTENT

1.0 Introduction

Team handball (handball) is a highly physically demanding team sport that requires players to be able to perform a wide range of physical activities such as sprinting, jumping, throwing, hitting, blocking, pushing, while also managing endurance demands and technical and tactical aspects of the game (Saavedra et al., 2018). In an average game, players may need to execute over 140 high-intensity actions, including duels, sprints, jumps, changes of direction, and breaking actions (Karcher & Buchheit, 2014). The literature has repeatedly shown that elite handball players, both male and female, possess superior physical abilities in terms of throwing velocity, jump qualities, sprint, lower-body Power, and 1 repetition maximum (1RM) bench press compared to amateur players (Gorostiaga et al., 2005; Granados et al., 2007; Manchado et al., 2013).

Previous studies have demonstrated that in-season strength programs can lead to improved sprint and jump abilities in male elite handball players (Hermassi, 2011; Hermassi et al., 2017). Limited studies have been conducted on this topic regarding female handball players, but one study showed that a strength program consisting of strength, endurance, and sprint training in-season led to improvements in isometric strength, maximal velocity sprint, and endurance in eight elite female handball players (Jensen et al., 1997). However, further research is needed to determine the effects of resistance training on female handball players in-season, and even further, how this effect might impact changes in performance measures such as power, change of direction, sprint-and jump abilities.

Based on prior research conducted on handball players, it has previously been hypothesized that an improvement in standardized performance measures, such as Power, sprint, CoD and jumping abilities could be advantageous for handball players wanting to improve their on-court performance (García-Sánchez et al., 2023; Granados et al., 2007; Pereira, Cal Abad, et al., 2018). To this date however there is a clear missing link in the literature on how these effects of improvement in performance measures are interrelated towards on-court performance in handball.

Previous studies have commonly used time-motion analysis or distance covered to measure on-court performance, which can be both time consuming, inaccurate of predicting playing level and can depend on the subjective analysis of the observer (Manchado et al., 2020).

In recent times however there has been a rise in measurement of on-court performance in handball by using wearable inertial movement units (IMUs). These devices facilitate detailed movement analysis and can provide information on each player's total amount of acceleration, deceleration, and change of direction during games or training, referred to as high-intensity events (HIE) (Luteberget & Spencer, 2017). Previous research has shown the positional and individual differences in HIE for female elite handball players. Yet, to the best of our knowledge, no study has examined whether changes in Power, change of direction, sprint, and jump abilities relate to changes in match-related performance in female handball players during season (Luteberget & Spencer, 2017).

The purpose of this study is therefore to investigate the relationship between resistance training-induced changes in performance measures and changes in match-related performance, as of HIE, for female handball players in-season.

1.1 Hypotheses

In this study, it was hypothesized that changes in lower-body Power, change of direction, sprint, and jumping abilities would correlate with changes in high-intensity events (HIE). It was further expected that high-responders to the changes in performance measures would experience a greater increase in the number of HIE compared to the low-responders.

2.0 Theoretical Framework

2.1 Physical Characteristics of Handball

Handball is a fast-paced team sport that involves seven players per team, with one goalkeeper and six outfield players. The game is played on a 40x20m court, with one goal on each half and the game being played over 2x30 minutes. The objective of the game is to score more goals than the opposing team, and the teams switches between attack and defense on every play. The rules of the game were modified in 2000, with added rules as “passive play” and “fast throw-off” which increased the speed of the game (Karcher & Buchheit, 2014). Handball is known for its repeated jumps, sprints, changes in direction, high-speed body contact, and specific technical movement patterns. Physical attributes such as strength, power, running speed, and throwing velocity are therefore important factors for success in competitive women's handball (Manchado et al., 2013).

2.2 What is Maximal Power?

Mechanical power is often referred to as the rate of doing work and is calculated by multiplying force by velocity (Haff & Nimphius, 2012). Maximal power is the highest level of power achieved in muscular contractions and represents the greatest instantaneous power during a single movement performed with the goal of producing maximal velocity at take-off, release, or impact. This applies to generic movements such as sprinting, jumping, changing direction, throwing, kicking and striking and is important for athletic performance (Haff & Nimphius, 2012). Stone et al., (2002) state that ability to express high rates of force development and high-power outputs are critical performance characteristics central to success in most sporting events, especially in activities that rely on jumping, change of direction, and/or sprinting performance.

2.3 Rate of Force Development

Rate of Force Development (RFD) is the ability to produce rapid forces in a short amount of time. This requires quick motor unit recruitment, high motor unit discharge rates, and fast motor unit force twitches (Cormie et al., 2011). Previous studies state that while maximal strength is important in producing high levels of force needed in sports, the time required to complete many sport-specific skills is shorter than that needed to express maximal strength (Stone et al., 2002). Many sport-specific skills such as sprinting, jumping, throwing, and kicking last 30-200 milliseconds, and the rate at which force is developed within these short periods dictates the gross amount of force applied during the skill. Taber et al., (2016) article also highlights that RFD is perhaps the most central factor to sport success across a wide spectrum of events, supported by studies on sprinting, jumping, change of direction ability, throwing, weightlifting movements, and endurance-based activities (Taber et al., 2016).

2.4 Factors Determining Maximal Power

There is an abundance of factors determining maximal power such as the force-velocity relationship, length-tension relationship, stretch reflexes, muscle fiber type, cross-sectional area, fascicle length, pennation angle, tendon properties, motor-unit recruitment and muscle environment (Haff & Nimphius, 2012; Kraemer & Newton, 2000). In the upcoming section, there will be a focus on the muscle mechanics (force-velocity relationship) and morphological factors (fiber types) before diving deeper into neural factors which include motor-unit recruitment and firing frequency.

2.4.1 Force-Velocity Relationship

The force-velocity relationship is a fundamental principle of muscle physiology that states that as force increases, velocity decreases and vice versa. This relationship is a consequence of the properties of muscle fibers and the neural control of muscle contraction.
When a muscle contracts, it generates force and movement (velocity). The force-velocity relationship states that the muscle fibers can generate different levels of force depending on the velocity of contraction Fast-twitch muscle fibers are capable of generating high levels of force at high velocities, which enables them to produce high power outputs (Lindberg, Solberg, et al., 2021). The relationship between force and velocity is not linear, but rather follows an double-hyperbolic curve (Alcazar et al., 2019). At low velocities, power production is low, and as velocity increases, power production increases up to a point where maximum power is achieved at a specific velocity. Beyond this point, as velocity continues to increase, power production decreases. In terms of increasing power, this relationship suggests that to increase power, one must increase the force generated at high velocities (Cormie et al., 2011).

2.4.2 Fiber Types

Fiber types can influence maximal power output due to differences in specific force, maximum velocity (Vmax), and the curvature of the force-velocity curve amongst the different fiber types. Fast-twitch muscle fibers are larger, contract rapidly, and generate force quickly. They are used for explosive movements like sprinting or weightlifting. They have fewer mitochondria and capillaries, limiting their oxygen supply. Slow-twitch muscle fibers are smaller, contract more slowly, and generate less force. They are involved in endurance activities like long-distance running or cycling. They have a higher density of mitochondria and capillaries, and contain more myoglobin, which stores oxygen (Cormie et al., 2011). Type II fibers, particularly type IIa and IIx fibers, have a greater capacity to generate power per unit cross-sectional area (CSA) compared to type I fibers. This is due to their higher specific force, Vmax, and shorter contraction time/twitch duration, which allows for rapid force development. In contrast, type I fibers have comparatively lower ATPase activity and Vmax with longer contraction times/twitch durations, resulting in lower power output. When the literature involving single fiber preparations is collated, a continuum of Vmax and Max Power (Pmax) for the fiber types is evident as follows: IIx > IIa > I. Therefore, muscles with a high percentage of type II fibers display greater Pmax in comparison to muscles with a high percentage of type I fibers (Cormie et al., 2011).

2.4.3 Neural Factors

To generate maximal power during a movement one not only has to rely on muscle morphology but also on the nervous system's ability to activate the involved muscles in a suitable manner. The nervous system achieves this by regulating motor unit recruitment, firing frequency, synchronization, and inter-muscular coordination.

2.4.4 Motor-Unit Recruitment

The force generated by muscles is dependent on the number and type of motor units activated, with the smaller alpha-motoneurons that innervate type I fibers being recruited initially at low force levels, while progressively larger alpha-motoneurons that activate type IIa and IIx fibres are activated at higher force levels. The maximum force capability of a motor unit can vary up to 50 times, which affects the force generated during movement. Training may lead to increased motor unit recruitment, preferential recruitment of high-threshold motor units, and/or lowering of the thresholds of motor unit recruitment. EMG amplitude increase suggests a possible adaptation associated with enhanced muscular power may be an increase in the level of motor unit recruitment (Cormie et al., 2011).

2.5 Importance of Maximal Power in Handball players

Studies have shown that higher maximal power and strength may be associated with an advantage in blocking, hitting, pushing and ball throwing velocity in handball players (Manchado et al., 2020). Additionally, it has previously been shown a relatively marked differences in power and strength between elite and amateur players. Elite players have been found to have 23% higher bench press 1RM and 12% higher average power output of the lower extremities when compared to amateur players. These findings suggest that high absolute values of maximal strength and maximal muscle power are required for successful performance in elite women's handball (Manchado et al., 2013).

2.6 Importance of Speed Abilities in Handball Players

Speed abilities are crucial for female handball players, as it is a fast-paced and dynamic sport that requires quick movements and reactions. Players with faster speed abilities can move quickly across the court, evade defenders, and execute effective offensive and defensive strategies. There has been shown that speed abilities such as agility, acceleration, and maximum sprint speed are important predictors of performance in handball players (Massuça et al., 2014). Previous studies found that players with better speed abilities were able to perform better in various handball-specific tasks, such as passing accuracy and shooting speed. Additionally, it´s highlighted the importance of speed abilities for defending against opponents and reducing the risk of injury (Buchheit et al., 2010). Other studies comparing elite versus amateur handball players, have shown that sprint performances over 5 and 15m are different between elite and amateur handball players. Elite players have been found to have 4% lower maximal sprint running time for 5m and 3% lower maximal sprint running time for 15m when compared to amateur players. These findings also suggest that high running speed is important for success in competitive handball (Manchado et al., 2013).

2.7 Importance of Jump Abilities in Handball Players

Jumping ability is a key factor in handball when it comes to either scoring goals or making important blocks. Previous research has shown that a vertical jump test like the countermovement jump (CMJ) can be used to measure lower-body Power and is related to other crucial performance tasks such as sprinting in high-performing athletes (T. Haugen & Seiler, 2015; Loturco et al., 2015; Wagner et al., 2018) Furthermore, Karcher & Bucheit

(2014) states that athletes who can jump higher have an advantage in offensive situations, as they can reach higher to score goals (Karcher & Buchheit, 2014). This also supports the findings from Pereira et al., (2018) study where they looked at the differences in Speed and Power capacities between Female National Team and National Olympic Team Handball Athletes. Accordingly, Olympic athletes performed better in the vertical jump tests, mean Power output, loaded jump squat and bench press than their «less qualified» peers (Pereira, Cal Abad, et al., 2018). These results are similar with previous findings from Granados et al., (2007) when they were examining difference in physical qualities between elites and amateurs. This difference in muscle power is thought to be related to better performance in specific game tasks such as jumps and ball throws. Additionally, studies have shown that handball players with stronger lower and upper limb muscles have a higher throwing velocity (Granados et al., 2007).

2.8 Improving Power in Handball Players

An improvement of Power can result to better sprint times, higher jumping, and faster change of directions. Power is therefore an overarching determining factor in athletic endeavors (Cormie et al., 2011). To develop high Power outputs in handball, it is thought essential to focus on maximizing overall muscular strength, developing the ability to express high forces in very short periods of time (RFD), and the ability to express high forces as the velocity of muscle contraction increases.

In the study by Marques et al., (2009), the researchers investigated the relationship between maximal strength, muscle power, and throwing velocity in elite handball players. They highlighted how enhancing maximal strength through appropriate training protocols, handball players can generate more force and power during explosive movements like throwing, jumping, and change of direction, ultimately enhancing their overall performance on the court (Marques et al., 2008). Similar findings have been shown in soccer players which improved their peak Power output induced from a resistance training intervention, and see improvements in sprint times and CMJ (Silva et al., 2015). Overall strength levels serve as the main driver for the ability to express high power outputs, and there is a strong interplay between each element.

Furthermore, to improve Power in handball there has also been shown the importance of improving the ability to express high forces in very short periods of time (RFD). By for example following a weightlifting program with the emphasis on expressing high amounts of force at high velocities. Hermassi et al., (2019) demonstrated that male handball players experienced improvements in power, sprinting, strength, change of direction ability, and throwing velocity through the integration of a 12-week biweekly in-season weightlifting training program. By addressing the specific demands of the sport, which require quick and forceful movements, weightlifting training becomes a great tool for enhancing maximal Power in handball (Hermassi et al., 2011). Less complex training methods, such as plyometric training, has also demonstrated their effectiveness in improving power among handball players. A study conducted with top elite adolescent male handball players revealed that engaging in an 8-week biweekly in-season plyometric training program, focusing on exercises for the lower limbs, resulted in enhanced jump ability and absolute leg power (Hermassi et al., 2019).

2.9 Match-Related Handball Performance

To track the characterized features of handball like numerous high-intensity actions and the total load placed on the athletes, previous research has commonly used either subjective or objective monitoring.

Subjective monitoring of load refers to the athlete's perception of the physical demands placed on them during training or competition. This involves self-reporting using various subjective measures such as ratings of perceived exertion (RPE), visual analog scales, and questionnaires that assess factors such as fatigue, soreness, and recovery. These types of monitoring can be useful to track total player load and perceived fatigue, but lacks application for tracking the quantity of high-intensity events (Zamunér et al., 2011). On the other hand, objective monitoring involves the use of various tools and technologies, such as wearable sensors, Global Positioning System (GPS) tracking devices, and heart rate monitors, to collect data on parameters such as distance covered, speed, acceleration, deceleration, and physiological responses. By objectively monitoring the load, coaches and sports scientists can gain insights into the athlete's training status, identify areas for improvement, and make informed decisions about training intensity, volume, and recovery (Luteberget et al., 2018). It can also help in preventing injuries by monitoring the workload and ensuring that athletes do not exceed their physical capabilities.

In the past two decades, the GPS has been extensively used to analyze the physical demands of outdoor team sports. However, GPS cannot be used for indoor sports due to signal blockage. To overcome this limitation, companies have developed local positioning systems (LPS) with ultra-wideband technology (UWB) to track and analyze indoor team sports. Recent scientific literature indicates the superiority of LPS over other systems, such as video-based systems with time motion analysis which can be both time-consuming and inaccurate (Karcher & Buchheit, 2014). With the advent of small, wearable inertial measurement units (IMUs), researchers have new opportunities to study the physical demands of different team sports. Many commercially available devices now include IMUs, which enable a more detailed analysis of movement and can serve as an alternative to the time-consuming process of video coding (Luteberget & Spencer, 2017).

2.9.1 Inertial Measurement Unit

Inertial measurement units (IMUs) are a type of sensor that include accelerometers and gyroscopes. They are commonly used for gait analysis but are increasingly being used in team sports as well. This is due to their high sampling frequencies, small size, and lack of interference with athletes' techniques. There are several manufacturers of IMUs for monitoring team-sport athletes, such as Catapult Sports, ChyronHego, and STATSports. These manufacturers have developed specific algorithms to convert raw IMU data into usable metrics for physical demand analysis in team sports. These metrics can be divided into two categories: workload variables, which measure overall physical activity, and event detection variables, which measure specific activities such as changes of direction and tackles/collisions (Luteberget et al., 2018). These event detection variables are commonly used to identify intensity in each session/game or to track how active a player is. Multiple studies have investigated the validity and reliability of IMUs in team sports which concludes that IMU systems have shown good to excellent reliability for measuring various movements, but the validity may vary depending on the specific movement being measured and the quality of the sensors and algorithms used (Luteberget et al., 2018).

2.9.2 High-Intensity Events

Luteberget & Spencer (2017) found that an average of 3.9 ± 1.5 high-intensity events per minute occurred during play in a handball match, or match-stimulated 6vs6 session (Luteberget & Spencer, 2017). This is in align with the findings of Font & colleagues (2020) which found that a handball player performs over 1000 accelerations and decelerations in a game (Font et al., 2020) (García-Sánchez et al., 2023). Having knowledge of the physical demands in sports is crucial for several reasons. Firstly, it is necessary for effectively planning and implementing training programs. Additionally, it is important to assess whether there are variations in the physical demands among different playing positions (Luteberget & Spencer, 2017). High-intensity events (HIE) is defined as the total number of acceleration (Acc), change of direction (CoD), or deceleration (Dec) events. The direction of the force applied during each event is determined and used to classify the event as an Acc, CoD or Dec. In most studies that measure HIE in handball, every event with a velocity greater than 2.5 m·s-1 is counted analysis as Acc, CoD, or Dec (Luteberget & Spencer, 2017). Previous studies have shown that players at the international level in handball exhibit higher rates of HIE compared to players at the national level (Luteberget & Spencer, 2017). Similar findings have been observed in soccer, where higher-level players engage in more high-intensity running than their lower-level counterparts (Ingebrigtsen et al., 2012; Mohr et al., 2003).

The ability to track high-intensity events during a full match or match-stimulated 6vs6 session can be a valuable tool for coaches and players to see if the given session has the desired outcome, or if the desired outcome is only targeted to some players. For instance, if a coach sets up a session where the aim is to have high intensity and full tempo, but the data shows that the overall HIE in the team are low, or that some players have low HIE, and some high. The coach might use this to evaluate how he can adjust his sessions accordingly.

3.0 Method

3.1 Study Design

This study was conducted as an experimental study which were a part of a bigger 12-week Randomized Controlled Trial (RCT), with both familiarization, and pre-and post-testing. For the performance measures subjects were measured in lower-body Power using a pneumatic leg press, countermovement jump (CMJ) using a force plate, and via timing gates, recorded sprints (30m) and change of direction (CoD) (4x180° turns). The Catapult System vest equipped with Inertial Movement Units (IMUs) was worn by the subjects proximally once a week in order to measure their high-intensity match performance during a 6vs6 session. This involved tracking the PlayerLoad™ and high-intensity events using the IMUs for a total of two 5-minute periods per session. Measurement 1-3 was used as pre-test, and measurement 6-8 was used as post-test.

3.2 Subjects

The subjects of this study were female handball players from two handball clubs playing in the third highest national level in Norway. Subjects were first randomly assigned to either heavy-load (HL) group (HL; n=16, 20±3yrs, 170±6cm, 70±14kg) or power-plyometric (PP) group (PP; n=15, 20±3yrs, 170±6cm, 66±7kg). A responder analysis was then conducted by dividing the subjects into high-responders or low-responders groups based their improvement from pre-to-post-test in the listed performance metrics. High-responders were defined as players who improved in 3 of the 4 tests, surpassing both each test´s smallest worthwhile change (SWC) and coefficient of variation (CV). Subjects had to achieve changes in SWC exceeding 0.3 times the baseline value, as well as passing each test´s CV by the process of computing the difference score for each participant, followed by calculation of the standard deviation of these different scores, and finally dividing the results by 2¯√. In order to be eligible for inclusion in this study, participants needed to meet certain criteria on the IMU recordings. Specifically, they were required to have at least three recorded IMU sessions in total. Furthermore, participants were required to have a minimum of one recorded session either in the pre-test or the post-test. So, no player for instance had zero recorded sessions in pre-test, and three recorded sessions in post-test. Goalkeepers were also excluded from the study since they did not have any recorded IMU sessions. Descriptive data of the subjects after inclusion and exclusion criteria are illustrated in Table 1.

Table 1. Subject characteristics

Mean ± SD	**High-Responders**	**Low-Responders**
N	7	18
Age (yrs)	20.3 ± 2.6	19.4 ± 2.4
Height (cm)	172.1 ± 7.2	169.1 ± 5.8
Weight (kg)	67.6 ± 8.1	69.8 ± 13.1

This study received approval from the Norwegian Centre for Research Data and was granted permission by the local ethics committee for the Faculty of Health and Sport Science at the University of Agder. The study was conducted in compliance with the Declaration of Helsinki, and all participants received an informed request regarding the study.

3.3 Training Programs

The high-load group executed 2-6 sets for each muscle group, working at intensities of 80-85% of their 1RM. While the power-plyo group executed 75-90 bodyweight jumps, along with 2-4 sets of 3-6 power exercises, utilizing weights less than or equal to 50% of their 1RM. The programs were made to the best of our ability to fit the individual, in terms of injury-history, playing time and potential technical difficulties. The programs were also made in collaboration with Olympatoppen´s strength and conditioning coach for the woman´s national team in handball. The coach(es) who were present gave instructions on intention, rest time, technique, load, and other relevant guidance during the session. Both groups conducted their given workouts 2 times a week for 12 weeks, by the supervision of a coach and tracked all their workouts using an app called XPS (XPS Sideline sports; Catapult Sports, Melbourne, Australia). Through the midst of the project both the power-plyo group replaced reverse row (barbell or slings) with medicine ball chest pass. The programs are presented in Table 2 and Table 3.

Table 2: Training Program Heavy-Load

Training Program Heavy-Load	
Session A	**Session B**
A1: Squat to Parallel 3 x 5 @ 3RIR	A1: Squat to Parallel 2 x 5 @ 1RIR
B1: Split Squat 3 x 5 @ 3RIR	B1: Nordic Hamstring Curl 2 x 5 @ high intensity
C2: Hip Thrust 3 x 5 @ 3RIR	B2: Superman in slings or rollouts 2 x 10 @ high intensity
C3: 1-leg calf raise 3 x 10 @ High Load	C1: Bulgarian Split Squat 2 x 5 @ 1RIR
D1: Romanian Deadlift 3 x 5 @ 3RIR	D1: Dumbbell Benchpress 2 x 5 @ 1RIR
E1: Barbell Bench Press 3 x 5 @ 3RIR	E1: Cable Row or 1-arm dumbbell row 2 x 5 @ 1RIR
E2: Pull-Ups or Lat Pulldowns 3 x 5 @ 3RIR	E2: Overhead Dumbbell Triceps Extensions 2 x 5 @ 1RIR
F1: Shoulder Press with Barbell or Dumbbells 2 x 5 @ 3RIR	
G1: Weighted Sit-Ups 2 x 10 @ High intensity	

Abbreviations: RIR, repetitions in reserve; 1RM, one-repetition maximum; 3 x 5, three sets & five repetitions; Kg, kilograms.

Table 3: Training Program Power-Plyo

Training Program Power-Plyo	
Session A	**Session B**
A1: Squat Jumps to parallel 4 x 5 @ 50% of 1RM	A1: Squat Jumps to Parallel 3 x 5 @ 50% of 1RM
B1: Push Jerk 3 x 5 @ max intent	B1: Single-Leg Hip Thrust Jumps 2 x 5
C1: Single-Leg Hip Thrust Jumps 3 x 5	B2: Medball Chest Throw 2 x 5 @ 2-3kg
C2: Barbell Bench Press with Elastic bands 3 x 5 @ 50% of 1RM	C1: Hurdle Jumps 3 x 10
D1: Depth Jump 3 x 10 @ 30cm	D1: Split Squat Jumps 3 x 5
E1: Kettlebell Swing 3 x 8 @ 12kg +	E1: Horizontal Jumps 2 x 5

E2: Medball Chest Throw 3 x 5 @ 3-4kg	F1: Box Jumps 2 x 10
F1: Bulgarian Split Squat-Jump 3 x 5	F2: Reverse Row (barbell or slings) 2 x 5
G1: Box Jumps 3 x 10 @ max intent	
G2: Reverse Row (barbell or slings) 3 x 5	

Abbreviations: RIR, repetitions in reserve; 1RM, one-repetition maximum; 3 x 5, three sets & five repetitions; Kg, kilograms.

3.4 Test Procedure and Measurements

3.4.1 Sprint

30m sprint was measured with single-beam photocells that measures the time from 0-30m by 5m intervals (Muscle lab; Ergotest AS, Porsgrunn, Norway). The first photocell was set 30 cm above the ground and the remaining ones at a height of 1 meter above the ground, spaced at distances of 5m, 10m, 15m, 20m, and 30m. The starting line were created 30 cm behind the first photocell. Participants had 2-4 acceleration runs, gradually increasing the effort as they went along. Once they felt warmed up, they could start the test. When attempting the sprint, the participants was instructed to place their front foot on the starting line and start the sprint from a stand-still position with staggered feet. As the subject crossed the starting line, the sprint measurement began, allowing the athlete to decide when to start sprinting. The goal was to continuously increase the speed throughout the entire 30m distance. The participants were instructed in maintaining momentum and pushing themselves to go faster with each stride. Participants got 2-3 attempts with 3 minutes rest between trials. The results were retrieved from an associated software (Musclelab; Ergotest, Langesund, Norway). Sprint-times were measured in a handball hall, where the subjects had most of their regular handball sessions.

3.4.2 Counter Movement Jump

To measure counter movement jump (CMJ) the subjects performed a countermovement jump where they got instructed to hold the hands on the hips, jump as high as possible, and try to hold still in the landing. The subjects performed 2 series of 2 jumps with 30 seconds rest between each jump, and 2-3 minutes rest between each set. If they improved their score on the last jump, they got another try.

Jump height and power in each jump were measured by a force platform (Advanced Mechanical Technology, Inc. Waltham Street, Watertown, USA). The best score was noted, and the results were taken from a self-made script in Matlab.

3.4.3 Lower-body Power

Measurement of lower-body Power were conducted in a pneumatic leg press device (Keiser A3000, Keiser, Fresno; USA). By utilizing compressed air, the Keiser A3000 regulates resistance, and activates lower-body muscles throughout the entire range of motion (90-180°). The power output is displayed in watts, which is calculated based on the force applied to the resistance system and the speed at which it is moved. The system is designed to measure power output accurately throughout the entire range of motion, providing athletes with precise feedback on their performance.

At the familiarization test all participants were noted of their seat positioning, which were adjusted individually with the goal that the femur should be vertical, which corresponds to a knee joint angle of 80 ° - 90 °. At the baseline testing, the seat positions of all participants were fixed to match their familiarization test, and the Keiser leg press system settings were adjusted accordingly. The participants started with a theoretical 1RM of 150, 200, or 250kg, depending on their familiarization score. Prior to starting of the test participants had 2 very light warm-up repetitions before gradually increasing 20-30kg per repetition, based on what their theoretical 1RM was set at. Participants were instructed to stretch both legs with maximum effort in each repetition and pause time between reps were determined by relation to the increasement of resistance.

Maximal concentric speed and maximal power output were tested against 10 resistances and resulted in a 1RM test. The results were retrieved from the Keiser Software. In order to ensure that the changes in lower-body Power were of meaningful changes and not solely influenced by increased mass, the score for maximal power was divided by the individual's bodyweight (Watt/bodyweight).

3.4.4 Change of Direction

Change of direction (CoD) was measured using a timing system that records the time from start to finish after several changes of direction using the standard "A180°" test from Olympiatoppen (Brower Timing Systems, Draper, USA). Participants were given 2-3 attempts with a 3-minute break between each attempt.

The test was conducted in a handball hall, with four tapelines marked along the track: at the starting line, after 7.5 meters, after 12.5 meters, and at the finish line after 20 meters (Figure 1). Each player started in a staggered sprint stance position and initiated the run themselves. They ran to the marked line after 12.5 meters and turned 180° down to the cone at 7.5 meters. In total they performed four 180° turns before running to the finish line at 20 meters. Players covered a total of 40 meters. The test was considered valid if the player placed the foot on the piece of tape on every turn. The players were instructed to turn with alternate feet and start turning with the same feet for each time.

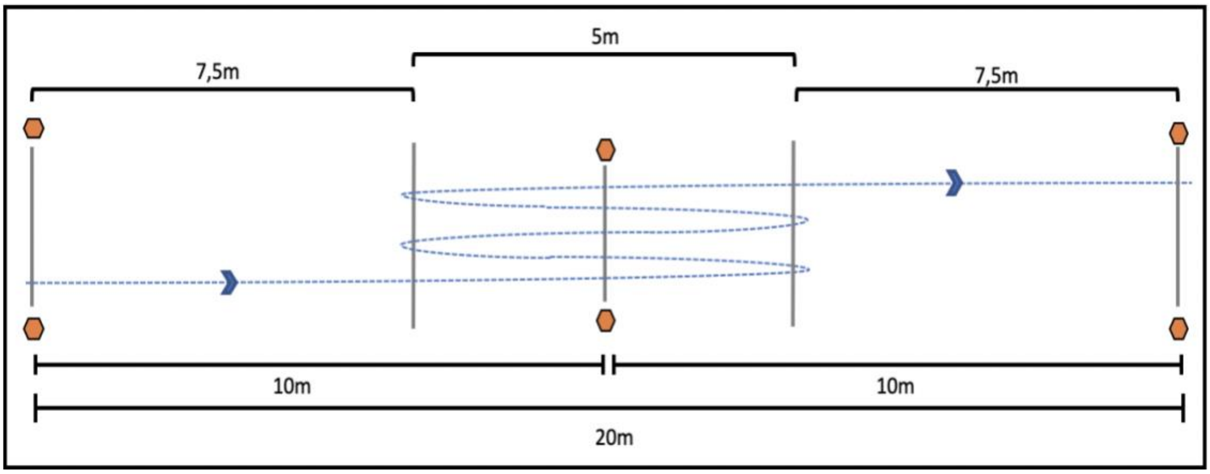

Figure 1: Illustration of A180° test. Borrowed by Eikbu (2021).

3.4.5 Inertial Movements Units

To measure high-intensity match performance, inertial movements sensors (IMU) (OptimEye S5, Catapult Sports, Melbourne, Australia) were used. These IMU´s contain an accelerometer, gyroscope, and magnetometer and collect data at 100 Hz. They measure 52 mm x 96 mm x 13 mm in size and weigh approximately 70 grams. In this study IMUs were utilized to track data directly from the accelerometer, gyroscope, and magnetometer, as opposed to Global Positioning System (GPS), or Local Positioning System (LPS), which are commonly used with the Catapult system.

Participants wore the IMU on the upper trunk in a manufacturer-supplied vest. After data acquisition, raw data from the IMU was imported into the software (OpenField, version 2.5) and converted into variables such as PlayerLoad™ and inertial movement analysis (IMA). PlayerLoad™ is a metric that measures the rate of change in acceleration, while IMA detects specific acceleration events, which are referred to as high-intensity events (HIE). The magnitude and direction of HIE were calculated and categorized into different bands (Luteberget et al., 2018). As to the previous work of Luteberget et al., (2018) an event had to be at >2.5 m·s-1 to be categorized as an HIE.

3.4.6 Match-Related 6vs6 Sessions

The subjects were measured using IMUs during 6vs6 match-related training sessions. The measurements were conducted proximally once a week in each group for the 12 weeks, and in total there were 8 recorded IMU sessions each team. The measurements were made in proximally from week 3 to week 11 of the project. The set-up of the 6vs6 IMU sessions were standardized by previous work done by Wik et al., (2017). Each handball session started with a general warm-up and a specific warm-up for handball conducted by their respective coach. How the built-up of the session before the 6vs6-part was all chosen by the handball coach. Participants engaged in game-based training 6vs6, with a duration of 5 minutes per half, in total of 10 minutes playing time. Rest periods were at 5 minutes. The 6vs6 condition featured six field players and a goalkeeper on each team, on a standard handball court (20 x 40m). The drills aimed to simulate a match-like setting, using official match rules apart from allowing the goalkeeper to have a spare ball for quick replacement. Coaches were allowed to give verbal encouragement similar to official matches. Participants needed to complete at least three monitored training sessions actively participating in 6vs6 to be included in the final analysis. Measurement 1-3 was set a pre-test, whereas measurement 6-8 was set as post-test.

3.5 Statistical Analysis

The normality was analyzed by looking at the skewness, kurtosis, and a q-q plot of the given data. An independent samples t-test was conducted to investigate the mean difference between groups in high-intensity events. Data from the t-test are presented as mean difference (MD) and standard deviation (SD) with a confidence interval of 95% and significant p-value set at an alpha level of 0.05. Furthermore, there was done a correlation matrix analysis to investigate correlation between absolute changes in HIE and absolute changes in CMJ, CoD, sprint, and relative lower-body Power. Additionally, a correlation analysis was conducted between HIEs, and a composite score derived from the performance measures. All data in the correlation analysis are presented using Pearson rank correlation coefficient (closer to 1 indicating strong positive correlation and closer to -1 indicating strong negative correlation) with a significant p-value set at an alpha level of 0.05. All statistical analysis were conducted using Jamovi 2.3 (The jamovi project 2022, *jamovi*, Version 2.3, Computer Software).

4.0 Methodical Discussion

4.1 Study Design

The aim of this study was to investigate how changes in performance measures would associate with changes in HIE for female handball players in-season. An experimental study design was conducted to examine this relationship.

To further advance studies like this, the use of IMUs on every handball session could be employed to track the total amount of HIE throughout the study period. This would allow for an examination of the correlation between the total amount of HIE and improvement in performance measures. It is possible to hypothesize that players who had most HIE throughout the study period would improve more on their sprint time and change of direction due to the Specific Adaptations to Imposed Demands (SAID) principle (Stone et al., 2007). By measuring HIE on every session throughout the study period, one can potentially mitigate the sudden increase in HIE that participants may experience when initially recruited for a study, as well as account for the day-to-day fluctuations that may occur. This approach has been recommended by previous studies to provide more accurate and reliable measurements of training load and performance outcomes (Halson, 2014).

Another interesting change would be to recruit a third group as a mixed or “complex group”, where participants were assigned a combination of heavy-load and power-plyo exercises. Complex training systems have demonstrated better outcomes than solely lifting heavy weights, according to earlier research (Sáez Sáez de Villarreal et al., 2011). Likewise, favorable results have been observed in female junior handball players with complex-strength programs (Hammami et al., 2020).

One important consideration in this study was that the participants were in-season. The competitive season can have an impact on recovery time, as handball players may experience inflammation and oxidative stress (Bresciani et al., 2010). External factors as these, as well as playing time and hectic schedules, may confound the results in an in-season study, making it more difficult to control external variables compared to a pre/off-season study. While it may not be possible to track high-intensity events in a period of no handball training, a pre-season phase may be more suited to collect meaningful changes in performance measures and provide the clearer opportunity to correlate changes with high-intensity events.

4.2 Study Sample

Statistical power, which is the sensitivity of an experiment, is the probability of rejecting a false null hypothesis. There are three factors that can impact statistical power: (a) the significance level (α), (b) the size of the treatment effect (effect size), and (c) the sample size (n). Among these factors, the sample size can be controlled by the investigator, as the significance level is typically predetermined before the study and the effect size is influenced by the efficacy of the treatment. Therefore, selecting an appropriate sample size is a crucial aspect of research design (Beck, 2013). In total 34 subjects were obtained for this study, but 3 subjects dropped out due to various reasons. By a total of 31 subjects, randomized from two different teams it can reduce the risk of type 2 errors and improve the generalizability of the study.

The subjects of this study played handball in the third highest division for females in Norway, with an average age of 20 ± 2.8. Age is an important factor when it comes to study effects of strength training interventions as it might heavily dictate the results. Individuals with a low training age may see more significant improvements in performance metrics compared to those with a higher training age. This is because individuals with a low training age have a greater potential for neuromuscular adaptation, as well as increased muscle mass and strength gains (Häkkinen & Komi, 1986). In a study by Rønnestad et al., (2011), it was shown that novice individuals (defined as having less than six months of resistance training experience) had a greater increase in muscle hypertrophy and strength gains following a 12-week strength training intervention, compared to experienced individuals (defined as having more than two years of resistance training experience) (Rønnestad et al., 2007). With a low biological average age of 20 ± 2.8 one can risk that some of the results are a matter of low-training age, and therefore can be harder to be applicable for athletes with a higher training age.

Previous research has shown that elite female handball players show a superior physique compared to lower levels players, one could therefore hypothesize that the subjects in this study were at an inferior physical level, and therefore one could easier see effect on performance measures (Pereira, Cal Abad, et al., 2018). Furthermore, previous research has analyzed the development of handball over the past eight years and found that the game has become more dynamic and rapid, particularly by European teams. The study conducted a technical analysis comparing European Championships with other tournaments and found that efficiency in fast breaks, pivot position, and back court players affected the ranking of European teams in significant international tournaments (Bilge, 2012). This study was conducted on male elite handball players, and even though it´s similarities between elite male and female handball, there are also some clear differences. When comparing the physical demands during match-play between male and female elite team handball players there has been shown that female players cover a greater total distance per match, exercises at a higher relative workload, and spend less time standing still compared to male players. However, male players receives more tackles and performs more high-intense, strength-related playing actions and high-intensity running than female players (Michalsik et al., 2014). Therefore, it’s an important notion that the findings of this study may be more applicable to female, than male handball players. Even further, it is possible to hypothesize that athletes at lower playing levels have less intense handball sessions, which may affect the generalization of measurements of HIE and its correlation with changes in performance metrics. While the findings of this study may be applicable to other female third division teams, their applicability to female handball players at a higher level may be questionable.

4.3 High-Responders & Low-Responders

In order to interpret individual data from group-based interventions, researchers must take into account measurement error and biological variability and utilize tools such as confidence intervals (CIs) and smallest worthwhile change (SWC) to determine meaningful changes. SWC refers to the minimum change in the outcome variable that is worth pursuing, in terms of time, resources, and effort required to achieve it. Usually expressed as a percentage of the baseline value, SWC is used to evaluate the clinical significance of the observed change. Changes that fall below the SWC are deemed insignificant or not worth pursuing (Swinton et al., 2018). To evaluate worthwhile changes on the performance measures there was used an SWC of 0.3, which means that a change in the outcome variable of at least 0.3 times the baseline value is considered meaningful or worthwhile. Similarly, each test´s CV was assessed to indicates less variability and greater consistency in the data. Calculated by computing the difference score for each participant, followed by calculation of the standard deviation of these different scores, and finally dividing the results by 2¯√ (Swinton et al., 2018).

Previous studies commonly uses a value of 0.2; however, using a stricter requirement of 0.3 ensures that changes exceeding 0.3 SWC are considered meaningful (Swinton et al., 2018). SWC and CV are crucial factors in this paper as the groups were pooled on these calculations. Subjects which achieved changes in SWC and CV exceeding 0.3 times the baseline value in 3 out of 4 measurements of either sprint, CoD, Keiser Power or/and CMJ, where grouped into high-responders, whereas subjects who experienced changes < 0.3 were grouped into low-responders. By imposing rigorous SWC and CV criteria, it is ensured that any observed changes are meaningful and significant in terms of performance enhancement.

The rigorous criteria to be included in the high-responders group meant that less people were likely to be pooled into high-responders group, which might affect the statistical power as mentioned earlier can be affected by sample size.

4.4 Training

4.4.1 Duration

The average intervention period for strength training studies is approximately 10 weeks, with one exception of a 25-week intervention from Rønnestad et al., (2010).
Most of the current knowledge on neurological and structural adaptations in strength training comes from short-term (8-12 weeks) interventions involving relatively untrained or inexperienced individuals (Kraemer & Ratamess, 2004). The duration of an intervention period required to observe changes in CMJ, sprint, and CoD performance can vary depending on several factors such as training volume, intensity, frequency, and the initial level of performance. However, some studies have reported significant improvements in CMJ, sprint, and CoD performance from anything within 4-12 weeks of training intervention (Ramírez-Campillo et al., 2014), (Lloyd et al., 2014). This present study was conducted in a 12-week period with subjects who were trained individuals. Which based on previous studies is seen upon more than sufficient to see potential results on CMJ, sprint and CoD performance.

4.4.2 Volume between groups

Previous studies done on heavy-load versus plyometrics training in athletes has shown heavy-load as a superior stimulus to see effects on power and jump height (Aghajani et al., 2014), Contradictory to this, studies has shown equal effects on leg power and CMJ, when programs is designed and implemented correctly, as well as with equated Volume (Sáez Sáez de Villarreal et al., 2011). There has also been shown similar effects in CMJ and sprint speed in studies looking at heavy-load versus plyometrics in young female handball players (Falch et al., 2022). In newer reviews on plyometric training compared to heavy-load, there has also been shown that plyometric-training can produce similar effects on hypertrophy, as resistance training, when volume is equated (Grgic et al., 2021).

Therefore, it was important to equate volume between groups and ensure that the programs were performed correctly with the right intent. To achieve this, both groups had roughly the same distribution of sets per targeted muscle group per session, with heavy-load having 6-8 heavy sets on quadriceps and glutes in session A, and power-plyo having 3 times as many targeted sets in session A. In session B, heavy-load had four heavy sets while power-plyo had

3 times as many sets. When resistance training is equated for volume, including both multi-joint and isolation exercises, there is no significant impact of resistance training frequency on muscle strength gain (Ralston et al., 2018). Therefore, for this study, it was sufficient for the subjects to have two strength sessions per week, accompanied by their regular handball games and practices. Other studies have looked at total Joule when comparing training modalities as power vs heavy-load, but for this study, performing the entire workout on a Force Plate with encoder was deemed too time-consuming and costly.

4.4.3 Execution of training

In this training intervention, several factors were taken into consideration to optimize the participants' resistance training adaptations. The heavy-load group, for instance, used the Reps in Reserve (RIR) method to prescribe loads. This method focuses on the number of remaining repetitions at the end of a set and may offer a more precise measurement of intensity, especially during near-limit loads (Helms et al., 2016). Every exercise in the program had a described RIR to hit, usually 1 or 3RIR. The participants also had supervision from a coach who assisted them in finding the proper load from the given RIR, in terms of intention and technique. To measure the velocity of the barbell during lifts, a Velocity Tracker (Vmax Pro) was used.

In weight training, intention, especially when it comes to power, can be detrimental in seeing improvements from a training intervention (González-Badillo et al., 2014). Research suggests that performing exercise repetitions at maximum intended velocity can lead to greater improvements in 1RM and power compared to submaximal repetitions, due to the enhanced firing rate of motor units and the stimulation of the highest threshold type of muscle fiber (Kaifang et al., 2021). Several benefits come with using velocity-monitoring systems in strength training. Firstly, it can be used to estimate the 1RM and adjust the intensity of the session in real-time. Secondly, monitoring velocity loss during a training set can help control the level of effort and fatigue within a specific range and ensure that lifted repetitions are in line with the intended training specificity. Finally, receiving instantaneous augmented feedback on velocity after each lifting repetition can motivate athletes to improve their acute physical performance and enhance cumulative adaptation (Kaifang et al., 2021).

In this intervention, both groups were instructed in the use of Vmax Pro and used it accordingly with the supervision of a coach. When using the Vmax Pro, the main intention was to monitor velocity on the concentric phase of a lift using m/s. A study done by Gonzalez-Badillo and colleagues (2015) proposed velocity ranges for different types of strength training. For instance, maximal strength should be 0.75 m/s or slower, strength-speed 0.75-1.0 m/s, speed-strength 1.0-1.3 m/s, and maximum power 1.3-1.5 m/s.

On the heavy-load session, the Vmax Pro was used to measure the m/s on the concentric phase and determine if the athlete could increase or decrease in weight. The coach could then guide how heavy the subject should lift using the data from Vmax Pro, combined with the subjective feeling from the subject and the objective view from the coach. This was also what the power-plyo group aimed to do in their given lifts, such as jumping back squats or push jerks. The power-plyo exercises were aimed to have a velocity of 0.75 m/s or higher.

4.5 Measurements

4.5.1 Sprint

The ability to sprint fast can be crucial in high-paced sport like handball. Previous research has shown that sprint performance is significantly correlated with lower-body muscular power and anaerobic capacity in handball players. Sprint-times has also been seen previously to be highly related to other physical measures, such as muscle strength and power, anaerobic capacity, and agility (Michalsik et al., 2014). Therefore, to be able to have a valid and reliable measures of sprint times are therefore indispensable for identifying authentic improvements in sprinting capabilities (Haugen et al., 2014). To ensure validity, it is essential to select a sprint test that accurately measures the desired sprint performance in question. In handball, athletes typically do not run continuously for more than 30 meters (Wik et al., 2017). Thus, to obtain a valid sprint test for handball players, it is crucial to keep the distance within the typical range of the sport. Moreover, taking measurements every 5 meters can enhance the reliability of the test results and provide further insights into the characteristics of the subjects' sprint times, thereby strengthening its validity. To measure sprint performance in the conducted study there were used a single-beam timing system which noted every 5 meters from 0-30 meters. Preferably one would use an a double-beamed system as its shown to have higher reliability than a single-beam timing system (Haugen et al., 2014). But as it were controlling for arm and leg movements, it has been previously shown that coefficient of variation (CV) for 0-20m and 20-40m sprint times was 0.4% and 0.7%, respectively, while the standard error of the mean

(SEM) was 0.01 seconds for both distances. But during regular sprinting (without controlling for arm and leg movements), the CV increased to 1.4% and 1.2% for 0-20m and 20-40m segments, respectively, with the SEM at 0.02 seconds for both. No bias was observed for 20-40m sprint times, but single beam timing produced 0.02 seconds slower 0-20m sprint times compared to double beam timing ($p < 0.01$) (Haugen et al., 2014). For that reason, it was important to control the arm and leg movements, so it wouldn't become a confounding factor in the sprint times.

Another possible confounding factor in sprint times is the starting procedures and triggering devices employed, which can cause significantly larger variations in sprint time than the effects typically attributed to several years of training. Hence, the participants were directed to assume an athletic starting stance and commence the sprint by themselves to that one removed potential difference in reaction time (Haugen & Buchheit, 2016).

Environmental factors like air resistance, running surface and footwear might also impact sprint times. The magnitude of air resistance exerted on an object depends on factors such as its speed in relation to the air, its shape and size, the surface area exposed to the air current, and the density of the air in the surrounding environment. Whereas specific footwear might improve mean performance in 20-40 m sprint by 0.7% (Haugen & Buchheit, 2016). Therefore, the test was completed in the handball hall where they did most of their matches and trainings, so the environment was specific to their everyday training regimen. This increases the test's reliability because of the potential learning effect that's removed by the subjects sprinting on an unusual environment and surface. Participants also used the same shoes as they usually train handball in.

4.5.2 Countermovement Jump

Validity requires a given test to provide relevant numbers that accurately reflect the desired performance improvement. Previous studies has shown a correlation between an athlete's Countermovement Jump (CMJ) and playing level and performance factors such as sprinting (T. Haugen & Seiler, 2015; Loturco et al., 2015; Wagner et al., 2018). Which suggests a CMJ test is of high validity for athletes. On the other hand, reliability ensures that the equipment used to measure vertical jump produces reproducible results over multiple attempts (Markovic et al., 2004). Measured CMJ through Force Plate is the preferred measurement of jumping ability within Olympiatoppen, and has in previous studies shown high test-retest reliability, with intra-class correlation coefficients ranging from 0.91 to 0.99, indicating good to excellent reliability (Cormack et al., 2008)

The CMJ test is commonly measured using a force platform that gauges the amount of force the subject exerts on the ground, or through a device that measures flight time (i.e., the time spent in the air). The force platform is regarded as the gold standard for measuring CMJ, due to its minimal limiting factors such as landing and technique, which strengthens its validity. Although devices that measure flight time are also valid, there may be variations in results depending on the type of device used and the execution method (Castagna et al., 2013). The subjects in this study tested CMJ on a Force Plate (Advanced Mechanical Technology, Inc. Waltham Street, Watertown, USA), and were instructed to go to preferred squat depth and jump as high as possible and try to stand still in the landing. Even though they got instructed to stand still in the landing, how they landed were of no importance. A limiting factor might be that the athletes counter movement depth weren´t standardized, as this might affect jump height (Castagna et al., 2013).

4.5.3 Lower-Body Power

Producing force across various velocities is a crucial aspect in most sports. To evaluate this ability, the Keiser leg press that uses pneumatic resistance has been utilized in this study. Previous research conducted by Redden et al., (2018) showed good reliability of maximal resistance, velocity, force pushed, average and peak power outputs when using the Keiser seated leg press to evaluate soccer players, with an intraclass correlation coefficient of >0.762 and acceptable typical percentage errors (<6.9%) (Redden et al., 2018). Compared to weight-based exercises, the pneumatic leg press offers minimal influence from inertia and body weight, which provides several benefits. Firstly, it eliminates the need to decelerate a large mass when performing maximal attempts. Secondly, it makes it possible to assess extremely low resistances since the resistance is not influenced by acceleration (Lindberg, Eythorsdottir, et al., 2021). To secure even more reliability the test participants had a familiarization test week prior where the participants seating positioning were noted to be the same as baseline testing. Performing strength and power tests while moving from a seated position with elevated feet allows for offloading and utilizes movements that are more applicable to sports, as compared to isokinetic dynamometry.

4.5.4 Change of Direction

Handball players are required to accelerate, decelerate, and change direction during the game in response to different stimuli, such as the movements of an opposing player or the ball itself (Hermassi, 2011). In elite handball CoD is one of the most frequent activities, and when combining both attack and defense a player might perform 30 CoD activities during a game (Pereira, Cal Abad, et al., 2018). Previous research has also shown that CoD ability is significantly related to neuromuscular performance (i.e., Squat Jump, CMJ, mean propulsive power in loaded squat jump, and sprinting velocity in 5, 10, and 20 m). For this reason, a valid and reliable measurement of one's physical ability to change direction is essential for understanding the physical requirements and capacities of handball athletes (Pereira, Nimphius, et al., 2018).

To this date, no studies have investigated the reliability of the A180° test, which could limit the ability to categorize performance levels for handball players. However, this has been examined in a similar test (S180°) as well as the S90° test, which has been shown to have good reliability with CV values of 5.1% and 2.9%, respectively (Sporis et al., 2010).

Furthermore, the A180° test has similarities as to the CoD movement seen in a handball game (i.e., counter attacks and movements in defense) but further research needs to be conducted to measure its validity as a CoD test for female handball players. It would have been interesting to incorporate an additional feature into the CoD test by having the participants wear their IMUs during the test. This would allow for an analysis of the inter-rater reliability between the CoD measures obtained from the IMU device and those obtained from the A180° test.

4.5.5 IMU Catapult System

Live and colleagues (2018) has previously established reliability and sensitivity of the IMU device from Catapult Sports using the coefficient of variation (CV) and smallest worthwhile difference (SWD). Findings indicate good reliability of Inertial Movement Analysis (IMA) magnitude in controlled tasks (CV=3.1%) but increased in complex tasks (CV=4.4-6.7%). In the field, total IMA counts (CV=1.8%, SWD=2.5%), PlayerLoad (CV=0.9%, SWD=2.1%), and associated variables (CV=0.4-1.7%) demonstrated good reliability. However, IMA CV increased when categorized by intensity bands (CV=2.9-5.6%). Overall, OptimEye's inertial measurement unit and software are sensitive for team handball as IMA counts showed good reliability when displayed as total, high, or medium/high counts, and PlayerLoad and associated variables demonstrated good reliability well below the SWD (Luteberget et al., 2018). To ensure the validity of the IMU system in handball practice, the subjects and handball coach received instructions to approach the 6vs6 sessions as a real game. While their handball coach executed the 6vs6 session, an instructor was present to ensure that the sessions went as planned, note player substitutions, injuries, unforeseen situations, and the structure of the handball practice. This approach strengthened the validity of the IMU system as it ensured that factors such as playing time, injuries, and deviations were noted. However, a limitation of the IMU session's validity was that the recordings were done at different times during the weekly micro-cycle for the respective teams. To improve the validity, it would have been better to record the sessions on the same day each week for both teams with similar handball session structure. By following the same protocol for the 6vs6 part on both teams each week, the validity would´ve improved.

While one of the study's strength lies in the duration of the strength training intervention, the duration of the IMU sessions is considered a significant weakness. Past research on female handball players using IMUs utilized 10 and 9 recorded sessions respectively (Luteberget, Trollerud, et al., 2018; Luteberget & Spencer, 2017). Although this study recorded 8 sessions for each team, which is comparable to previous research, the number may not be sufficient to detect significant changes in high-intensity events related to the training intervention. The present study aims to track changes in HIE over time, as opposed to examining factors such as performance demands and activity profiles, which were explored in previous research conducted by Luteberget and colleagues. Even though HIE scores are generally consistent within a player across multiple sessions, there can be some variability in HIE scores between sessions. This variability could be due to factors such as changes in playing position, tactical demands of the game, and fatigue (Wiig et al., 2019). Thus, increasing the duration of the study and recording more sessions can help to mitigate the potential effects of confounding factors on HIE scores.

In order to gather pre-and post-scores of the number of HIE throughout the measurement period, the pre-test was set to include measurements 1-3 and the post-test was set to include measurements 6-8. Additionally, to be included in the analysis, each subject had to have a minimum of three recorded IMU sessions. This resulted in some players having only one recorded session at pre-test and three recorded sessions at post-test, or vice versa, which could potentially affect the average score pre-to-post test results due to the limited duration of the study. To obtain more valid results, the inclusion criteria could have been set to a minimum of four recorded IMU sessions for each subject, with at least two recordings both pre-and post-test. This would have allowed for a smaller sample size but less variability in the results.

4.6 Main strength and limitations

The main strength of this study was the close follow up of the subjects and it´s valid and reliable measurement devices. An additional strength was the strict requirements of SWC and CV to ensure that the changes seen in performance measures where meaningful changes. However, in terms of the study's objective to investigate the relationship between changes in performance measures and changes in HIE, it is important to note that the duration of the IMU 6vs6 sessions might be a limiting factor. The duration of measurements may not be long enough to detect significant changes and minimize potential fluctuations. Additionally, implementing a more standardized training protocol within each team's respective micro-cycle would enhance the validity of the HIE results. Including a third control group would enable assessment of whether changes in HIE were affected by the training intervention, thereby serving as a major strength in researching the correlation between two variables, namely changes in performance measures and HIE.

5.0 References

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PART 2

RESEARCH PAPER

Relationship between resistance training-induced changes in Power, Change of Direction, Sprint, Jumping abilities and match-related handball performance in female players during season

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Abstract

Purpose: The purpose of this study was to investigate the relationship between resistance training-induced changes in lower-body Power, sprint, change of direction, jumping abilities and changes in match-related handball performance during season in female handball players.

Methods: Twenty-five female handball players from the third highest level in Norway completed a 12-week strength- and power training intervention. Players were subsequently pooled into high-responders (n=7) and low-responders (n=18) based on pre-post changes in four tests; lower-body Power (pneumatic device), countermovement jump height (CMJ), sprint (30m) and change of direction (CoD) times (4x180° turns). High-responders were defined as players who improved in 3 of the 4 tests, surpassing both each test´s smallest worthwhile change and coefficient of variation. Match-related handball performance were measured as High-Intensity Events (HIE) proximally once a week during 6vs6 match-related sessions for 10min (5minx2).

Results: There were revealed no significant differences between groups in HIE-changes from pre-to post (high-responders: -3.44 ± 8.88 vs low-responders: -0.211 ± 9.22, p= 0.435). Furthermore, a correlation analysis on changes in performance measures (lower-body Power, CMJ, 30m sprint, COD) and changes in HIE revealed no significant correlation between the variables (r=-0.127, p= 0.553).

Conclusion: Our findings suggest that resistance training-induced changes in performance measures does not correlate with changes in HIE among female handball players in-season.

KEYWORDS

Inertial movement units, handball, Catapult System, neuromuscular.

1 Introduction

Team handball (handball) is a highly physically demanding team sport that requires players to be able to perform a wide range of physical activities such as sprinting, jumping, throwing, hitting, blocking, pushing, while also managing endurance demands and technical and tactical aspects of the game [1]. In an average game, players may need to execute over 140 high-intensity actions, including duels, sprints, jumps, changes of direction, and breaking actions [2]. The literature has repeatedly shown that elite handball players, both male and female, possess superior physical abilities in terms of throwing velocity, jump qualities, sprint, lower-body Power, and 1 repetition maximum (1RM) bench press compared to amateur players [3–5]. Previous studies have demonstrated that in-season strength programs can lead to improved sprint and jump capabilities in male elite handball players [6,7]. Limited studies have been conducted on this topic regarding female handball players, but one study showed that a strength program consisting of strength, endurance, and sprint training in-season led to improvements in isometric strength, maximal velocity sprint, and endurance in eight elite female handball players [8]. However, further research is needed to determine the effects of resistance training on female handball players in-season, and even further, how this effect might impact changes in performance measures such as Power, change of direction (CoD), sprint-and jumping abilities.

Based on prior research conducted on handball players, it has previously been hypothesized that an improvement in standardized performance measures, such as Power, sprint, CoD and jumping abilities could be advantageous for handball players wanting to improve their on-court performance [4,9,10]. To this date however there is a clear missing link in the literature on how these effects of improvement in standardized performance measures are interrelated towards on-court performance in handball. Previous studies have commonly used time-motion analysis or distance covered to measure on-court performance, which can be both time consuming, inaccurate of predicting playing level and can depend on the subjective analysis of the observer [11]. In recent times however there has been a rise in measurement of on-court performance in handball by using wearable inertial movement units (IMUs). These devices facilitate detailed movement analysis and can provide information on each player's total amount of acceleration, deceleration, and change of direction during games or training, referred to as high-intensity events (HIE) [12]. Previous research has commonly shown the positional and individual differences in HIE for female elite handball players. Yet, to the best of our knowledge, no study has examined whether changes in Power, CoD, sprint, and jumping abilities relate to changes in match-related performance in female handball players during season [12]. The purpose of this study was therefore to investigate the relationship between resistance training-induced changes in performance measures and changes in match-related performance, as HIE, for female handball players in-season. It was hypothesized that changes in lower-body Power, CoD, sprint, and jumping abilities would correlate with changes in HIE. Furthermore, it was expected that the subjects with the largest improvement in performance measures would display a greater increase in the number of HIE compared to those of an inferior improvement.

2 Materials and Methods

Study Design

The present study used an experimental study design to investigate the relationship between resistance training-induced changes in performance measures and changes in HIE during season. Firstly, subjects performed a 12-week resistance training intervention as either high-load or power-plyo group. Subjects were then pooled into either high-responders or low-responders based on their results from pre-to post-test in relative lower-body Power, CMJ, CoD and 30m sprint. High-responders were defined as players who improved in 3 of the 4 tests, surpassing both each test´s smallest worthwhile change (SWC) and coefficient of variation (CV). Subjects had to achieve changes in SWC exceeding 0.3 times the baseline value, as well as passing each test´s CV by the process of computing the difference score for each participant, followed by calculation of the standard deviation of these different scores, and finally dividing the results by 2‾√. Later, the tests of Power, CMJ, CoD and sprint were grouped as “performance measures” and calculated to a composite score. To measure match-related handball performance, subjects wore proximally once a week a Catapult System vest with IMUs to measure HIE through a match-related 6vs6 session of 2x5 minutes play. The recorded 6vs6 sessions were of a total of 8 sessions, ranging from proximally week 3 to week 11.

Subjects

The subjects for this study were female athletes recruited from two handball clubs playing in the third highest national level in Norway. The total number of participants were n=25.

Table 1. Group and subject characteristics

Mean ± SD	**High-Responders**	**Low-Responders**
N	7	18
Age (yrs)	20.3 ± 2.6	19.4 ± 2.4
Height (cm)	172.1 ± 7.2	169.1 ± 5.8
Weight (kg)	67.6 ± 8.1	69.8 ± 13.1

Match-Related 6vs6 Sessions

The IMU´s which was used in this study contain an accelerometer, gyroscope, and magnetometer and collect data at 100 Hz (OptimEye S5, Catapult Sports, Melbourne, Australia). They measure 52 mm x 96 mm x 13 mm in size and weigh approximately 70 grams.

Each handball session started with a general warm-up and a specific warm-up for handball conducted by their respective coach. How the build-up of the session before the 6vs6-part was all regulated by the handball coach. The 6vs6 sessions featured six field players and a goalkeeper on each team, on a standard handball court (20 x 40m). The drills aimed to simulate a match-like setting, using official match rules apart from allowing the goalkeeper to have a spare ball for quick replacement. The sessions were standardized by previous work done on 6vs6 sessions in handball players [13]. While their handball coach executed the 6vs6 session, an instructor was present to ensure that the sessions went as planned, note player substitutions, injuries, unforeseen situations, and the structure of the handball practice. Recordings were made in different days of the weekly micro-cycle as result of logistical reasons. Participants needed to complete at least three monitored training sessions actively participating in 6vs6 to be included in the analysis. Measurement 1-3 were set a pre-test, whereas measurement 6-8 were set as post-test.

Sprint

30m sprint was measured with single-beam photocells that measures the time from 0-30m by 5m intervals (Muscle lab, Ergotest AS, Porsgrunn, Norway). The first photocell was set 30cm above the ground and the remaining ones at a height of 1 meter above the ground, spaced at distances of 5m, 10m, 15m, 20m, and 30m. The starting line were created 30 cm behind the first photocell. Participants had 2-4 acceleration runs, gradually increasing the effort as they went along. Once they felt warmed up, they could start the test. When attempting the sprint, the participants was instructed to place their front foot on the starting line and start the sprint from a stand-still position with staggered feet. As the subject crossed the starting line, the sprint measurement began, allowing the athlete to decide when to start sprinting. The goal was to continuously increase the speed throughout the entire 30m distance. The participants were instructed in maintaining momentum and pushing themselves to go faster with each stride. Participants got 2-3 attempts with 3 minutes rest between trials. The results were retrieved from an associated software (Musclelab, Ergotest, Langesund, Norway). Sprint-times were measured in a handball hall, where the subjects had most of their regular handball sessions.

Countermovement Jump

To measure counter movement jump (CMJ) the subjects performed a CMJ where they got instructed to hold the hands on the hips, jump as high as possible, and try to hold still in the landing. The subjects performed 2 series of 2 jumps with 30 seconds rest between each jump, and 2-3 minutes rest between each set. If they improved their score on the last jump, they got another try. Jump height and power in each jump were measured by a force platform (Advanced Mechanical Technology, Inc. Waltham Street, Watertown, USA). The best score was noted, and the results were taken from a self-made script in Matlab.

Lower-body Power

To measure lower-body Power, a pneumatic leg press device (Keiser A3000, Keiser, Fresno; USA) was utilized. The system utilizes compressed air to regulate resistance and activate lower-body muscles throughout the entire range of motion (90-180°). The power output is displayed in watts, which are calculated based on the force applied to the resistance system and the speed at which it is moved, providing athletes with precise feedback on their performance. During the familiarization test, participants were individually adjusted for seat positioning to ensure that the femur was vertical, corresponding to a knee joint angle of 80°-90°. At baseline testing, the seat positions of all participants were fixed to match their familiarization test, and the Keiser leg press system settings were adjusted accordingly. The participants began with a theoretical 1RM of 150, 200, or 250kg, depending on their familiarization score. Prior to starting the test, participants completed 2 light warm-up repetitions, gradually increasing 20-30kg per repetition based on their theoretical 1RM. Participants were instructed to stretch both legs with maximum effort in each repetition, and the pause time between reps was determined by the resistance increase. Maximal concentric speed and maximal power output were tested against 10 resistances, resulting in a 1RM test. The results were retrieved from the Keiser Software. In order to ensure that the changes in lower-body Power were of meaningful changes and not solely influenced by increased mass, the score for maximal power was divided by the individual's bodyweight (Watt/bodyweight).

Change of Direction

Change of direction (CoD) was measured using a timing system that records the time from start to finish after several changes of direction using the standard "A180°" test from Olympiatoppen (Brower Timing Systems, Draper, USA). Participants were given 2-3 attempts with a 3-minute break between each attempt. The test was conducted in a handball hall, with four tapelines marked along the track: at the starting line, after 7.5 meters, after 12.5 meters, and at the finish line after 20 meters. Each player started in a staggered sprint stance position and initiated the run themselves. They ran to the marked line after 12.5 meters and turned 180° down to the cone at 7.5 meters. In total they performed four 180° turns before running to the finish line at 20 meters. Players covered a total of 40 meters. The test was considered valid if the player placed the foot on the piece of tape on every turn. The players were instructed to turn with alternate feet and start turning with the same feet for each time.

Training Programs

All subjects were divided into two groups, either high-load or power-plyo. Training sessions were conducted twice a week for a duration of 12 weeks, with weekly supervision. The supervisor assisted the subjects in correct lifting technique, proper intention, and measured the velocity of various lifts such as squats, push jerks, and bench press. The velocity measurements were taken using a Vmax Pro (Vmaxpro Inc, San Francisco, USA). The high-load group carried out 2-6 sets for each muscle group at 80-85% of their one-rep maximum

(1RM). Whereas, the power-plyo group completed 2-4 sets of 3-6 power exercises at ≤50% of their 1RM and additionally performed 75-90 bodyweight jumps.

3 Statistical Analysis

The normality was analyzed by looking at the skewness, kurtosis, and a q-q plot of the given data. An independent samples t-test was conducted to investigate the mean difference between groups in high-intensity events. Data from the t-test are presented as mean difference (MD) and standard deviation (SD) with a confidence interval of 95% and significant p-value set at an alpha level of 0.05. Furthermore, there was done a correlation matrix analysis to investigate correlation between absolute changes in HIE and absolute changes in CMJ, CoD, sprint, and relative lower-body Power. Additionally, a correlation analysis was conducted between HIEs and a composite score derived from the performance measures. All data in the correlation analysis are presented using Pearson rank correlation coefficient (closer to 1 indicating strong positive correlation and closer to -1 indicating strong negative correlation) with a significant p-value set at an alpha level of 0.05. All statistical analysis were conducted using Jamovi 2.3 (The jamovi project 2022, *jamovi*, Version 2.3, Computer Software).

4 Results

Initially, 34 subjects were tested at baseline. However, three subjects dropped out, and one were excluded from the study due to non-compliance with attendance on IMU sessions and one subject was excluded due to incorrect IMU data. Upon further inspection of the data, we found that the IMU measures for this participant were unreliable and did not accurately reflect their movements during the study tasks. As a result, we made the decision to exclude this subject from our final analysis to ensure the integrity of our results. In addition, four goalkeepers were excluded as they did not have any recordings on HIE. As a result, the final sample size was reduced to N=25. Whereas by the inclusion criteria of passing each test´s SWC and CV, the high-responders were N=7 and low-responders N=18. Shown in figure 1 & 2 is the absolute changes in performance measures within groups high-and-low-responders.

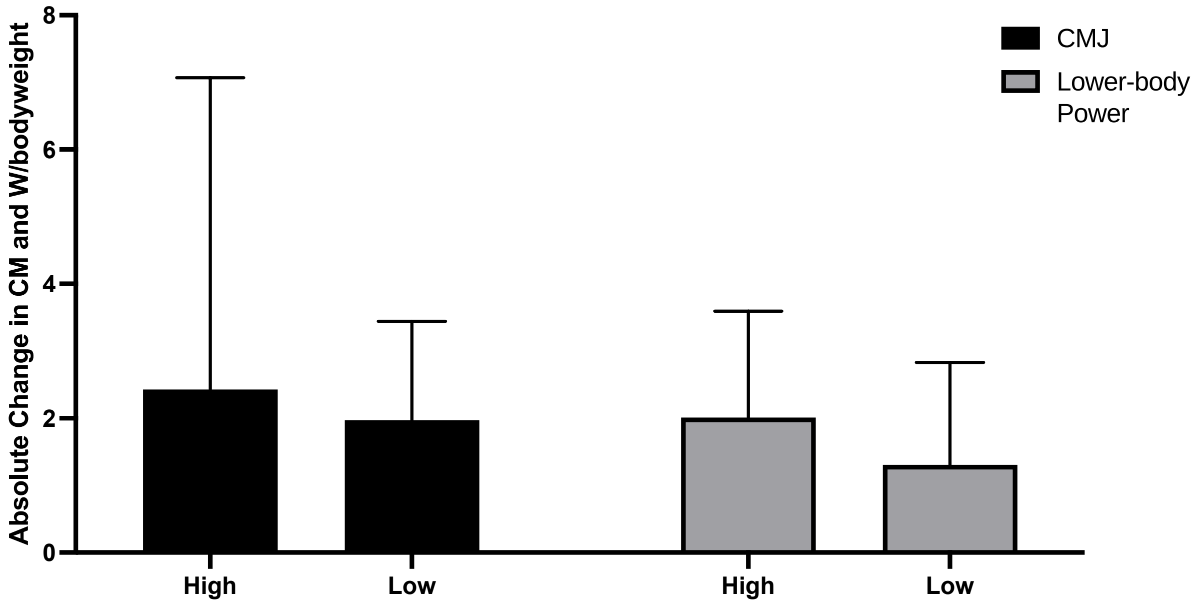

Figure 1: Absolute within-group pre-post changes in CMJ and lower-body Power.
Note: High: High-Responders, Low: Low-Responders, W: Watt.

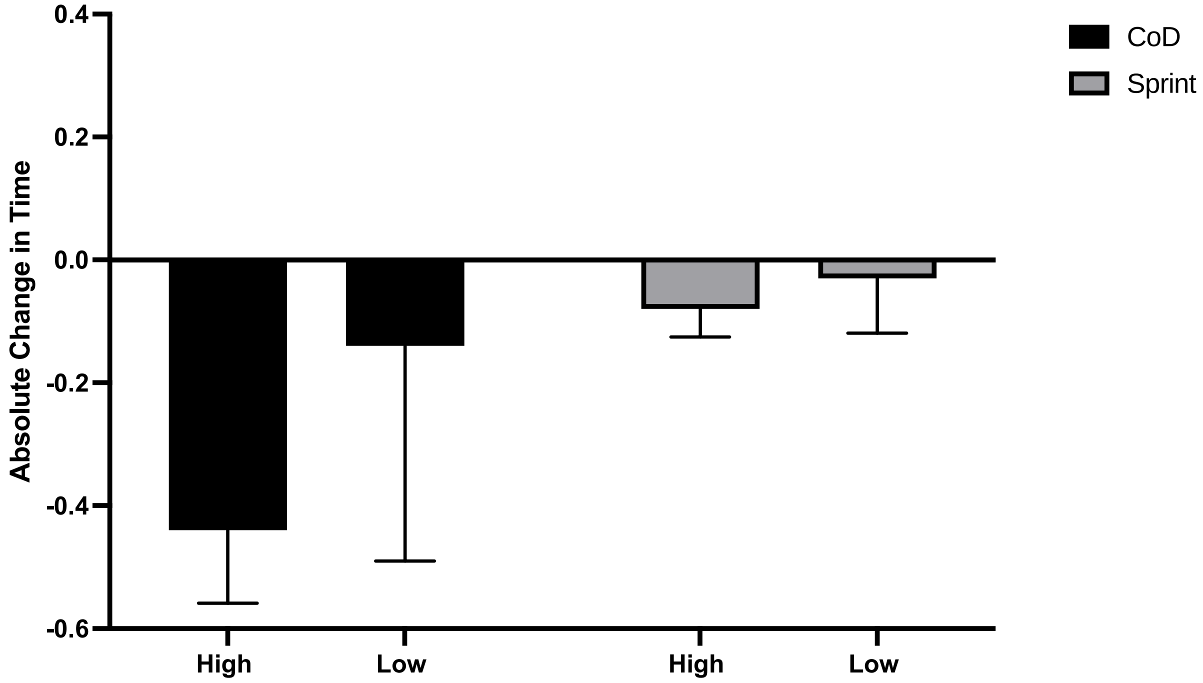

Figure 2: Absolute within-group pre-post changes in CoD and sprint.
Note: High: High-Responders, Low: Low-Responders.

High-Intensity Events & Performance data

Analysis of the data revealed no significant difference in absolute changes in HIE between groups (p= 0.435, table 2).

Table 2. Absolute pre-post group changes in high-intensity events

Groups	M ± SD	MD	p	95% Confidence Interval	
				Lower	Upper
High-Responders	-3.44 ± 8.88	-3.23	0.435	-11.7	5.19
Low-Responders	-0.211 ± 9.22				

Abbreviations: M: median, SD: standard deviation, MD: mean difference, p: p-value

Pre-test was set at measurement 1-3, whereas post-test was set at measurement 6-8. Absolute changes in HIE from pre-post between groups are shown in Figure 3.

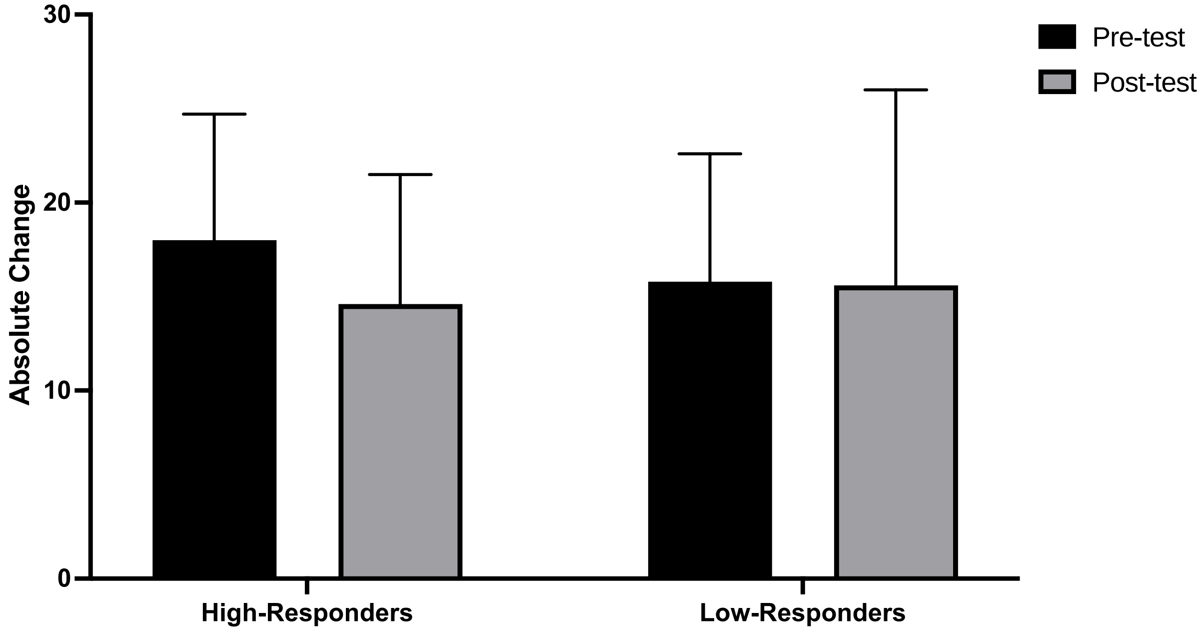

Figure 3: Absolute within-group pre-post changes in high-intensity events.
Note: Y-axis = Amount of absolute High-Intensity events

In total, high-responders had an average of 2.5±0.41 HIE·min-1 on all the eight measurements, whereas low-responders had an average of 2.8±0.23 HIE·min-1. Additionally, the total average of HIE·min-1 in all subjects were 1.6±0.32 HIE·min-1.

The absolute changes in HIE between groups through all measurement are illustrated in Figure 4.

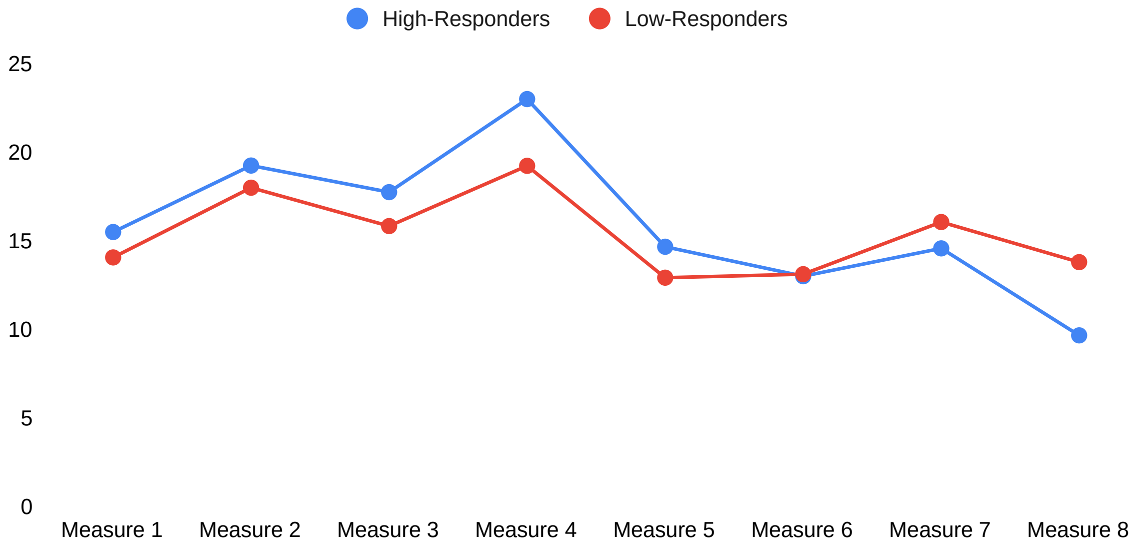

Figure 4: Absolute changes in high-intensity events from measure 1-8. Note: Measure 1-3 = pre-test, measure 6-8 = post-test.

No significant correlation was observed between the changes in HIE and changes in CMJ, sprint, CoD, or relative lower-body Power (Table 3). All results are presented as changes in each respective variable up against each other.

Table 3. Correlation between changes in HIE and changes in each performance measure variable.

		HIE	**CMJ**	**Lower-body Power**	**CoD**	**Sprint**
HIE	Pearson´s r p-value	-				
CMJ	Pearson´s r p-value	-0.217 0.309	-			
Lower-body Power	Pearson´s r p-value	-0.068 0.748	0.388 0.061	-		
CoD	Pearson´s r p-value	0.199 0.351	-0.047 0.830	-0.173 0.419	-	
Sprint	Pearson´s r p-value	0.115 0.584	-0.181 0.396	-0.256 0.217	0.169 0.431	-

*Note: *p < .05, ** p < .01, *** p < .001*
Abbreviations: HiE: High-intensity events, CMJ: Countermovement jump, CoD: Change of direction.

Additionally, no correlation was observed between absolute changes in HIE and absolute changes in performance measures as a composite score (r=-0.127, p= 0.553).

5 Discussion

Our primary objective was to examine the impact of in-season resistance training on performance measures and their relationship with changes in HIE. Although improvements in performance measures were observed in both groups, there were no correlation found between the changes in performance measures and changes in HIE. Interestingly, we hypothesized that those who demonstrated the greatest improvement in performance measures (high-responders) would also exhibit a greater increase in HIE, but our results demonstrated the opposite. Both groups saw no changes in HIE from pre-to post-test, more specifically, low-responders exhibited a lesser decrease in HIE compared to high-responders. The intended relationship between performance measures and the number of HIE can be an interesting topic of interest in relation to the results of this study. The extent to which they reflect each other and whether it is natural to expect higher HIE with greater physical capacity is worth discussing further in depth.

Relationship between HIE & Performance Measures

Previous studies have shown a positive correlation between improved change of direction time and agility performance in soccer players [14], faster sprint times and improved performance in handball-specific actions [15], as well as the effectiveness of improving energy utilization through enhanced muscular power. [16]. These factors collectively contribute to the ability to display high amounts of HIE. Based on this previous research, one could hypothesize that individuals who demonstrated improvements in their performance measures would likely exhibit an increasement in HIE. But the findings of this study, which showed no significant differences between high-responders and low-responders in changes of HIE dismiss parts of this hypothesis. One potential explanation of this dismission is a well-studied phenomenon in sports science where resistance training might enhance running economy, allowing athletes to perform tasks such as sprints, CoD, and jumps with less effort [17]. This might explain why high-responders in the current study showed superior improvements in performance measures but did not exhibit the same superiority of changes in HIE. On the other hand, there are opposing viewpoints that challenge the notion of a direct correlation between performance measures and HIE. They argue that on-court performance, such as HIE, is not solely dependent on physical capacity but rather relies on various factors, including technique, skill, training specificity, and even psychological factors like motivation and mental focus [2]. By following this line of thinking one could propose that individuals could achieve high levels of HIE despite having lower physical capacities if they possess exceptional technique or strategic advantages in their specific sport or activity. However, a more plausible explanation to the lack of significant differences between group-changes could be that the duration of IMU recorded sessions was not long enough to observe any significant patterns. Previous research has demonstrated that when subjects are initially exposed to an intervention, they often increase their activity levels rapidly, and it takes some time to observe more accurate reflections of their effort. Often referred to an “early-phase response” [18]. In this current study, both groups reached a peak in HIE during the 4th out of 8 measurements, and then gradually declined, even surpassing their pre-test levels. This pattern suggests that if the duration of IMU measurements were extended, it may reveal a clearer pattern of change in HIE, instead of just early-phase response and fluctuations.

Relevance of HIE in Handball

Although the accelerative nature of handball and on-court performance is poorly described in previous literature, it is evident that acceleration and other high-intensity actions play a crucial role in the game and impact handball players' performance [19]. Published studies often highlight the significance of factors such as the ability to accelerate, quickly change direction, jump, and throw for top-level playing performance in team handball [5]. Similar to these findings, Live & Spencer (2017) state in their article “High-intensity events in international women's team handball matches” that there’s little doubt that HIE are crucial for physical performance both in woman’s and men’s handball [12]. However, an analysis of the ambiguous HIE patterns in this current study and their lack of significant correlation with performance measure improvements may question these previous statements. Thus, to explore the relevance of HIE in handball, it is essential to not only assess the reliability of the IMUs, which have demonstrated high reliability in previous studies [20], but also investigate their relationship with performance measures and the level of play.

Font et al., (2020) reported that handball players had over 1000 accelerations and decelerations per game, while Luteberget & Spencer (2017) found an average of 3.9 high-intensity events per minute within international players through 9 measurements. In relation to the findings of this study, that´s a substantial difference where there was shown an average of all subjects at 1.6±0.32 HIE·min-1, through all the 8 measurements [12,21]. This is consistent with previous studies investigating the comparison between HIE in international and national level handball players. Where it has been shown that international level, both backs and wings demonstrated higher HIE·min-1 than their national level counterparts [19]. Similarities to these findings' studies shown in soccer has demonstrated that players competing at a higher standard perform more high-intensity running compared to their counterparts at lower standards [22–24]. For example, Ingebrigtsen et al., (2012) found that players at a higher level sprinted 25-33% farther than those at a lower level, despite covering a similar total distance. Similarly, Mohr, Krustrup, and Bangsbo (2003) reported that Italian League players engaged in 28% more high-intensity running compared to elite Danish players [24] [23]. These findings, in combination of the work of Luteberget (2018) and previous studies on elite handball players indicating the superiority of performance measures [5], all suggested that both performance measures and HIE are indicative of playing level and are likely to be interrelated. Even though the interrelation between changes in performance measures and HIE were not seen in this present study.

Implications

To the knowledge of the author there are no studies on handball players investigating the relationship between changes in performance measures and changes in HIE. Therefore, it´s difficult to draw definitive conclusions about the relationship between improving one's performance measures, and how this translates to improved match-related performance, via HIE measurements. Our objective was to investigate deeper into this relationship, whereas we found no clear pattern. Previous research on handball players conducted with IMU have primarily focused on external load, activity profiles, and high-intensity events during a game or tournament. Implicating a need for more research investigating into how changes in performance measures might affect results in HIE.

The interrelationship between changes in performance measures and HIE is hard to interpret. Whereas previous research has shown that handball players at an higher level displayed superior performance measures compared to their lower peers [5], Karcher & Buchheit (2014) noted that technical and tactical skills, as well as team dynamics, were likely to be more important factors in determining playing level, than physical measurements [2]. Similarly, another study by Wagner et al., (2014) found that while physical fitness measures such as aerobic capacity, speed, and power were important for handball performance, they were not the only factors that influenced playing level. The study highlighted the importance of cognitive and technical skills, such as decision-making, anticipation, and ball control, as well as team cohesion and communication [25]. Therefore, while physical measurements such as CMJ, sprint, CoD, jump abilities, Power and even HIE withing a game can provide some information about a player's physical abilities, they should be considered alongside other factors such as technical and tactical skills, team dynamics, and cognitive abilities when investigating handball performance. These reflections shed light on the potential explanation for the absence of correlation between the variables in this present study.

Perspective

Team-sports, like handball, is a highly complex and multi-factorial game. It's a tempting thought pattern to see links between performance measures and playing level, and therefore conclude that improving one´s physical measures will directly translate to superior changes in match-related performance such as HIE in an 6vs6 session. Whereas the more nuanced approach is that the complexity of the game makes it hard to quantify with physical measures what improved performance is. Whereas elite players might be physical superior to their counterparts in closed-environment physical tests, this doesn't automatically mean that this relationship will be shown in a game through either goals or assist, or in HIE scores. One might increase one capabilities of physical performance, but the display of it via HIE will be depended on factors such as playing time, positioning, tactics, philosophy of the coach, game built up, your teammates and additional external factors. According to the one study on the topic within handball, international-level players exhibit more HIE than national-level players [19]. Which may indicate that it would be beneficial for players and teams to try to increase amount of HIE per game or season. Similarly, if studies were conducted where all teams were measured throughout a tournament or season, and a correlation between HIE and wins was observed, it would further emphasize the significance of HIE in handball performance. However, until such studies are conducted, a significant gap remains between the resistance training-induced improvements in performance measures, and their actual translation to the match-related performance, such as HIE.

The research on HIE is a very interesting line of research that might be detrimental in how one looks at improving physical capabilities within the weight room. It would be valuable for future research to delve deeper into the relationship between HIE, playing level, and the newly introduced PlayerScore, which is a combined score based on various factors such as goals, assists, and defensive actions [26]. By doing so, we could gain a better understanding of the significance of HIE measures and explore how changes in performance measures may affect HIE. Such investigations would provide valuable insights for coaches and athletes seeking to optimize their training regimens and achieve better on-court performance.

6 Main strengths and limitations

The main strengths of this study were the standardized performance measurements which were assessed from previous research, as well as the close follow-up in execution of the training programs. This improved the validity of the findings from resistance training on performance measures. The biggest limitation of this study however was in the study design of the 6vs6 IMU sessions. The duration of recorded session might not be sufficient to see any meaningful changes other than fluctuations and early-phase response. Additionally, the standardization of the recorded 6vs6 IMU sessions in terms of when they were performed in the weekly micro-cycle, as well as the warm-up and preparation before the sessions could all affect the results of the measurements.

7 Acknowledgements

Supervisors: TB, FTV. I would like to thank the subjects that participated in this study, your effort and participation is highly appreciated. The author declares that he has no conflict of interest.

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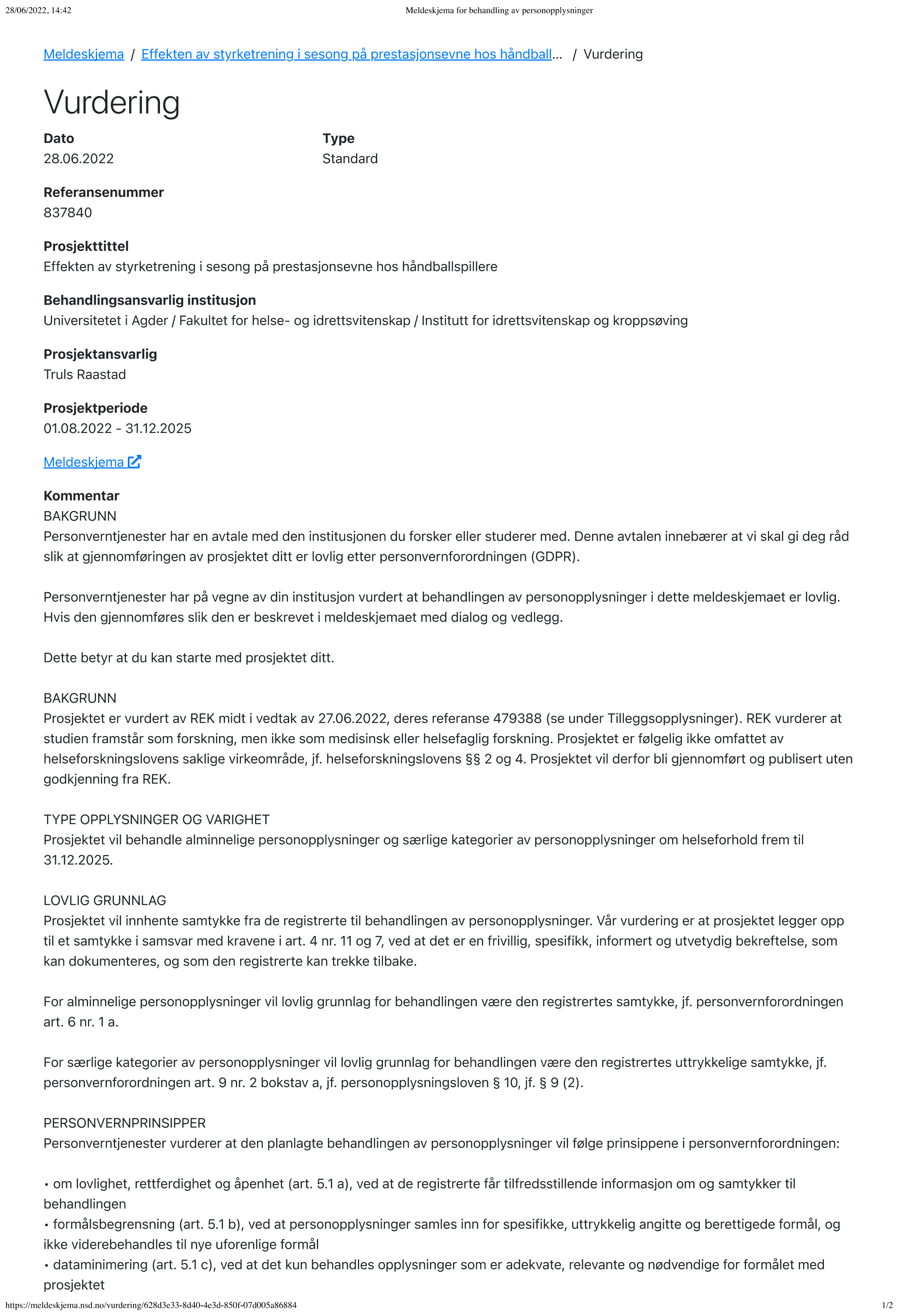
Part 3:

Appendices

APPENDIX 1 Approval by the Norwegian Centre for Research Data



28/06/2022, 14:42 Meldeskjema for behandling av personopplysninger

Meldeskjema / Effekten av styrketrening i sesong på prestasjonsevne hos håndball... / Vurdering

Vurdering

Dato	**Type**
28.06.2022	Standard

Referansenummer
837840

Prosjekttittel
Effekten av styrketrening i sesong på prestasjonsevne hos håndballspillere

Behandlingsansvarlig institusjon
Universitetet i Agder / Fakultet for helse- og idrettsvitenskap / Institutt for idrettsvitenskap og kroppsøving

Prosjektansvarlig
Truls Raastad

Prosjektperiode
01.08.2022 - 31.12.2025

Meldeskjema

Kommentar

BAKGRUNN
Personverntjenester har en avtale med den institusjonen du forsker eller studerer med. Denne avtalen innebærer at vi skal gi deg råd slik at gjennomføringen av prosjektet ditt er lovlig etter personvernforordningen (GDPR).

Personverntjenester har på vegne av din institusjon vurdert at behandlingen av personopplysninger i dette meldeskjemaet er lovlig. Hvis den gjennomføres slik den er beskrevet i meldeskjemaet med dialog og vedlegg.

Dette betyr at du kan starte med prosjektet ditt.

BAKGRUNN
Prosjektet er vurdert av REK midt i vedtak av 27.06.2022, deres referanse 479388 (se under Tilleggsopplysninger). REK vurderer at studien framstår som forskning, men ikke som medisinsk eller helsefaglig forskning. Prosjektet er følgelig ikke omfattet av helseforskningslovens saklige virkeområde, jf. helseforskningslovens §§ 2 og 4. Prosjektet vil derfor bli gjennomført og publisert uten godkjenning fra REK.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige personopplysninger og særlige kategorier av personopplysninger om helseforhold frem til 31.12.2025.

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 nr. 11 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse, som kan dokumenteres, og som den registrerte kan trekke tilbake.

For alminnelige personopplysninger vil lovlig grunnlag for behandlingen være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 a.

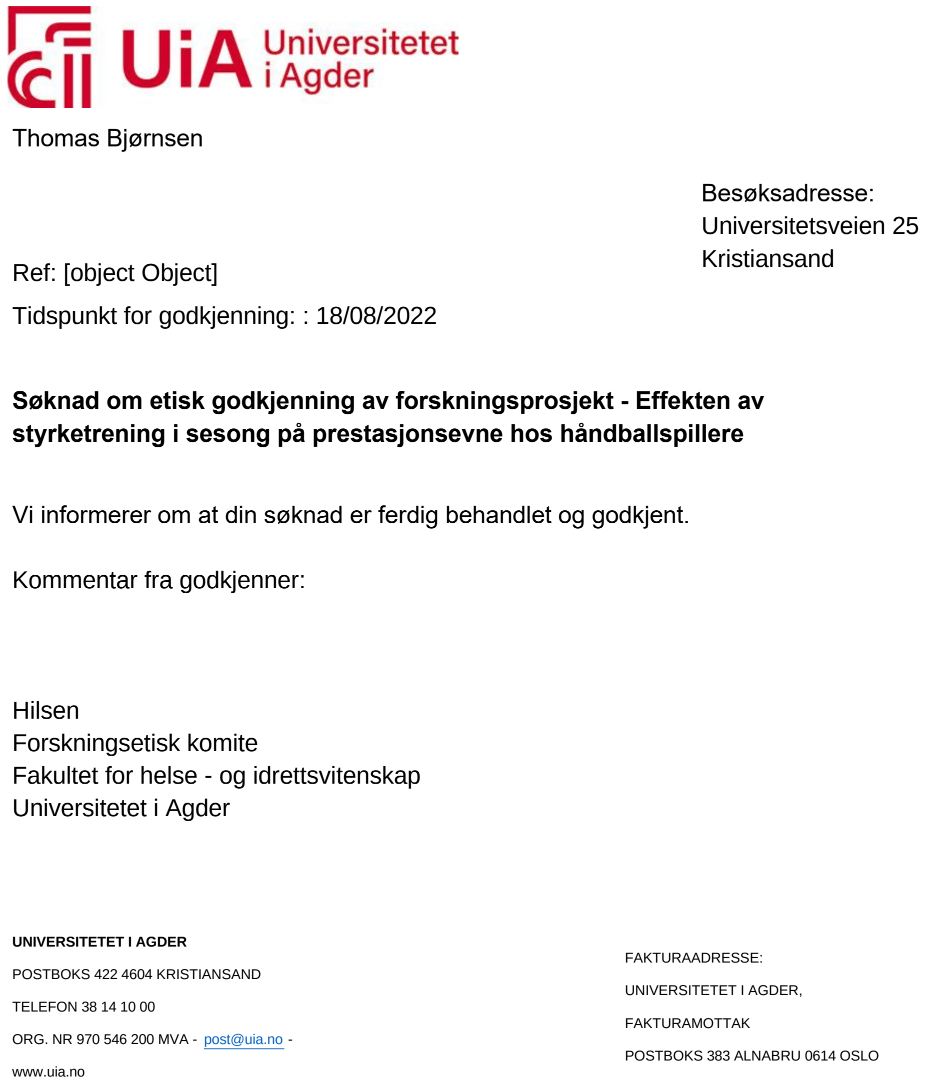
For særlige kategorier av personopplysninger vil lovlig grunnlag for behandlingen være den registrertes uttrykkelige samtykke, jf. personvernforordningen art. 9 nr. 2 bokstav a, jf. personopplysningsloven § 10, jf. § 9 (2).

PERSONVERNPRINSIPPER
Personverntjenester vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen:

- om lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke viderebehandles til nye uforenlige formål
- dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet

https://meldeskjema.nsd.no/vurdering/628d3e33-8d40-4e3d-850f-07d005a86884 1/2

APPENDIX 2 Application for ethical approval of research project



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Kristiansand

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Tidspunkt for godkjenning: : 18/08/2022

Søknad om etisk godkjenning av forskningsprosjekt - Effekten av styrketrening i sesong på prestasjonsevne hos håndballspillere

Vi informerer om at din søknad er ferdig behandlet og godkjent.

Kommentar fra godkjenner:

Hilsen
Forskningsetisk komite
Fakultet for helse - og idrettsvitenskap
Universitetet i Agder

UNIVERSITETET I AGDER
POSTBOKS 422 4604 KRISTIANSAND
TELEFON 38 14 10 00
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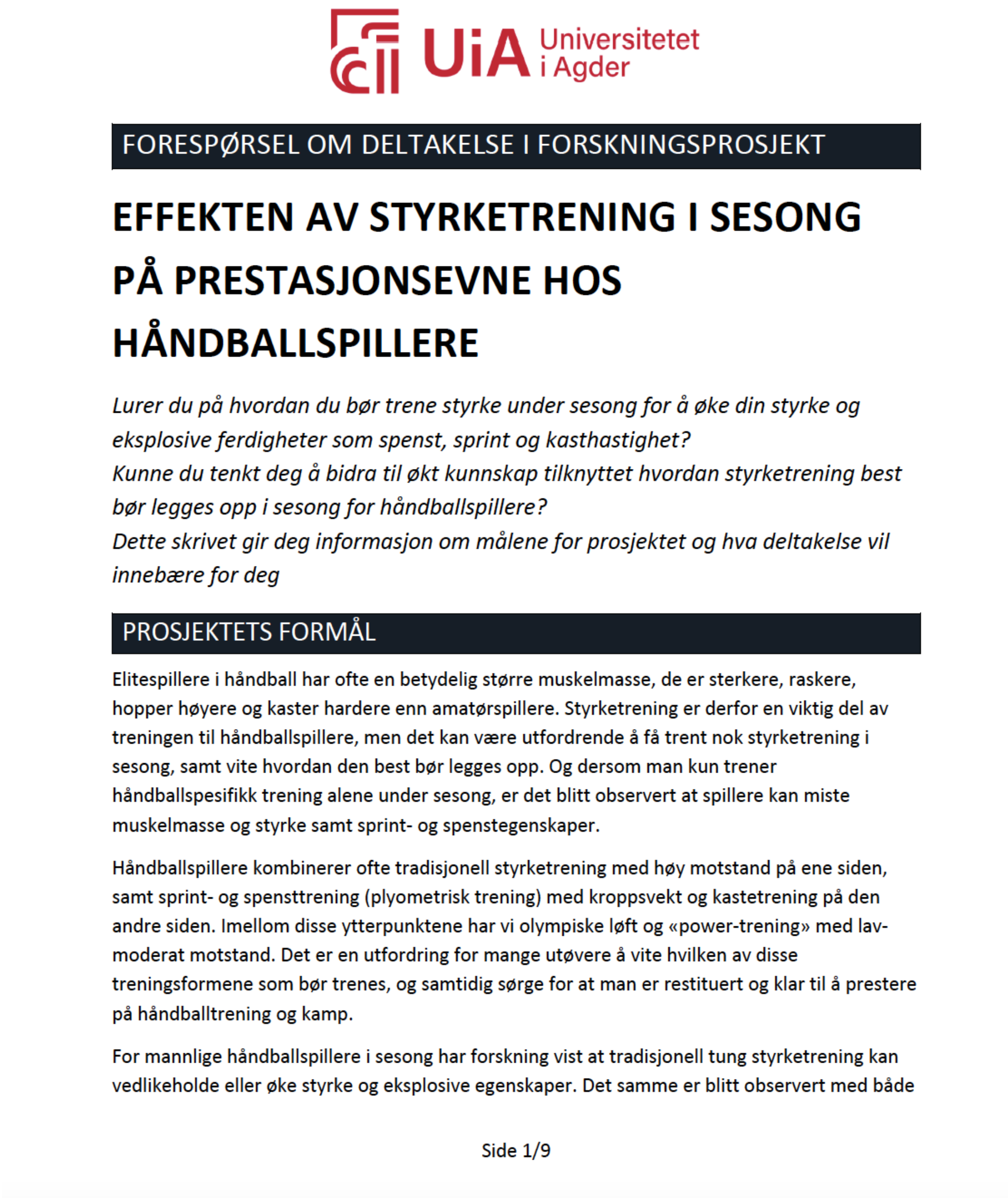
FAKTURAADRESSE:
UNIVERSITETET I AGDER,
FAKTURAMOTTAK
POSTBOKS 383 ALNABRU 0614 OSLO

APPENDIX 3 Informed request regarding the study



FORESPØRSEL OM DELTAKELSE I FORSKNINGSPROSJEKT

EFFEKTEN AV STYRKETRENING I SESONG PÅ PRESTASJONSEVNE HOS HÅNDBALLSPILLERE

Lurer du på hvordan du bør trene styrke under sesong for å øke din styrke og eksplosive ferdigheter som spenst, sprint og kasthastighet?
Kunne du tenkt deg å bidra til økt kunnskap tilknyttet hvordan styrketrening best bør legges opp i sesong for håndballspillere?
Dette skrivet gir deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg

PROSJEKTETS FORMÅL

Elitespillere i håndball har ofte en betydelig større muskelmasse, de er sterkere, raskere, hopper høyere og kaster hardere enn amatørspillere. Styrketrening er derfor en viktig del av treningen til håndballspillere, men det kan være utfordrende å få trent nok styrketrening i sesong, samt vite hvordan den best bør legges opp. Og dersom man kun trener håndballspesifikk trening alene under sesong, er det blitt observert at spillere kan miste muskelmasse og styrke samt sprint- og spenstegenskaper.

Håndballspillere kombinerer ofte tradisjonell styrketrening med høy motstand på ene siden, samt sprint- og spensttrening (plyometrisk trening) med kroppsvekt og kastetrening på den andre siden. Imellom disse ytterpunktene har vi olympiske løft og «power-trening» med lav-moderat motstand. Det er en utfordring for mange utøvere å vite hvilken av disse treningsformene som bør trenes, og samtidig sørge for at man er restituert og klar til å prestere på håndballtrening og kamp.

For mannlige håndballspillere i sesong har forskning vist at tradisjonell tung styrketrening kan vedlikeholde eller øke styrke og eksplosive egenskaper. Det samme er blitt observert med både sprint- og spenst-trening, samt power-trening. Men det mangler både forskning som direkte sammenligner effekten av de ulike treningsformene på håndballspillere i sesong, og generelt hvordan kvinnelige håndballspillere i sesong blir påvirket av styrketrening.

Av den grunn er det av interesse å sammenligne tilpasninger i muskelmasse, styrke, spenst og hurtighet mellom disse treningsformene under en treningsperiode i sesong. Resultatene kan hjelpe deg og andre håndballspillere til å sette opp hvilken styrketreningsform som bør prioriteres i sesong for utøvere med ulike utgangspunkt og egenskaper. I tillegg vil vi undersøke om treningsøktene gir ulike akutte treningsstimuli og restitusjonsforløp som kan forklare tilpasningene. Mer kunnskap om det kan hjelpe i å planlegge styrketreningen opp imot håndballkamper og trening. Dette er et tema som landslagstrener Thorir Hergeirsson har kommet med spesielt ønske om å undersøke nærmere for å forbedre prestasjonsutvikling i sesong for håndballspillere.

For å utforske dette inviterer vi nettopp deg til å delta. Du må være aktiv håndballspiller mellom 16 og 35 år (foreldresamtykke dersom under 18 år) og ha erfaring med styrketrening. Du kan ikke delta om du har skader i muskelskjelettapparatet som hindrer deg i å trene og yte maksimalt i styrke-spenst- og sprint-tester. Du kan heller ikke delta dersom du som kvinnelig utøver er gravid.

Prosjektet blir gjennomført av forskere tilknyttet Universitetet i Agder, Norges idrettshøgskole og Olympiatoppen, i samarbeid med Thorir Hergeirsson og landslagets fysiske trener Benjamin Jensen.

HVA INNEBÆRER DET FOR DEG Å DELTA I PROSJEKTET?

Deltakelse innebærer at hver utøver gjennomfører fysiske tester ved Universitetet i Agder. Deretter blir man randomisert (tilfeldig fordelt) i to treningsgrupper som skal trene i 16 uker under kampsesong. Tidspunkt for testing og trening er planlagt for høsten 2022 og 2023. I tillegg vil vi kartlegge treningsbelastning fra perioder med håndballtrening og kamper med sporingsenheter.

For å kunne delta er det ønskelig at hver deltaker:

- Gjennomfører fysiske tester fordelt på totalt syv dager
    - Én tilvenningsøkt og tester før og etter treningsperioden (opptil 2 timer per økt)
    - 4 «akutte» testdager i slutten av prosjektet (opptil 1 time per økt)
    - Testene må gjennomføres i utvilt tilstand før og etter treningsperioden samt på akutt testdag 1. Uthvilt tilstand betyr uten å ha gjennomført hard anstrengende trening de siste 48 timene og unngå all *uvant* trening de siste 72 timene.

- Gjennomfører styrketreningsprogrammet som er blitt utdelt under hele treningsperioden.
- Registrerer kostholdet i sju dager fordelt på tre perioder; i starten, midtveis, og på slutten av prosjektet.
- Registrering av sykdom og skader og enkel loggføring av styrketrening hver 14.dag
- For kvinnelige deltagere: registrerer menstruasjonssyklus i egen app og rapporterer inn avvik.

Testene som utføres før og etter treningsperioden:

- Høyde, vekt, subjektiv vurdering av opplevd restitusjon og menstruasjonssyklus.
- En kroppsscan (dual-x-ray-absorptiometry [DXA]) som måler din totale muskelmasse i kroppen samt hvor sterkt skjelettet er.
- Muskelvevsprøve i lårmuskulaturen (m. vastus lateralis) etter bedøvelse totalt 3 ganger.
- Muskelstørrelse av samme lårmuskulatur med ultralyd.

Deretter er det en 10 minutters lang oppvarming etterfulgt av 3 forsøk for hver test og med 3 minutter pause mellom hvert forsøk:

- 30 meter sprint (med splittider) og sprint med retningsforandring.
- Kastehastighet.
- Svikthopp og en 3-steg hopp-rekkevidde test («jump & reach»).
- Styrke og power med beinpress og benkpress.

I tillegg vil det gjennomføres et akutt forsøk i slutten av treningsperioden.
Subjektiv grad av opplevd restitusjon og testene muskelvevsprøve og svikthopp utføres rett før en treningsøkt, i tillegg til styrke og elektrisk stimulering av musklene for å måle tretthet i muskulaturen. Deretter vil deltakerne trene en økt med de oppsatte treningsøktene som de har fulgt i treningsperioden. Rett etter treningsøkten vil deltakerne rapporterte subjektiv grad av opplevd anstrengelse før en ny runde med de samme testene som deltakerne gjorde rett før treningsøkten. Testene, med unntak av muskelvevsprøver, vil gjentas 24- og 48-timer etter økten.

Kartlegging av treningsbelastning fra håndballspesifikk trening vil gjennomføres med at hver deltaker spiller håndball med enheter som festes til treningstoppen under aktivitet. Dette vil brukes til å se effekten av styrketrening opp imot treningsbelastningen fra idretten. Vi vil gjøre 3 perioder med målinger på 2-3 uker; i starten, midten og slutten av prosjektet.

Treningsgruppene
Selve intervensjonsopplegget (treningen) utarbeides ut fra erfaring med oppfølging av håndballspillere gjennom Olympiatoppen, innspill fra landslagsteamet, samt tilsvarende program som er brukt i tidligere forskning på lagspillutøvere.

Deltakerne vil bli tilfeldig delt inn i to treningsgrupper. Treningen i den ene gruppa vil bestå av maksimal styrketrening med høy motstand (~70-90 % av 1RM) på ulike styrkeøvelser for bein og overkropp. Imens den andre gruppen to vil trene eksplosiv «power» styrketrening med lavere belastning (20-60% av 1RM) på bein og overkropp, samt plyometrisk trening (sprint- og spenstøvelser) med kroppsvekt. Gruppene vil trene 2-3 ganger per uke under hele prosjektperioden, ved siden av lagtreninger og kamper.

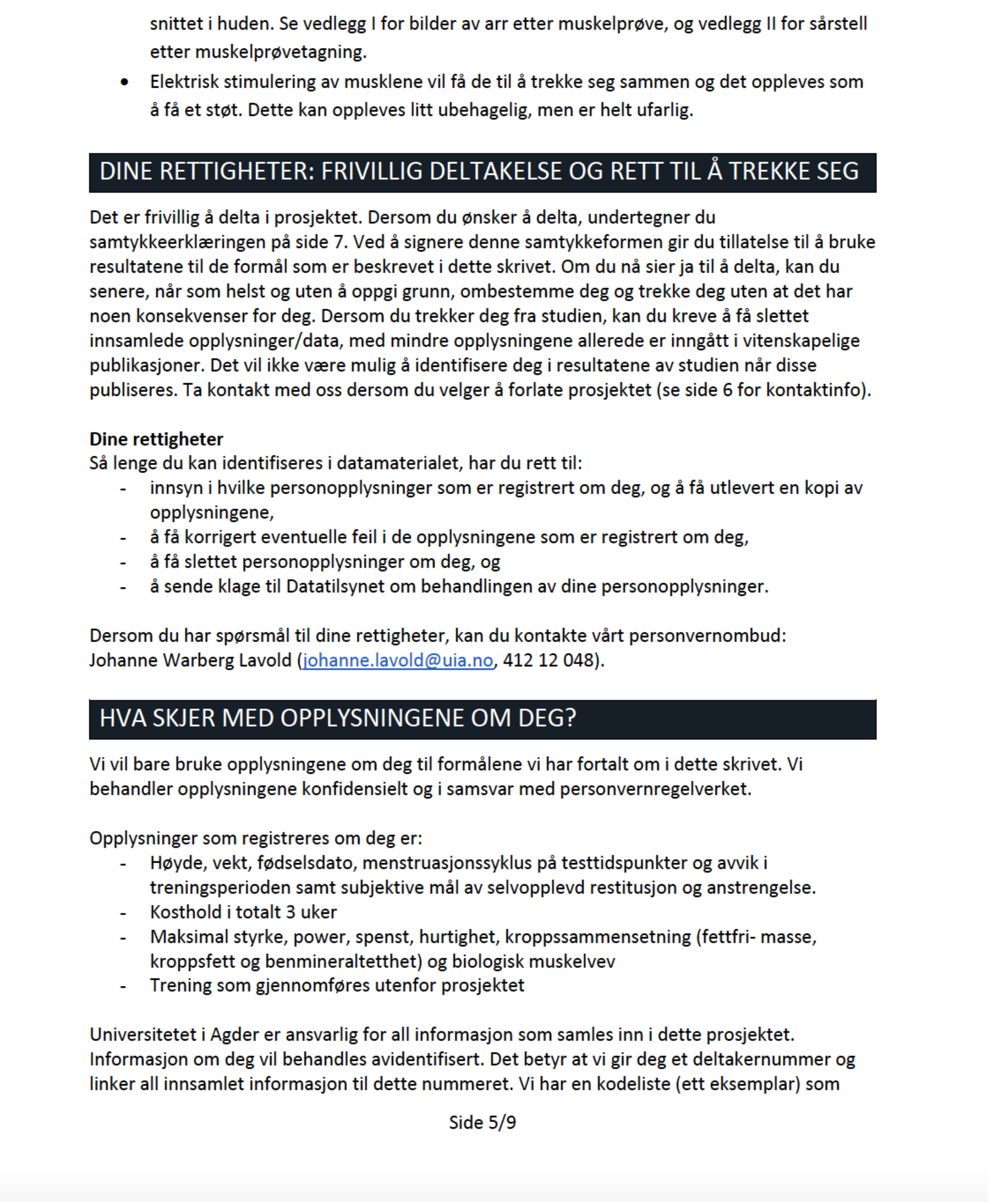
MULIGE FORDELER OG ULEMPER

Mulige fordeler med deltakelse:

- Treningsprogrammene er laget for at du skal oppnå en prestasjonsøkende effekt.
- Du vil få treningsoppfølging og veiledning.
- Du vil få kjennskap til hvordan den spesifikke treningen påvirker deg.
- Du vil få økt kunnskap om din kapasitet og prestasjon relatert til styrke, spenst, hurtighet og power, som normalt ikke er tilgjengelig.
- Resultatene kan inngå i egen treningsplanlegging.
- Du vil bidra til å øke kunnskapen på temaet og fremheve prestasjonsfremmende forskning på håndballutøvere.
- Du vil få mulighet til å stille spørsmål om det du måtte lure på angående trening.
- Du kan få økt kunnskap om idrettsernæring ved å bli invitert til å delta på foredrag

Mulige ulemper med deltakelse:

- Deltakelse i prosjektet vil kreve at du setter av tid til testing og trening
- Trening og testing kan føre til stølhet og oppfattes som ubehagelig/smertefullt i etterkant, og det fører også med seg en viss risiko for skader. Denne risikoen anses imidlertid ikke som større enn ved den treningen du er vant til fra før.
- DXA-kroppsskann medfører en lav røntgenstrålingsdose, men anses ikke som farlig og tilsvarer dosen en utsettes for under en interkontinental flyreise.
- Muskelprøvetaking kan være ubehagelig, selv om huden og bindevevet rundt muskelen bedøves for å minimere ubehag. I om lag et døgn etter muskelprøven opplever man ømhet og stølhet i området rundt snittet. Ømheten vil deretter avta og forsvinner vanligvis i løpet av én-fire dager. Enkelte personer kan få tydelig arrdannelse etter



snittet i huden. Se vedlegg I for bilder av arr etter muskelprøve, og vedlegg II for sårstell etter muskelprøvetagning.

- Elektrisk stimulering av musklene vil få de til å trekke seg sammen og det oppleves som å få et støt. Dette kan oppleves litt ubehagelig, men er helt ufarlig.

DINE RETTIGHETER: FRIVILLIG DELTAKELSE OG RETT TIL Å TREKKE SEG

Det er frivillig å delta i prosjektet. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på side 7. Ved å signere denne samtykkeformen gir du tillatelse til å bruke resultatene til de formål som er beskrevet i dette skrivet. Om du nå sier ja til å delta, kan du senere, når som helst og uten å oppgi grunn, ombestemme deg og trekke deg uten at det har noen konsekvenser for deg. Dersom du trekker deg fra studien, kan du kreve å få slettet innsamlede opplysninger/data, med mindre opplysningene allerede er inngått i vitenskapelige publikasjoner. Det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres. Ta kontakt med oss dersom du velger å forlate prosjektet (se side 6 for kontaktinfo).

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få korrigert eventuelle feil i de opplysningene som er registrert om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Dersom du har spørsmål til dine rettigheter, kan du kontakte vårt personvernombud:
Johanne Warberg Lavold (johanne.lavold@uia.no, 412 12 048).

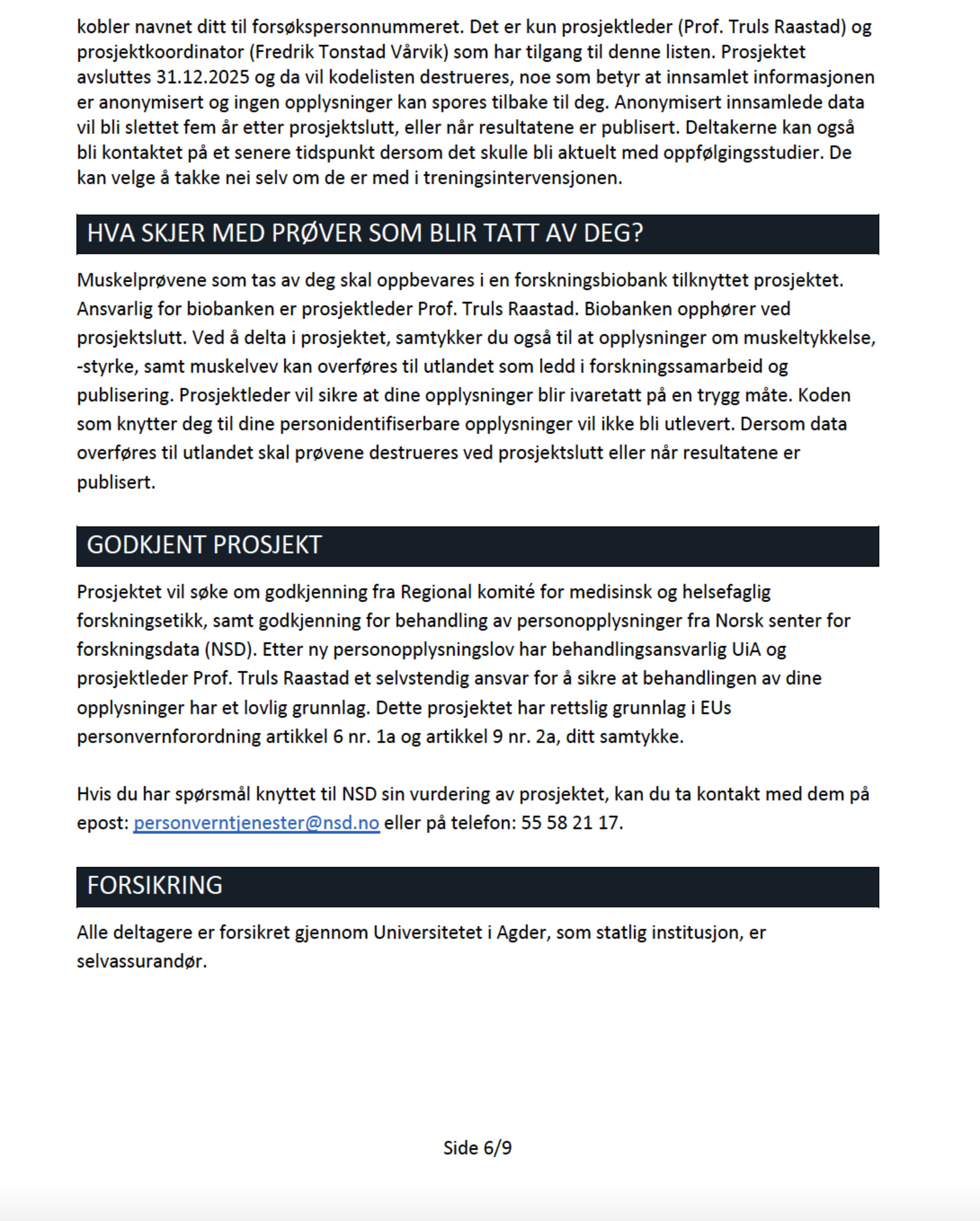
HVA SKJER MED OPPLYSNINGENE OM DEG?

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

Opplysninger som registreres om deg er:

- Høyde, vekt, fødselsdato, menstruasjonssyklus på testtidspunkter og avvik i treningsperioden samt subjektive mål av selvopplevd restitusjon og anstrengelse.
- Kosthold i totalt 3 uker
- Maksimal styrke, power, spenst, hurtighet, kroppssammensetning (fettfri- masse, kroppsfett og benmineraltetthet) og biologisk muskelvev
- Trening som gjennomføres utenfor prosjektet

Universitetet i Agder er ansvarlig for all informasjon som samles inn i dette prosjektet. Informasjon om deg vil behandles avidentifisert. Det betyr at vi gir deg et deltakernummer og linker all innsamlet informasjon til dette nummeret. Vi har en kodeliste (ett eksemplar) som



kobler navnet ditt til forsøkspersonnummeret. Det er kun prosjektleder (Prof. Truls Raastad) og prosjektkoordinator (Fredrik Tonstad Vårvik) som har tilgang til denne listen. Prosjektet avsluttes 31.12.2025 og da vil kodelisten destrueres, noe som betyr at innsamlet informasjonen er anonymisert og ingen opplysninger kan spores tilbake til deg. Anonymisert innsamlede data vil bli slettet fem år etter prosjektslutt, eller når resultatene er publisert. Deltakerne kan også bli kontaktet på et senere tidspunkt dersom det skulle bli aktuelt med oppfølgingsstudier. De kan velge å takke nei selv om de er med i treningsintervensjonen.

HVA SKJER MED PRØVER SOM BLIR TATT AV DEG?

Muskelprøvene som tas av deg skal oppbevares i en forskningsbiobank tilknyttet prosjektet. Ansvarlig for biobanken er prosjektleder Prof. Truls Raastad. Biobanken opphører ved prosjektslutt. Ved å delta i prosjektet, samtykker du også til at opplysninger om muskeltykkelse, -styrke, samt muskelvev kan overføres til utlandet som ledd i forskningssamarbeid og publisering. Prosjektleder vil sikre at dine opplysninger blir ivaretatt på en trygg måte. Koden som knytter deg til dine personidentifiserbare opplysninger vil ikke bli utlevert. Dersom data overføres til utlandet skal prøvene destrueres ved prosjektslutt eller når resultatene er publisert.

GODKJENT PROSJEKT

Prosjektet vil søke om godkjenning fra Regional komité for medisinsk og helsefaglig forskningsetikk, samt godkjenning for behandling av personopplysninger fra Norsk senter for forskningsdata (NSD). Etter ny personopplysningslov har behandlingsansvarlig UiA og prosjektleder Prof. Truls Raastad et selvstendig ansvar for å sikre at behandlingen av dine opplysninger har et lovlig grunnlag. Dette prosjektet har rettslig grunnlag i EUs personvernforordning artikkel 6 nr. 1a og artikkel 9 nr. 2a, ditt samtykke.

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med dem på epost: personverntjenester@nsd.no eller på telefon: 55 58 21 17.

FORSIKRING

Alle deltagere er forsikret gjennom Universitetet i Agder, som statlig institusjon, er selvassurandør.

INFORMASJON OM UTFALLET AV PROSJEKTET

Du vil få informasjon om resultatene av studien. Det vil bli gjennomført en presentasjon på et informasjonsmøte for forsøkspersonene i etterkant av studien. Resultatene vil bli publisert i nasjonale/internasjonale vitenskapelige tidsskrift, kronikker og foredrag.

SPØRSMÅL OM PROSJEKTET? TA GJERNE KONTAKT

Prosjektansvarlig/stipendiat Fredrik Tonstad Vårvik
E-post: fredriktv@uia.no / Tlf: 928 54 969

Prosjektleder/Professor Truls Raastad
E-post: truls.raastad@nih.no / Tlf: 23 26 23 28

SAMTYKKEERKLÆRING

JEG SAMTYKKER TIL Å DELTA I PROSJEKTET OG TIL AT MINE PERSONOPPLYSNINGER OG BIOLOGISK MATERIALE BRUKES SLIK DET ER BESKREVET

Sted og dato Deltakers signatur

Deltakers navn med BLOKKBOKSTAVER

Prosjektmedarbeider bekrefter å ha gitt informasjon om prosjektet

Sted og dato Signatur

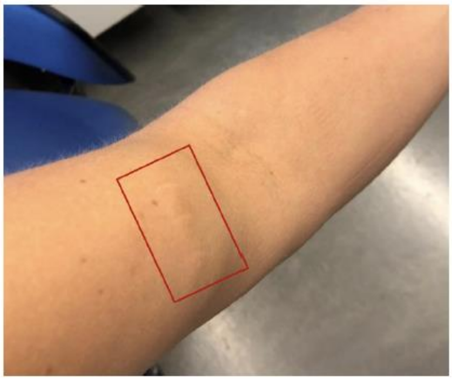
Rolle i prosjektet

VEDLEGG 1: MUSKELVEVSPRØVE

Bilde 1 → viser tre arr etter tre muskelprøver på venstre lår (samme sted som denne studien).
Det øverste er 6 måneder gammelt,
de to nederste er 3 måneder gamle.

Bilde 2 under viser to arr etter to muskelprøver på høyre lår (samme sted som denne studien).
Det øverste arret er 7 år gammelt og det nederste er 6 måneder gammelt.

Bilde 3 → viser tre arr etter tre muskelprøver på overarm. Det er over 10 år siden muskelprøvene ble tatt.



VEDLEGG 2: SÅRSTELL ETTER MUSKELVEVSPRØVE

Du er nå deltager i et forskningsprosjekt hvor vi har tatt muskelprøver (biopsi) fra låret ditt (m. vastus lateralis). Dette er et lite inngrep som ikke skal ha noen negative følger annet enn sår muskulatur noen dager etter inngrepet. Det kan gjøre vondt/være sårt i kveld når bedøvelsen går ut, og i morgen, men det vil gå over i løpet av en dag eller to.

Det er imidlertid en minimal risiko for infeksjon etter slike inngrep. Vi ber deg derfor om å følge rådene under. Om det skulle oppstå noe av medisinsk karakter som du tror kan settes i sammenheng med forsøket, må du ta kontakt med oss uansett tid på døgnet (se kontaktinformasjon nederst i skrivet).

Det er nå viktig at du tar følgende forhåndsregler slik at sårene dine skal gro godt:

- Bandasjen som er surret rundt låret ditt kan tas av i kveld før du legger deg.
- Hvit plasterlapp og strips skal sitte på én uke. Vi anbefaler at stripsene ikke rives av, men tas av når de løsner fra selve såret. Dersom dette skjer før det har gått én uke, ta kontakt slik at vi kan sette på nye.
- Hold sårområdet tørt. Du bør ikke vaske området ved sårene eller dusje slik at tapen rundt såret blir våt. Vann vil øke faren for infeksjon og det vil også medføre at tapen som skal hold sårflatene sammen, løsner. Du kan dusje, men sørg for at du ikke får vann i nærheten av sårene. Dersom du skal dusje, vær forsiktig og bruk plastfolie/"gladpack", vanntette plaster eller lignende for å hindre vann å trenge gjennom plasterlappen.

For å sikre at arrene blir så lite synlige som mulig, anbefaler vi å smøre arrene med høy solfaktor ved soleksponering.

Kontaktpersoner ved Universitetet i Agder:
Truls Raastad: 91 36 88 96
Fredrik Tonstad Vårvik: 928 54 969