Overuse problems in Icelandic male handball

Search for risk factors in the knee, low-back and shoulder

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Thesis for the degree of Philosophiae Doctor

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Álagseinkenni í handknattleik karla á Íslandi

Leit að áhættuþáttum álagseinkenna í hnjám, mjóbaki og öxlum

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I dedicate this thesis in memory of my parents,

Aðalheiður Karlsdóttir, 1939-2011
Rafn Valgeirsson, 1937-2014

“It does not matter how slowly you go as
long as you do not stop”.

- Confucius -

Ágrip

Bakgrunnur

Áhugi á handknattleik hefur vaxið mikið á heimsvísu á liðnum árum. Íþróttin hefur þróast hratt og líklega hraðast í kjölfar reglubreytingar frá árinu 2000 þar sem liðum varð heimilt að hefja leik umsvifalaust eftir að mark var skorað. Sú breyting jók hraða leiksins til mikilla muna. Líkamlegar kröfur til leikmanna hafa aukist með þróun leiksins, ekki síst með tilliti til hraða, krafts og styrks. Þrátt fyrir þessa þróun hafa tiltölulega fáar niðurstöður rannsókna á meiðslum og orsakaþáttum meiðsla í handknattleik verið birtar.

Markmið

Markmið þessarar doktorsrannsóknar var að: 1) Afla gagna um líkamlegt atgervi íslenskra handknattleiksmanna með 9+ skimunarprófi. 2) Að skrá algengi og alvarleika álagseinkenna í hnjám, mjóbaki og ríkjandi öxl og kanna hvort skor úr 9+ skimunarprófi hefði forspárgildi fyrir álagseinkenni. 3) Að skrásetja æfingaálag leikmanna, ásamt algengi og alvarleika álagseinkenna í hnjám, mjóbaki og ríkjandi öxl á undirbúningstímabili og kanna hvort samband sé þar á milli.

Aðferðir

Ritgerðin samanstendur af þremur vísindagreinum. Í vísindagrein I voru nokkrir þættir líkamlegrar getu leikmanna frá 13 íslenskum liðum prófaðir með 9+ skimunarprófi að hausti og leikmenn hlutu einkunn miðað við frammistöðu og samanburður gerður með tilliti til aldurs, getustigs og leikstöðu. Í vísindagrein II voru sömu leikmenn fengnir til þess að svara Oslo Sport Trauma Research Centre (OSTRC) álagseinkenna spurningalista um breytingar á þátttöku, æfingamagni, frammistöðu og verkjum tengt álagseinkennum. Svöruðu leikmenn á tveggja vikna fresti yfir 32 vikna keppnistímabil eða 16 spurningalistum alls. Línuleg aðhvarfsgreining var notuð til að bera niðurstöðurnar saman við einkunnir leikmanna úr vísindagrein I til að kanna hvort 9+ skimunarprófið hefði forspárgildi fyrir álagseinkenni í hnjám, mjóbaki og ríkjandi öxl. Í vísindagrein III voru leikmenn frá 10 íslenskum liðum fengnir til að svara OSTRC álagseinkenna spurningalistanum vikulega yfir 6 vikna undirbúningstímabil. Að auki voru þjálfarar liðanna fengnir til að skrá æfingaálag og tegundir æfinga yfir sama tímabil á skrásetningarform sem unnið var af doktorsnema í samvinnu við landsliðsþjálfara Íslands í handknattleik. Niðurstöður frá leikmönnum og þjálfurum voru bornar saman með línulegri aðhvarfsgreiningu til að meta tengsl á milli álagseinkenna og æfingaálags og ákefðar.

Niðurstöður

Í vísindagrein I kom fram að markverðir hlutu hærri heildareinkunn á 9+ skimunarprófinu en aðrir leikmenn (p=0,0009). Ungir leikmenn hlutu lægri einkunn en þeir eldri í prófunum er mældu stöðugleika og styrk í bol (p<0,0001 (próf 5), p<0,0001 (próf 6) og p=0,006 (próf 7)) , en hærri einkunn en þeir eldri í prófum sem mældu liðleika í öxlum og bol (p<0,0001 (próf 8) og p<0,0001 (próf 9)). Í vísindagrein II kom fram að um 30% leikmanna voru með óþægindi (OP) í hnjám, mjóbaki eða öxlum á hverjum tíma og um 10% leikmanna voru með umtalsverð óþægindi (SOP), sem höfðu áhrif á iðkun og frammistöðu. Algengi álagseinkenna í móbaki var hærra en í sambærilegum rannsóknum. Það fundust engin tengsl á milli einkunnar á 9+ skimunarprófinu og álagstengdra einkenna hjá handknattleiksmönnunum. Í vísindagrein III kom fram að algengi álagseinkenna var hærra í öxlum á undirbúningstímabili en á keppnistímabili (OP; 40% á móti 28% og SOP; 14% á móti 10%), en lægra í SOP í mjóbaki (6% á móti 11%). Hné voru mest útsett fyrir álagseinkennum og voru hlaup (OP; OR 1.30, SOP; OR 1.59) og skotæfingar (OP; OR 1.82, SOP; OR 3.22) líklegustu orsakavaldarnir. Eins voru hopp að orsaka álagstengd einkenni frá mjóbaki (OP; OR 4.47).

Ályktanir

9+ skinumarprófið greindi mun milli hópa. Aldurstengdur munur fannst í nokkrum af þáttum prófsins. Ekki fundust tengsl á milli einkunnar á 9+ skimunarprófinu og álagstengdra einkenna hjá íslenskum handknattleiksmönnum. Álagseinkenni í mjóbaki voru algengari en í sambærilegum rannsóknum. Handknattleiksmenn eru mest útsettir fyrir álagstengdum einkennum í hnjám á undirbúningstímabili.

Lykilorð

Handknattleikur, 9+ skimunarpróf, álagseinkenni, meiðsli, meiðslahætta, æfingaálag.

Abstract

Background

Worldwide, handball has become increasingly popular during the last years. The sport has developed fast, with the most significant changes occurring in 2000 when teams were allowed a quick throw-off, increasing the speed of the game. The physical requirements of players have increased during this development, not least in speed, power and strength. Despite this, relatively few studies on injuries and risk factors for injuries in handball have been published.

Aim

The aims of this doctoral thesis were: 1) to provide data regarding the physical abilities of Icelandic male handball players, by using 9+ screening test. 2) to register prevalence of overuse problems in the knee, low back and dominant shoulder and to investigate if 9+ screening test score could predict for overuse problems. 3) to record the players training load during pre-season, to register prevalence of overuse problems in the knee, low back and dominant shoulder and assess the possible association between the training volume and overuse problems.

Method

The doctoral thesis consists of three papers. In paper I, several physical factors of the handball players from 13 teams were tested using 9+ screening test during the early months of the competitive season. The players earned score according to their performance in the 9+ screening test and a comparison was made regarding age, level of play and playing position. In paper II the same players answered the Oslo Sport Trauma Research Centre (OSTRC) overuse questionnaire regarding overuse problems in the knee, low-back and shoulder. The players answered the questionnaire every second week for the 32-week competitive season. Linear regression was performed to assess the possible relationship between the overuse problems and the 9+ score (from paper I). In paper III, players from 10 teams answered weekly the OSTRC overuse questionnaire during the 6-week pre-season. As well, the team coaches recorded their teams training volume, training intensity and type of training during the research period. The registration form was designed by the doctoral student in cooperation with the Icelandic National Team coaches. The data from the players and coaches were calculated using linear regression to assess the possible association between overuse problems and training volume and intensity.

Results

In paper I, goalkeepers displayed a higher total score in the 9+ screening test than other players (p=0.0009). Age-related differences were observed. Junior players displayed lower scores than senior players in tests measuring abdominal strength and stability (p<0.0001 (test 5), p<0.0001 (test 6) and p=0.006 (test 7)), but higher in tests measuring trunk and shoulder mobility (p<0.0001 (test 8) and p<0.0001 (test 9)). In paper II, 30% of the handball players reported overuse problems in the knee, low back or shoulder at any given time during the research period. Ten percent reported substantial overuse problems, affecting their performance and/or participation. No association was found between overuse problems and the 9+ screening test score among Icelandic elite male handball players. In paper III, the prevalence of overuse problems (OP) and substantial overuse problems (SOP) was higher in the shoulder in the pre-season compared to the competitive season (OP; 40% vs. 28% and SOP; 14% vs. 10%), but lower in substantial overuse problems in the low back (SOP; 6% vs. 11%). The knees were most susceptible for overuse problems during the pre-season, with running exercises (OP; OR 1.30, SOP; OR 1.59) and shooting practice (OP; OR 1.82, SOP; OR 3.22) as the main risk factors. As well, jumping was associated with overuse problems in the low back (OP; OR 4.47).

Conclusions

The 9+ screening test indicated there were difference between groups. Age-related differences were seen in many individual tests. No association was found between 9+ screening tests score and overuse problems among Icelandic elite male handball players. The prevalence of overuse problems in the low back was higher than in comparable studies. Handball players are most susceptible for overuse problems in the knees during their pre-season.

Key words:

Handball, 9+ Screening test, overuse problems, injuries, injury risk, training intensity.

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Contents

List of abbreviations

CI	Confidence interval
FMS	Functional Movement Screening
GPS	Global positioning system
ICC	Intra-class correlation
IHF	International Handball Federation
OP	Overuse problems
OSTRC	Oslo Sports Trauma Research Centre
SD	Standard deviation
SOP	Substantial overuse problems
SS	Severity score
TLOP	Time-loss overuse problems
TL/SOP ratio	Time-loss/substantial overuse problems ratio
USTA-HPP	American Tennis Association – High Profile Performance
Yrs	Years

List of figures

List of tables

List of original papers

This thesis is based on the following original publications, which are referred to in the text by their Roman numerals (I-III):

I. Rafnsson ET, Myklebust G, Bahr R, Valdimarsson Ö, Frohm A, Árnason Á. (2019). Characteristics of functional movement screening testing in elite handball players: Indicative data from the 9+. *Physical Therapy in Sport.*; 37: 15-20. doi: 10.1016/j.ptsp.2019.02.001. *

II. Rafnsson ET, Myklebust G, Bahr R, & Arnason A. (2021). No relationship between a movement screening test and risk of overuse problems in low back, shoulder, and knee in elite handball players—A prospective cohort study. *Translational Sports Medicine; 4*: 481-487. doi.org/10.1002/tsm2.245. **

III. Rafnsson ET, Myklebust G, Valdimarsson Ö, Árnason Á. (2021). Association between training load, intensity, and overuse problems during pre-season in Icelandic male handball. *Translational Sports Medicine; 4* : 837-844. doi.org/10.1002/tsm2.287. **

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Declaration of contribution

Study I:

Elis Thor Rafnsson (ER), Grethe Myklebust (GM), Roald Bahr (RB), Anna Frohm (AF), Örnólfur Valdimarsson (ÖV) and Árni Árnason (ÁÁ) were responsible for the study conception and design. ER performed the literature search and conducted the study. ER performed the analysis and interpretation of the results with assistance from ÁÁ and Professor Þórarinn Sveinsson. ER was responsible for writing the manuscript with supervision from ÁÁ, GM, and RB. AF and ÖV made important critical revisions for the article.

Study II:

Elis Thor Rafnsson (ER), Grethe Myklebust (GM), Roald Bahr (RB), and Árni Árnason (ÁÁ) were responsible for the study conception and design. ER performed the literature search and conducted the study. ER performed the analysis and interpretation of the results with assistance from ÁÁ and Professor Þórarinn Sveinsson. ER was responsible for writing the manuscript with supervision from ÁÁ. GM and RB made important critical revisions for the article.

Study III:

Elis Thor Rafnsson (ER), Grethe Myklebust (GM), Örnólfur Valdimarsson (ÖV) and Árni Árnason (ÁÁ) were responsible for the study conception and design. ER performed the literature search and conducted the study. ER performed the analysis and interpretation of the results with assistance from ÁÁ and Professor Þórarinn Sveinsson. ER was responsible for writing the manuscript with supervision from ÁÁ. GM and ÖV made important critical revisions for the article.

1. Introduction

The modern game of handball (also known as team handball) was first played towards the end of the 19th century in Scandinavia and Germany (Hapková I, 2019) and Danish students were playing handball at that point of time (Steinarsson, 1993). At the beginning of the 20th century, the first rules for handball were issued. Handball became popular and the first competitive game was played around 1920 (Lúðvíksson, 2012). In 1946 the International Handball Federation was established (Hapková I, 2019). Handball was introduced at the 1936 Olympics, as a field sport, and became an official Olympic sport for men in 1972, and for both genders in 1976 (Hapková I, 2019). Today, handball is popular with approximately 27 million participants in 28 thousand handball clubs (IHF, 2021). In 2019, the men's World Cup broke records, with a total of 900.000 spectators watching the games live, and a cumulative audience of 2 billion (IHF, 2021). In Iceland, handball was first played in 1921, by young students and instantly became popular among the Icelandic people (Steinarsson, 1993). The first national game was played 1950, which started an era of regular participation in international tournaments, peaking with the Olympic silver medal in 2008 and the bronze medal in European Championships 2010 (Lúðvíksson, 2012).

1.1 Physical demands of handball

Handball has developed from a slow outdoor sport into a fast dynamic indoor sport, with the most significant change occurring in 2000 when teams were allowed a quick throw-off to increase the speed of the game (Karcher & Buchheit, 2014). An official match is divided into two 30-minute halves with a half-time break of 10 minutes. A match is filled with activities where elite players run approximately 4 km (Michalsik, Aagaard, & Madsen, 2013; Povoas et al., 2012), make about 1500 activity changes, like jumping, cutting movements and hard defensive tackles (Michalsik, Aagaard, & Madsen, 2015) and perform between 18 to 94 passes and take on average 7 to 8 shots per match (Prestkvern, 2013). Performance in handball can be determined by various factors. Physical, cognitive, social, tactical and external factors are believed to affect both players and teams, with variations between playing positions and level of play (Wagner, Finkenzeller, Wurth, & von Duvillard, 2014).

Fundamental physical factors determining the ability of handball players are coordination, strength, power, endurance and a special body constitution (Karcher & Buchheit, 2014; Wagner et al., 2014; Wagner et al., 2017). Positive association has been found between strength in the lower extremities and level of play (Ghobadi, Rajabi, Farzad, Bayati, & Jeffreys, 2013; Gorostiaga, Granados, Ibanez, & Izquierdo, 2005), as well as strength and power in the upper extremities and throwing velocity, an integral part of attacking play (Chelly, Hermassi, & Shephard, 2010; Debanne & Laffaye, 2011; M. C. Marques, van den Tilaar, Vescovi, & Gonzalez-Badillo, 2007; Saeterbakken, van den Tillaar, & Seiler, 2011; Wagner, Buchecker, von Duvillard, & Muller, 2010). A study from the men's 2013 World Cup tournament demonstrated a clear association between physical fitness and success in the tournament (Ghobadi et al., 2013). Consequently, the majority of handball players are tall and heavy. However, the physical demands differ between playing positions. Wing players who perform more fast breaks and are less involved in physical tackling and confrontations, have lower height and weight than players in other positions (Ghobadi et al., 2013; Karcher & Buchheit, 2014; Massuca, Branco, Miarka, & Fragoso, 2015; Michalsik, Madsen, & Aagaard, 2015; Rafnsson, Valdimarsson, Sveinsson, & Arnason, 2019; Sibila & Pori, 2009). Even in youth handball, there is a clear tendency that playing positions are determined by anthropometrical and physical abilities (Zapartidis, Kororos, T., Skoufas, & Bayios, 2011).

1.2 Pre-season training

1.2.1 Strength and power

The intensive nature of modern handball requires appropriate pre-season preparation to fulfill the physical demands of the game. Strength is a fundamental factor for handball players (Cardinale, 2014; Karcher & Buchheit, 2014). Therefore, training methods in pre-season should include strength training to sustain the physical demands of the game such as throwing velocity in offensive play, defensive duels and tackling (Chelly et al., 2010; Gorostiaga, Granados, Ibanez, Gonzalez-Badillo, & Izquierdo, 2006; Hermassi, Chelly, Fathloun, & Shephard, 2010; M. C. Marques et al., 2007; Wagner et al., 2014). Furthermore, strength training not only improves players fitness, but it also decreases the injury risk (Gabbett, 2016; Windt, Gabbett, Ferris, & Khan, 2017). The need for power differs according to players' field positions (Karcher & Buchheit, 2014; Massuca et al., 2015). Goalkeepers are known for their fast reactions and movements in a small area, wing players use their power while sprinting and during their high jumps, back court players for quick cutting movements, high jumping and shooting and pivot players for quick movements in their attacking play (Chelly et al., 2010; Karcher & Buchheit, 2014; Kruger, Pilat, Uckert, Frech, & Mooren, 2014). Every outfield player needs strength and power during their quick movements and tackling in their defensive play (Cardinale, 2014; Karcher & Buchheit, 2014). Strength training sessions, three times a week, are believed to be appropriate in pre-season or in intensive preparation periods to improve players strength and power (Cardinale, 2014). During the competitive season, strength training can be performed one to three times per week in professional teams, according to playing schedule, with at least one session per week to maintain strength and power levels (Cardinale, 2014), which seems to have tendency to change from pre-season into mid-season (Liaghat et al., 2020). Unlike strength training, other physical training factors can be maintained in on-court training during the competitive season. It is important to consider when designing a training regimen that, even though handball is a team sport, the physical requirements differ regarding playing positions and individual physical capacity (Kruger et al., 2014; Michalsik, Madsen, et al., 2015; Wagner et al., 2017). The training program must be individualised and considered a balance between exercise and recovery (Michalsik & Aagaard, 2015). New strength training exercises should not be introduced too close to games due to injury risk (Cardinale, 2014).

1.2.2 Endurance

Elite handball players, except goalkeepers, cover between 3200 to 4900 meters per game with great variations between playing positions with wing players covering the most distance (Michalsik & Aagaard, 2015; Sibila, Vuleta, & Pori, 2004). One half of the playing time consists of walking or jogging, and only four percent of intensive running (Michalsik & Aagaard, 2015). Aerobic moderate-intensity training is a fundamental training factor for handball players (Michalsik et al., 2013). Aerobic training aims to increase the capacity to perform for long periods, i.e., for the entire match and training sessions (Jones & Carter, 2000; Povoas et al., 2012; Tomlin & Wenger, 2002). Furthermore, it increases the ability for quick recovery during high intensity exercise trainings or competitive games (Michalsik et al., 2013; Povoas et al., 2012; Tomlin & Wenger, 2002). An optimal way to perform an aerobic training should be through a game-like training with a ball with a player's heart rate continuously alternating during the session (Karcher & Buchheit, 2014; Povoas et al., 2014). Since the intensity depends on the player's involvement in the training sessions, it can be difficult to control the training load precisely (Michalsik, Aagaard, et al., 2015; Wagner et al., 2017). To regulate the training load, players most commonly perform continuous training, controlled individually by the player's heart rate (Karcher & Buchheit, 2014; Michalsik, Madsen, & Aagaard, 2014).

Players' physical performance tends to impair in the latter stages of matches (Michalsik et al., 2013; Povoas et al., 2014; Povoas et al., 2012). Therefore, trainings should consist of intensive position-specific exercises to maintain and improve the ability to keep quick intensive movements throughout the game (Michalsik, Madsen, et al., 2015; Povoas et al., 2014).

1.2.3 Flexibility

For handball players, flexibility in the shoulders is believed to be the most important, since an association has been shown between reduced gleno-humeral internal rotation and reduced throwing velocity in a standing position (Schwesig et al., 2016). Handball requires constant load on the shoulder (Prestkvern, 2013), and there is a tendency for the internal rotation deficit to increase during the competitive season (Fieseler et al., 2015). Results from systematic reviews have not shown a significant connection between shoulder range of motion and shoulder injuries (Johnson, Fullmer, Nielsen, Johnson, & Moorman, 2018; Keller, De Giacomo, Neumann, Limpisvasti, & Tibone, 2018). However, results have suggested a relationship between shoulder injuries and deficits in internal rotation, as well as reduced gleno-humeral rotation (Andersson, Bahr, Clarsen, & Myklebust, 2017; Clarsen, Bahr, Andersson, Munk, & Myklebust, 2014). For goalkeepers, flexibility is a fundamental ability, not least in hips, where they frequently move their lower extremities fast and high in attempt to save the opponents' shots (Karcher & Buchheit, 2014).

1.3 Training effects

According to studies, there is a thin line between the positive training effects gained in pre-season training and risk of injuries and overuse problems (Bowen, Gross, Gimpel, & Li, 2017; Gabbett & Ullah, 2012; Merete Møller et al., 2017; R. Nielsen et al., 2014; K. J. Weiss, Allen, McGuigan, & Whatman, 2017). In team sports, acute workload is classified as a one-week of training load and chronic workload as the 3-6-week rolling average of the acute training load (Bowen et al., 2017; Gabbett, 2016). Controlling the training load by keeping a low ratio between acute and chronic workload is a key factor in pre-season training with a workload ratio (acute/chronic) between 1-1.5 believed to be optimal for athletes' preparation (Blanch & Gabbett, 2016; K. J. Weiss et al., 2017). Low- and moderate-intensity trainings have positive effect on protecting athletes from injuries and overuse problems by developing physical tolerance to higher acute loads (Bowen et al., 2017; Gabbett & Ullah, 2012; K. J. Weiss et al., 2017). The progression should be slow, since accumulated workload and sudden increase in workload were associated with injury risk (Bowen et al., 2017; Merete Møller et al., 2017; R. Nielsen et al., 2014). A suggested approach to a training schedule for athletes is for it to be individualized and symptom based. Monitoring the relationship between training load and injuries creates important knowledge, helping coaches, physical therapists and physicians to organize a player-specific training schedule (Soligard et al., 2016; K. J. Weiss et al., 2017).

1.4 Injury registration methods

Injuries in sports have been defined and classified with various methods, such as by location, type, body side, and mechanism of injury (traumatic or overuse) and whether the injury was a recurrence (C. W. Fuller et al., 2006). A traumatic injury refers to an injury resulting from a specific, identifiable event where the cause can usually be pinpointed, making the appropriate definition and treatment easier. Traumatic injuries are common among athletes and have been source of majority of sport injury studies in recent years (C. W. Fuller et al., 2006; Peterson & Renström, 2001). Overuse injuries/problems are caused by excessive bouts of physical exercise, resulting in microtrauma without a single, identifiable event responsible for the injury (C. W. Fuller et al., 2006; Timpka et al., 2014). These problems have increased with more intensive training and training volume (Peterson & Renström, 2001). The definition of injury has been unclear with three main types: “any physical complaint”, “medical attention injury”, and “time-loss injury”. The difference between these definitions is great, with “any physical complaint” capturing all injuries occurring, “medical attention injury” excluding minor complaints, and “time-loss” only capturing injuries causing absence from participation (Fuller 2006). The majority of the papers published have only recorded time-loss injuries, the last dimension of the injury definition (Bahr, 2009).

Using a time-loss injury definition when capturing injuries caused by overuse may represent limitations, since many athletes ignore clinical symptoms caused by repetitive low-grade forces during their participation (Bahr, 2009; Clarsen, Myklebust, & Bahr, 2013; Myklebust, Hasslan, Bahr, & Steffen, 2013). Based on this knowledge, the, The Oslo Sports Trauma Research Centre (OSTRC) developed a self-reported questionnaire to register overuse problems. The Questionnaire consists of four questions regarding participation, training volume, performance and extent of pain (Clarsen et al., 2013). This new Questionnaire better captures the full burden of problems caused by excessive training, not just injuries (Clarsen et al., 2013). Therefore, from now on, we will use the term “Overuse problems” (OP).

1.5 Causes of injuries in sports

Risk factors for injuries in sport are normally divided into intrinsic (internal) and extrinsic (external) risk factors. Intrinsic risk factors are related to the athlete, such as: age, biomechanics, injury history and somatotype, while extrinsic risk factors are related to factors such as weather and equipment (Willem H. Meeuwisse, 1994) (Figure 1).

Athletes might be able to minimize their internal risk factors by adapting to their sports environment without sustaining injuries. That adaptation, for example could be an athlete less disposed to injury who makes himself stronger, and increases his exposure to external factors, and thus, in effect, lowers his injury risk (W. H. Meeuwisse, Tyreman, Hagel, & Emery, 2007). One the other hand, the opposite could be the case, where the increased training load can cause microtrauma or affect strength and neuromuscular control, making the athlete predisposed to injury (W. H. Meeuwisse et al., 2007).

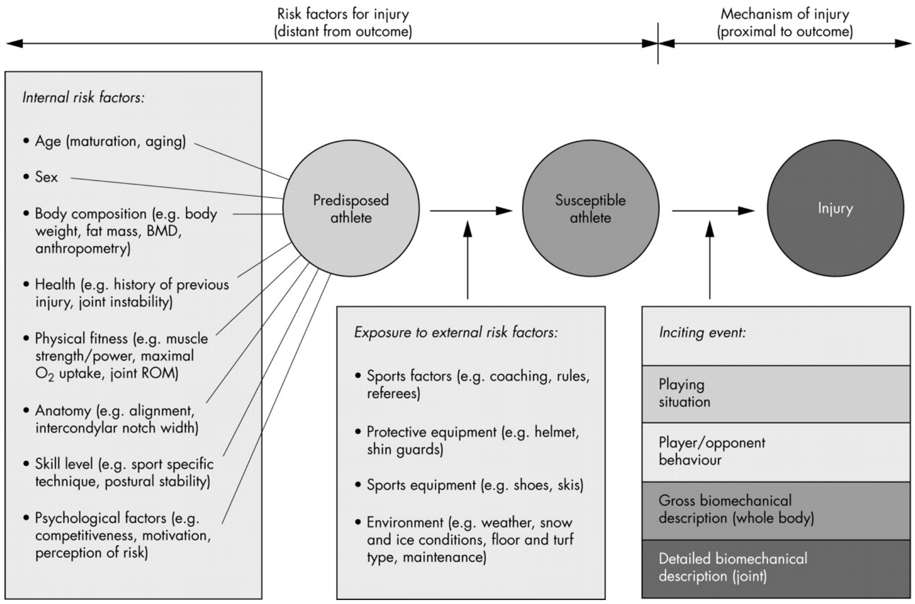

Figure 1. A multifactorial model developed by Willem Meeuwisse (1994) and improved by Bahr and Krosshaug (2005) used to analyze the sport injury etiology and to examine interaction of various causative factors.

1.6 Injuries in handball

Even though research interest in handball is growing, few papers have reported injuries in the sport. In the reported studies, incidence and definitions of injuries have been described with various research approaches (Laver, Luig, Achenbach, Myklebust, & Karlsson, 2018), such as: all reported injuries (Langevoort, Myklebust, Dvorak, & Junge, 2007), injuries seeking medical attention (Asembo & Wekesa, 1998) and time loss injuries (M. Møller, Attermann, Myklebust, & Wedderkopp, 2012; Rafnsson et al., 2019; Seil, Rupp, Tempelhof, & Kohn, 1998). This variance can make a comparison between studies difficult. A high incidence of time-loss injuries among male handball players has been shown, particularly during matches (10.6-22.2 injuries/1000 match hours vs. 0.5-3.0 injuries/1000 training hours) (Barič, Hlebš, Novak, & Brumat, 2021; M. Monaco et al., 2019; Myklebust et al., 2003; A. B. Nielsen & Yde, 1988; Olsen, Myklebust, Engebretsen, & Bahr, 2006; Rafnsson et al., 2019; Seil et al., 1998; Wedderkopp, Kaltoft, Lundgaard, Rosendahl, & Froberg, 1999) and up to 31-50 injuries/1000 hours in international tournaments with a congested match schedule (Bere et al., 2015; Langevoort et al., 2007).

Even though intensive training, required for elite handball players, is impossible without risk of injury, a limited number of studies have recorded overuse problems and the proportion with current complaints has varied widely (M. Møller et al., 2012; Olsen et al., 2006; Rafnsson et al., 2019; Wedderkopp, Kaltoft, Lundgaard, Rosendahl, & Froberg, 1997). A recent study on Icelandic elite handball players revealed that the most common anatomical areas for overuse problems causing absence from training were the shoulder, low back and knee (Rafnsson et al., 2019). Employing a time-loss injury definition may represent a significant limitation, since it may not capture problems which still may affect performance and participation (Bahr, 2009).

1.7 Risk factors for injuries in handball

Despite the intensive manner of handball, relatively few papers have been published regarding risk factors for injuries in the sport. However, during the last years, researchers have been focusing on risk factors associated with overuse problems in the shoulders (Andersson et al., 2017; Clarsen, Bahr, Andersson, et al., 2014; Fredriksen, Cools, Bahr, & Myklebust, 2020) and the anterior cruciate ligaments (Eitzen, Moksnes, Snyder-Mackler, Engebretsen, & Risberg, 2010; Herbst et al., 2017; Krosshaug et al., 2016) with conflicting results. As shown in table 1, the main factors believed to determine the risk of injuries are training volume, training intensity, injury history and player's age.

Table 1. Risk factors associated with injuries in handball and effect sizes.

Papers	Associations	Effect size
Giroto et al. 2017	Risk of overuse problems increases with one additional match per week	1.31*
Giroto et al. 2017	Additional training hour per week and risk of traumatic injury	1.09*
Tsigilis et al. 2007	Number of practices per week increases the prediction of risk of injuries in handball	10.73‡
Møller et al. 2017	An increase in handball load by >60% is associated with greater shoulder injury rate	1.91ϕ
Luig et al. 2018	Higher injury risk in the last third (last 10 min.) of each match half during competitive game	1.71*
Slodownik et al. 2018	History of any injury in the last 12 months and risk of injury	13.71*
Giroto et al. 2017	All previous injuries occurring in 6 months before the research period and risk of overuse injuries	2.42*
Møller et al. 2012	Two or more previous injuries causing absence for more than a month and risk of time-loss injury in youth players	1.79–2.23†
Dirx et al. 1992	Increased risk of injuries in players older than 20 years compared to younger players	1.9*

*Odds ratio, ϕHazard ratio, ‡Wald test, †Incidence rate ratio.

Studies have found associations between injury risk and participation in competitive matches where an additional match per week was associated with a higher risk of overuse problems. The players are at highest injury risk during the last third of each match half (Giroto, Hespanhol Junior, Gomes, & Lopes, 2017; Luig et al., 2020) (Table 1). As well, an association was found between training volume and risk of injuries (Giroto et al., 2017; Tsigilis & Hatzimanouil, 2005) (Table 1). Table 1 shows studies displaying associations between previous injuries and a higher risk of overuse problems and injuries (Giroto et al., 2017; M. Møller et al., 2012; Slodownik, Ogonowska-Slodownik, & Morgulec-Adamowicz, 2018), where players with an injury history have almost a fourteen times higher risk of new injury (M. Møller et al., 2012; Slodownik et al., 2018). An athlete's rising age is believed to be a risk factor for injuries in sports (Arnason et al., 2004; Green & Pizzari, 2017) with a study on handball players revealing a similar tendency (Dirx, Bouter, & de Geus, 1992). These results are in harmony with an age-related difference in time-loss injury incidence published in several studies (Langevoort et al., 2007; M. Monaco et al., 2019; A. B. Nielsen & Yde, 1988; Olsen et al., 2006).

1.8 OSTRC overuse problem questionnaire

Researchers and physicians have in recent years focused on the need to promote a different kind of a research model to analyze overuse problems occurring in training and competition in sports (Bahr, 2009; Clarsen & Bahr, 2014). The OSTRC Overuse Injury Questionnaire was developed to capture the full burden of overuse injuries occurring in sport. The primary objectives were to develop a method to examine the extent of overuse problems and to provide greater information on overuse problems in comparison to standard methods of injury registration (Clarsen et al., 2013). The registration method has been used on various sports in recent years, revealing previously unidentified data on problems integrally related to sports (Table 2) (Andersen, Clarsen, Johansen, & Engebretsen, 2013; Bissell & Lorentzos, 2018; Clarsen, Bahr, Andersson, et al., 2014; Clarsen, Bahr, Heymans, et al., 2014; Leppänen et al., 2019; Nagano, Shimada, Sasaki, & Shibata, 2021; Kaitlyn J Weiss, McGuigan, Besier, & Whatman, 2017). A study comparing the new method to the time-loss method has shown that time-loss injury registration only covers around 10% of the overuse problems reported using the new registration method (Clarsen et al., 2013). Studies on handball players have shown that the prevalence of all reported overuse problems were 14-20% in the knees, 12-14% in the low back and 17-32% in the shoulders (Table 2). The prevalence of overuse problems affecting players' performance or participation (substantial overuse problems) was 5-8% in the knees, 2-6% in the low back and 5-15% in the shoulders (Table 2) (Aasheim, Stavenes, Andersson, Engbretsen, & Clarsen, 2018; Andersson et al., 2017; Asker, Walden, Kallberg, Holm, & Skillgate, 2017; Clarsen, Bahr, Andersson, et al., 2014; Clarsen, Bahr, Heymans, et al., 2014). Considerable differences were seen in these studies with respect to age, gender and level of play.

Table 2. Overuse problems in the knee, low back and shoulder in team sports recorded with OSTRC overuse injury questionnaire.

			Knee		Low back		Shoulder	
Author	**Gender**	**Level**	**OP**	**SOP**	**OP**	**SOP**	**OP**	**SOP**
Other team sports								
Clarsen et al. 2014 (Volleyball)	M/F	Elite & junior	36 (32-39)	15 (13-17)	14 (11-16)	1 (1-2)	16 (14-19)	5 (4-6)
Clarsen et al. 2014 (Floorball)	M/F	Elite & junior	27 (24-31)	4 (2-6)	29 (25-33)	3 (1-4)	15 (9-20)	1 (0-2)
Weiss et al. 2017 (Basketball	M	Elite	24 (20-29)	3 (1-5)	26 (20-32)	3 (1-4)		
Bissell et al. 2018 (Netball)	M	Amateur	47 (NA)	11 (NA)			22 (NA)	3 (NA)
Leppainen et al. 2019 (Football)	M/F	Junior	6 (NA)	2 (NA)	1 (NA)	1 (NA)		
Nagano et al. 2021 Basketball)	F	Junior	10 (9-10)	5 (5-6)	14 (14-15)	4 (4-5)	1 (0-1)	0 (NA)
Handball								
Clarsen et al. 2014	M/F	Elite & junior	20 (16-25)	8 (6-10)	12 (6-16)	2 (1-3)	22 (16-17)	6 (4-8)
Aasheim et al 2018	M	Junior	14 (13-15)	5 (4-5)	12 (11-13)	3 (2-3)	17 (16-19)	7 (7-8)
Andersson et al. 2016*	M/F	Elite					17 (16-19)	5 (4-6)
Andersson et al. 2016 †	M/F	Elite					23 (21-26)	8 (7-9)
Asker et al. 2018	F	Junior					32 (NA)	15 (NA)
Asker et al. 2018	M	Junior					23 (NA)	10 (NA)

* Intervention group
† Control group

1.9 Screening Tests

The high number of injuries in sports have been a source of concern for many researchers and clinicians, who are attempting to develop tools or methods to have a positive impact on injury risk. Until recently, studies on risk factors in sports have mainly focused on “static” factors such as tests for flexibility, strength and power (Arnason et al., 2004; Eitzen et al., 2010; Engebretsen, Myklebust, Holme, Engebretsen, & Bahr, 2011; Ostenberg & Roos, 2000; Soderman, Alfredson, Pietila, & Werner, 2001). Aiming to assess the presence of risk factors for future injuries and recovery from previous injuries, researchers and clinicians have demanded tools for musculoskeletal screening of athletes (Brukner, White, Shawdon, & Holzer, 2004; Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010; Frohm, Heijne, Kowalski, Svensson, & Myklebust, 2012; Kiesel, Plisky, & Voight, 2007). Most notably, the Functional Movement Screening (FMS) was developed in the USA for the purpose of creating a more “dynamic“ test battery to screen athletes performance and to reveal possible variations in body function (Grey Cook, 2004). Studies have analyzed the FMS test’s ability to predict serious injuries, where athletes with low FMS score were found to be more likely to suffer injury during their participation (Bonazza, Smuin, Onks, Silvis, & Dhawan, 2017; Chorba et al., 2010; Kiesel et al., 2007). Also, a relationship was detected between pre-season FMS scores and injuries in the lower extremities, where athletes from various sports with FMS scores under 17 were at 4.7 times higher injury risk in the lower extremities than athletes with higher FMS scores (Letafatkar, Hadadnezhad, Shojaedin, & Mohamadi, 2014). On the other hand, other studies have failed to show an association between a low score on the FMS (McCunn, Aus der Funten, Whalan, Sampson, & Meyer, 2018; J.-T. Monaco & Schoenfeld, 2019; Trinidad-Fernandez, Gonzalez-Sanchez, & Cuesta-Vargas, 2019) or painful movement when testing (J. T. Fuller et al., 2019) and higher risk of injuries. USTA-High performance profile (HPP) is a test battery developed by the American Tennis Association, designed to identify possible strength imbalance and/or flexibility deficits, and then target areas where players should focus on in their physical training to minimize the risk of injuries and overuse problems (Frohm, Flodström, & Kockum, 2013). A number of other movement screening tests, such as, Y Balance/Star Excursion Balance Test, Tuck Jump Assessment, and the Landing Error Scoring System, have been developed and used by clinicians as tools to estimate injury risk in lower extremities (Chimera & Warren, 2016). The validity of screening tests has been questioned and factors like sex differences, injury history, and participation can influence the accuracy of the score. Conflicting findings on injury prediction make recommendations for use difficult (Chimera & Warren, 2016). For upper extremities, a number of tests, such as Y Balance Test - Upper Quarter, Closed Kinetic Chain Upper Extremity Stability Test, and Seated Medicine Ball Throw, have been developed, mostly to estimate performance (Borms & Cools, 2018; Borms, Maenhout, & Cools, 2016).

A number of tests have managed to assist physicians and researchers to understand causative factors by demonstrating a statistically significant association with injury risk (Bahr, 2016). Despite these associations, such tests are unlikely to be able to predict injuries since, within the performance of a group with similar abilities, overlap can be expected irrespective of injury risk (Bahr, 2016).

1.10 The 9+ Screening Test

Based on the FMS and USTA-HPP screening tests (G. Cook, Burton, Hoogenboom, & Voight, 2014; Frohm et al., 2013), a Swedish group has expanded and developed further these methods as the "The 9+ Screening Test" (Frohm et al., 2012). The 9+ screening test initially consisted of 9 different functional movement tests, testing for factors like stability, mobility and neuromuscular control (Frohm et al., 2013). Six of the tests were from FMS (G. Cook et al., 2014), one test from the American Tennis Association (USTA-HPP) (Frohm et al., 2013) and two tests were standardized from the research group (Frohm et al., 2013; Frohm et al., 2012). In addition, two tests were added later: the single leg squat (to increase the reliability since the deep squat's reliability was considerably low), and drop jump test (to spot young athletes with extreme knee valgus during landing) (Frohm et al., 2013). The 9+ Screening test had a high ICC score when tested for inter- and intra-rater reliability and seemed reliable (Frohm et al., 2012). Until now, the studies published have failed to find an association between the results on the 9+ Screening Test and injuries in elite male football players (Bakken et al., 2017; Bakken et al., 2016), non-contact injuries in handball (Karlsson, Heijne, & von Rosen, 2021), and a history of previous injury among recreational athletes (Flodstrom, Heijne, Batt, & Frohm, 2016).

2. Aims of the dissertation

The overall aim of this doctoral thesis was: (1) to assess the prevalence of overuse problems in the shoulder, low-back and knees among Icelandic male handball players, (2) to provide normative 9+ Screening test data on Icelandic elite male handball players, and (3) to analyse the possible association between overuse problems, total 9+ score and training volume, intensity and training factors.

The following was addressed in the three papers:

Paper 1. The aim of this study was to test Icelandic junior and senior elite handball players using the 9+ screening test to provide normative data, as well as to compare groups according to age, level of play and player position.

Paper 2. The aims of this study were to assess the prevalence and severity of overuse problems in the dominant shoulder, low back and knee among Icelandic male handball players using the OSTRC overuse injury questionnaire and to test if total score on the 9+ screening test was associated with the risk of overuse problems in these regions.

Paper 3. The aim of this study is threefold: First, to register prevalence and severity of overuse problems in the knee, low back and shoulder in Icelandic male handball players for the 6-week pre-season. Second, to register the magnitude and intensity of trainings/games for 6-week pre-season in Icelandic handball. Third, to analyse if some possible associations were found between magnitude, intensity or type of training in the 6-week pre-season period and prevalence/severity of reported overuse problems in the knee, low back and shoulder in Icelandic handball players.

3. Materials and methods

The studies were performed in the Reykjavík region – in the participating team's sports halls. The teams were visited during the clubs training sessions. The teams from other regions were tested during their visit to Reykjavík prior to the 2012-2013 competitive season. Icelandic national players were tested during one international training session in Reykjavík.

The first two studies were prepared during the spring of 2012. The first study was conducted from August to November 2012. The second study was conducted from September 2012 to May 2013. The data analysis was completed in March 2015. The papers were published in February 2019 (Study I) and in March 2021 (Study II) (Table 3).

The third study was prepared during the spring 2015 and conducted for a 6-week time period, from the beginning of August 2015 to mid-September 2015. The data analysis was completed July/August 2016. The paper was published in November 2021 (Table 3).

The studies were approved by The National Bioethics Committee in Iceland (12-043) and reported to The Icelandic Data Protection Authority.

Table 3. Overview of designs of studies I, II and III.

	Study I	**Study II**	**Study III**
Aim	To screen Icelandic elite handball players for the quality of movement and physical factors. To use the results to analyze difference between playing positions, level of play and age.	To examine the prevalence of overuse problems in low back, knee and shoulder. To assess possible associations between overuse problems score and score on the 9+ Screening Test.	To examine the prevalence of overuse problems low back, knee and shoulder. To register the training volume in pre-season. To assess association between overuse problems and training volume and intensity.
Study type	Cohort study.	Prospective cohort study.	Prospective cohort study.
Participants	132 senior and 50 junior Icelandic elite handball players.	229 Icelandic elite handball players in the prevalence part. 130 players in assessing association between overuse problems and the 9+ Test score.	139 Icelandic elite male handball players. 10 head coaches in elite Icelandic handball teams.
Research period	Three months	A competitive season (nine months)	A pre-season (six weeks)
Data collection and Instruments	9+ Screening Test tools	OSTRC overuse problem questionnaire	OSTRC overuse problem questionnaire Training volume/intensity questionnaire
Data analysis	ICC coefficient (ICC 3.1) Spearman's correlation Anova Linear regression	Percentage difference Linear regression	Percentage difference Logistic regression

3.1. Study I "Characteristics of functional movement screening testing in elite handball players: Indicative data from 9+"

3.1.1. Settings and participants

The study had a descriptive cohort research design. The sixteen senior clubs in the two highest divisions in Iceland were contacted before their competitive season started, with 13 teams agreeing to participate. As well, junior players from four of the clubs were invited and all agreed to participate. Icelandic national team players from professional teams in Europe were also invited to participate and were tested during a training session in Iceland. A total of 182 players participated in the study, 27 were Icelandic national team players, 61 premier division players (no national team games), 44 second division players (no national team games) and 50 were junior players.

3.1.2. Equipment

The 9+ screening test standard research tool set was used for the research (Frohm et al., 2013). The 9+ screening test is designed to estimate mobility, joint stability, muscular control and coordination. The main objective is to use functional exercises and complex movements to quickly assess important fundamental function among athletes, rather than single joint movement or muscle strength. The first version of the 9+ screening test consisted of nine tests, but later the research group enlarged it by adding two tests; a drop jump test, and single leg squat, added afterwards. The latter test was added in when the research period for this study was already complete (Frohm et al., 2013). In this study, the screening test was comprised of: 1. Deep squat test, 2. Deep single leg squat test, 3. In-line lunge test, 4. Active hip flexion test, 5. Straight leg raise test, 6. Push up test, 7. Diagonal lift test, 8. Seated rotation test, 9. Functional shoulder mobility test and 10. Drop jump test. The score was recorded for each test according to the test protocol where the score varied from 0 to 3 points depending on the performance with 30 points as the possible best score (Appendix 1).

3.1.3. Data collection

Prior to the data collection, the doctoral student, who performed all the tests, underwent a weekend course supervised by two of the 9+ inventors. After receiving information regarding the study, including the risks and benefits, each participant (and parents for players below 18 years of age) signed an informed consent form. Player characteristics (age, height, weight, playing position and level of play) were recorded before the test was performed. Players were tested barefoot, wearing shorts and a t-shirt. Before each test, players were shown photos of the optimal starting and finishing position of the exercise. When performing the test, the players received standardized verbal instructions and verbal corrections between attempts if needed. The players performed each test three times, starting on the left extremity. If difference between sides was observed, the lower score was used for data analysis. The highest score achieved was recorded and used in the analyses. For each senior player, the data was collected during one test session, completed on average in 30 minutes. To test for intra-rater reliability, the fifty junior players were tested twice with a one-week interval between measurements. Their score from their first test was used in the dataset, to avoid a possible learning effect.

3.1.4 Analysis

The descriptive data of the players characteristics are presented as the mean ± standard deviation. Intra-class correlation coefficient (ICC(3.1)) was used to analyze intra-rater reliability in the two sessions' total score in the reliability study, and Spearman´s correlation was used to calculate the intra-rater reliability of the two repeated measurements in each of the screening tests. Standard error of measurement was calculated with the formula: $SDdiff/\sqrt{2}$. Analyzing the test scores, t-tests and ANOVA were used to test for group differences and linear regression to analyze the relationship between players age and test scores. The data were analyzed using SAS Enterprise Guide 7.1 and Microsoft Office Excel 2013. The significance level was set at $p<0.05$.

3.2 Study II "No relationship between a movement screening test and risk of overuse problems in low back, shoulder and knee in elite handball players – A prospective cohort study"

3.2.1 Settings and participants

The study was a prospective cohort study. The participants were 229 handball players from the same 13 elite Icelandic male handball teams participating in Study I. The 9+ Screening test dataset from Study I was used to assess possible association between the 9+ score and the overuse problems reported by the handball players.

3.2.2 Equipment

The OSTRC questionnaire was designed by a research group to capture problems and injuries caused by overload in sports (Clarsen et al., 2013). The questionnaire consists of four questions registering the athlete's participation in normal training or competition, possible reduction in training volume, influence on performance, and the extent of symptoms (Appendix 2). The questionnaire was translated from Norwegian into Icelandic by two specialists in the field, then translated again into Norwegian by a physical therapist fluently speaking Norwegian and reviewed by one of the authors. The questionnaire was distributed online through e-mail using Questback V. 9692, online survey software.

3.2.3 Data collection

First, the participants received information regarding the study, including the risks and benefits, and each participant (and parents for players below 18 years of age) signed an informed consent form. Players were asked to respond to 16 OSTRC Overuse Injury Questionnaires received through e-mail every second week for one competitive season, from the beginning of September 2012 to the end of April 2013. Each questionnaire was active for a week, with two automatic reminders, on day three and five. Also, the players got information and motivation through a Facebook group during the research period. Players were asked to register any overuse problems in the shoulder, low back or knee during the previous week. Overuse problems (OP) were defined as any reduction in participation, training volume, performance or occurring pain/symptoms. Substantial overuse problems (SOP) were defined as moderate or severe reductions in participation or training volume with players selecting option 3, 4 or 5 in questions 2 and/or 3 in the questionnaire (Appendix 2) and time-loss overuse problems (TL OP) if players were unable to participate. If needed, the players were contacted for further injury classification. The team physical therapists registered injury types and further diagnoses were sought by physicians. Acute injuries, defined as injuries with a clear onset caused by trauma, were excluded from the research data. The dataset from Study I was used to assess the possible relationship between overuse problems and 9+ test score.

3.2.4 Analysis

Player's age is presented as mean values with standard deviation. Prevalence of overuse problems was calculated as the mean with 95% confidence interval for all, and substantial and time-loss overuse problems for each anatomical area by dividing the number of players reporting a problem by the number of questionnaire respondents, multiplied by a hundred. The response for each of the four questions were allocated a numerical value (0-25). The severity score was calculated as the sum of these values to create an objective measure of the consequences of the overuse problems. It can also be plotted for each athlete and used to monitor the progress of overuse problems of each athlete during a study (Clarsen et al., 2013). The ratio between time-loss and substantial overuse problems was calculated by dividing the number of reported time-loss problems by the number of substantial overuse problems, multiplied by a hundred. As recommended by Clarsen et al. (2013), the data from the first questionnaire was removed from all prevalence analyses. Linear regression was performed to assess the relationship between reported overuse problems and the player's 9+ test score from study I. The data were analyzed using SAS Enterprise Guide 7.1 and Microsoft Office Excel 2013. The significance level was set at $p<0.05$.

3.3 Study III "Association between training load, intensity and overuse problems during pre-season in Icelandic male handball"

3.3.1 Settings and participants

This was a prospective cohort study. All the sixteen senior clubs in the two top male divisions in Iceland were contacted prior to their pre-season. Ten teams, including 139 Icelandic elite handball players and ten head coaches agreed to participate.

3.3.2 Equipment

The OSTRC overuse injury questionnaire was used identically as in Study II, to register the prevalence of overuse problems. The head coaches recorded data on a special registration form designed by the doctoral student in cooperation with the coaches of the Icelandic senior national team, based on a review (Karcher & Buchheit, 2014). Weekly number of trainings, estimated training intensity, and training exposure in hours were recorded, as well as types of training (Appendix 3).

3.3.3 Data collection

First, the participants received information regarding the study, including the risks and benefits. Players who consented to participate (parents also signed for those who were under 18 years of age) were asked to respond to the OSTRC Overuse Injury Questionnaire by e-mail weekly for 6 weeks, from the beginning of August to mid-September 2015, covering the teams pre-season. The distribution protocol was identical to Study II. During the pre-season, the coaches recorded their teams' weekly training volume, estimated training intensity, and types of training.

3.3.4 Analysis

Players' demographic values were presented as mean with standard deviation. Prevalence of overuse problems, severity score, and time-loss/substantial overuse problems ratio were calculated by using the same method as in Study II. The association between reported overuse problems and reported training volume and intensity was assessed by using logistic regression. The data was analysed and figures created in Microsoft Excel 2019 and Jamovi 1.1.9.0. The significance level was set at $p<0.05$.

4. Results

A summary of the main results from studies I, II and III is presented in this chapter, corresponding to the aims of the thesis (Table 3). Detailed results are presented in the publications at the end of the thesis.

4.1 Study I

4.1.1 Reliability test

The score from the 50 junior elite handball players in the reliability study varied from 16-30 points in both tests with high correlation between test sessions (ICC (3.1)=0.95, $p<0.0001$). A significant improvement in the total score (0.32 points, $p=0.041$) was discovered between the test sessions (test 1: 21.6±3.5; 95% CI 20.7-22.6 and test 2: 22.0±3.4; 95% CI 21.0-22.9), indicating some learning effect. According to Spearman's correlations, the intra-rater reliability for each of the tests ranged from 0.65 to 0.95.

4.1.2 Screening

The average total score for Icelandic elite handball players tested in the 9+ screening test was 22.2±3.0 points (95%CI 19.0 to 25.4). As shown in Figure 2, a difference was observed in total score between playing positions with goalkeepers earning a higher score than other players. Goalkeepers achieved higher scores than other players in tests 3 and 4 and, along with wing players, higher scores in test 9 than back court and pivot players.

As shown in Table 4, when looking at the players' total score according to their level of play, no significant difference was observed ($p=0.26$). Analyzing the score for each of the tests, junior players scored lower than other groups in tests requiring trunk strength and stability (tests 1, 5, 6, and 7) and higher in tests requiring mobility (3, 8 and 9). Significant age-related differences were observed in tests assessing trunk strength and stability with younger players earning a lower score than the older ones (Figure 3).

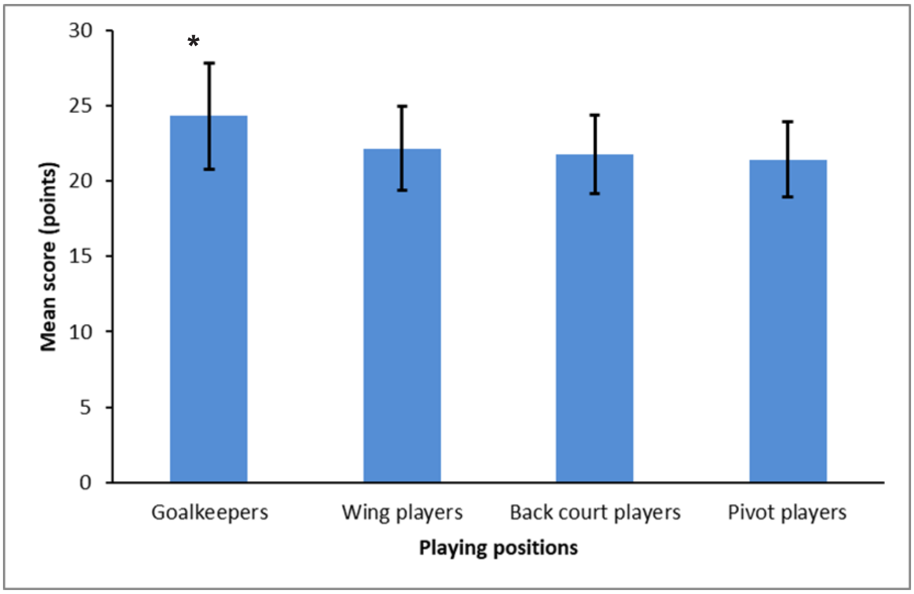

Figure 2. The average total score of the 9+ Screening Test in different playing positions. Standard deviations are shown as error bars for each playing position.
*Goalkeepers had a significantly higher total score than other players (p=0.0009).

Table 4. The average screening test score for each test and the average total score shown for different skill levels of players.

	1	2	3	4	5	6	7	8	9	10	Total
Junior players	2.15a	1.32	2.39b	1.71	1.29a	2.37a	2.02a	2.39b	2.80b	2.95	21.39
Premier division	2.24	1.47c	2.26	1.70	2.17	2.89	2.23	2.29	2.21	2.80	22.26
Second division	2.23	1.21	2.27	1.94	2.00	2.98	2.38	2.19	2.27	2.77	22.23
National players	2.19	1.44d	2.11	2.07e	2.59e	2.96	2.33	2.00	2.33	2.78	22.81
Average score	2.20	1.36	2.26	1.85	2.01	2.80	2.24	2.22	2.41	2.83	22.17

a Significantly lower score than in other groups (p=0.007 (1), p<0.0001 (5) p<0.0001 (6), p=0.006 (7)).
b Significantly higher score than in other groups (p=0.001 (3), p<0.0001 (8), p<0.0001 (9)).
c Significantly higher score than in second division players group (p=0.006).
d Significantly higher score than in second division players group (p=0.03).
e Significantly higher score than in other groups (p=0.03 (4), p=0.003 (5)).

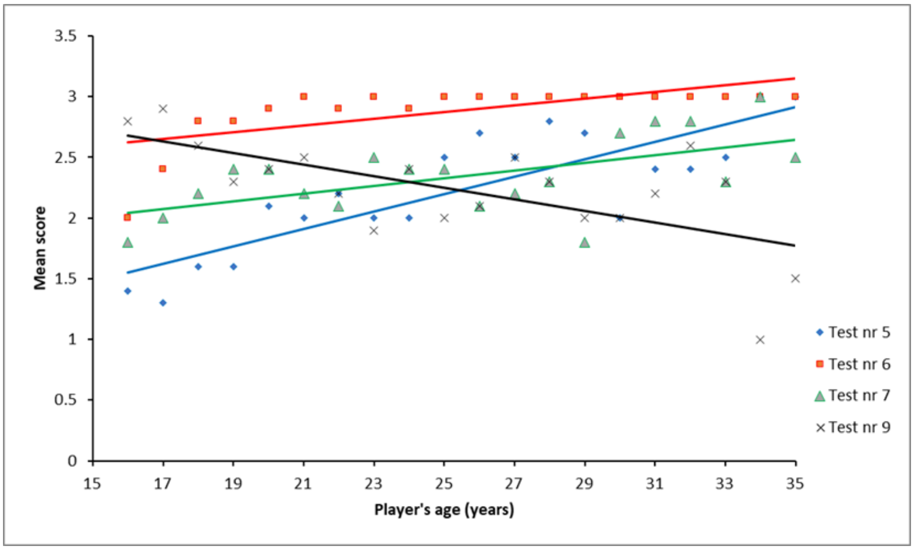

Figure 3. The relationship between age and the mean test score of each year of age in the four tests that showed significant age-related difference. Test 5; Straight leg raises test, (β=0.85, 95%CI: 0.59-1.11, p<0.0001), Test 6; Push up test, (β=0.65, 95%CI: 0.28-1.03, p=0.002), Test 7; Diagonal lift test, (β=0.58, 95%CI: 0.18-0.99, p=0.0068), Test 9; Functional shoulder mobility test, (β=-0.65, 95%CI: -1.03-0.27, p=0.002).

4.2 Study II

4.2.1 Participation and progress

During the 32-week research period, 229 players 23.8 ± 4.6 yrs. of age participated, responding to at least one questionnaire. The total response rate was 72%. Sixty-eight percent of reported problems were not affecting player's performance or participation but substantial problems, affecting performance or participation, occurred in 28% of cases. In total, 4% of registered problems were causing absence from participation. Figure 4 shows the prevalence of overuse problems during the 32-week observation period.

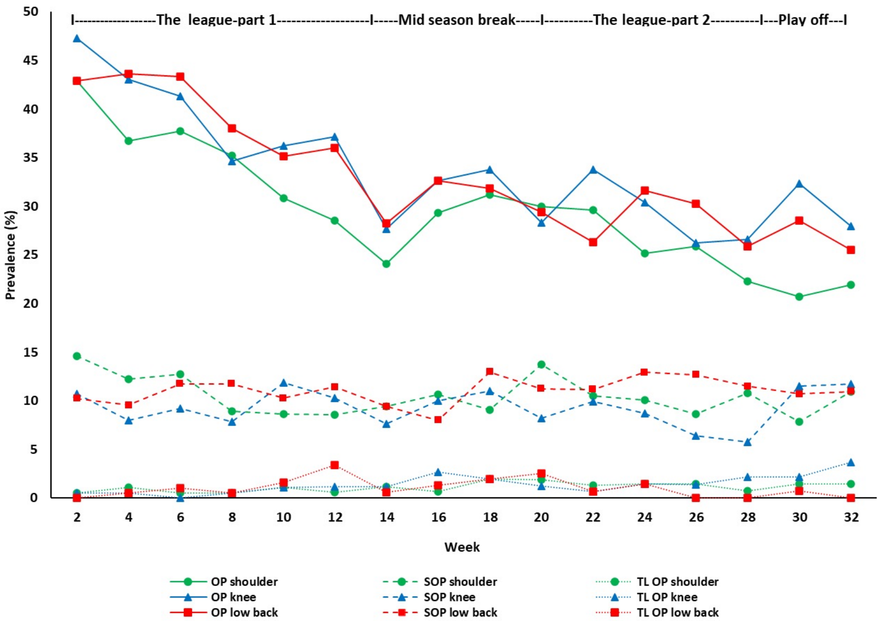

Figure 4. Prevalence of overuse problems in 32-week research period (16 questionnaires). OP= Overuse problems, SOP= Substantial Overuse problems, TL OP= Time loss overuse problems. The bar above the chart shows the timespan during the research period.

4.2.2 Prevalence of overuse problems

During the observation period, the vast majority (95%) of the participants reported at least one overuse problem and 64% at least one substantial problem in one or more anatomical areas. Problems causing absence from participation were reported by 4% of participants. Further results are displayed in table 5.

Table 5. Average prevalence of overuse problems, Tl/SOP ratio and average severity score in Icelandic male handball for the 32-week observation period.

	Knee	Low back	Shoulder	Any proportion†
All overuse problems*	33 (30-36)	32 (29-35)	28 (25-31)	61 (57-65)
Substantial overuse problems*	10 (9-11)	11 (10-12)	10 (9-11)	24 (22-26)
Time loss overuse problems*	2 (1-2)	1 (1-2)	1 (1-2)	4 (3-5)
TL/SOP ratio*	17 (13-21)	11 (8-14)	11 (10-13)	
Severity score**	10 (9-11)	11 (10-12)	9 (8-10)	

† Proportion of any overuse problems registered during the research period.
Tl/SOP ratio=Time loss/substantial overuse problems ratio.
*Values are shown in percentages with 95% CI in parentheses.
**Values are shown as arbitrary units with 95% CI in parentheses.

4.2.3 Relationship between overuse problems and 9+ Screening Test score

As shown in table 6, no associations were observed between total score on the 9+ screening tests and the risk of overuse problems in the shoulder, low back or knee during the 32-week observation period.

Table 6. Association between total scores on the 9+ Screening Test and risk of overuse problems in the knee, low back and shoulder.

	R^2	P
Knee		
All overuse problems	0.0011	0.23
Substantial overuse problems	0.003	0.54
Severity score	0.0125	0.23
Low back		
All overuse problems	0.011	0.70
Substantial overuse problems	0.024	0.08
Severity score	0.036	0.50
Shoulder		
All overuse problems	0.008	0.39
Substantial overuse problems	0.03	0.20
Severity score	0.0002	0.86

4.3 Study III

4.3.1 Participation and progress

During the 6-week research period, 139 players 22.5 ±4.6 yrs. of age participated by responding to at least one questionnaire. The total response rate was 70%. Sixty-nine percent of the reported problems were not affecting performance or participation, but substantial problems, affecting performance or participation, occurred in 28% of cases. Problems causing absence from participation occurred in 3% of cases. Figure 5 shows the weekly prevalence of registered problems divided by anatomical location.

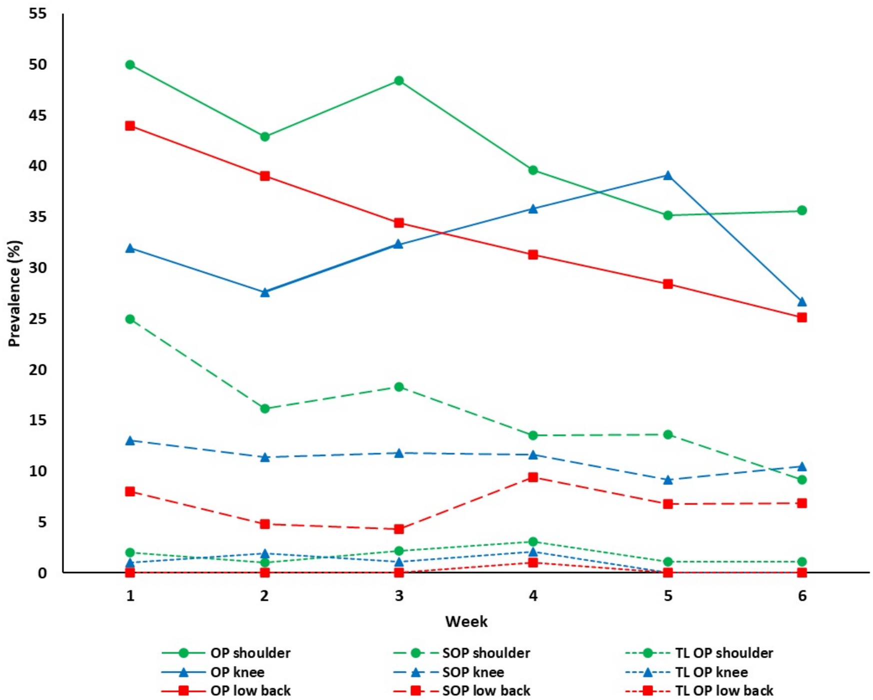

Figure 5. Prevalence of registered overuse problems in the knee, low back and shoulder. OP=Overuse problems, SOP=Substantial overuse problems, TL OP=Time loss overuse problems.

4.3.2 Prevalence of overuse problems

During the observation period, 69% of participants reported at least one overuse problem and 27% at least one substantial overuse problem in one or more anatomical areas. Problems causing absence from participation were 3% (Table 7).

Table 7. Average prevalence and severity score of overuse problems during pre-season in Icelandic male handball.

	Knee	Low back	Shoulder	Any proportion†
All overuse problems*	33 (28-38)	31 (26-36)	40 (36-44)	74 (71-77)
Substantial overuse problems*	11 (10-12)	6 (4-8)	14 (11-17)	29 (26-32)
Time loss overuse problems*	1 (0-2)	0 (0-1)	2 (1-3)	3 (1-5)
TL/SOP ratio*	9 (1-17)	2 (0-4)	11 (7-15)	
Severity score**	10 (9-11)	8 (7-9)	13 (11-15)	

† Proportion of any overuse problems registered during the research period.

TL/SOP ratio=Time loss/substantial overuse problems ratio.

*Values are shown in percentages with 95% CI in parentheses.

**Values are shown as arbitrary units with 95% CI in parentheses.

4.3.3 Training exposure and intensity

Each team trained an average of 6.9 ±1.3 training sessions for 8.9 ±1.3 training hours per week during the 6-week pre-season period. The training hours split into 3.7 ±1.5 hours of physical training and 5.2 ±1.3 hours of handball training (Table 8).

Table 8. Training exposure, estimated training intensity and number of trainings during the 6-weeks pre-season (values are shown as Mean ±SD).

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Average
Weekly number of training	**6.4 ±1.6**	**8.0 ±1.5**	**7.6 ±1.6**	**6.9 ±1.6**	**6.2 ±1.6**	**6.5 ±0.7**	**6.9 ±1.3**
Estimated intensity*	**7.9 ±0.6**	**7.6 ±0.7**	**7.5 ±0.6**	**7.7 ±0.6**	**7.5 ±0.6**	**7.2 ±0.7**	**7.6 ±0.5**
Weekly training hours	**8.2 ±1.2**	**10.2 ±2.2†**	**9.6 ±2.4‡**	**9.1 ±1.9**	**8.1 ±1.5**	**8.1 ±1.1**	**8.9 ±1.3**
Physical training	**4.5 ±1.6**	**4.5 ±2.6**	**4.0 ±2.1**	**3.3 ±2.3**	**3.3 ±1.6**	**2.3 ±1.7**	**3.7 ±1.5**
Running	1.6 ±0.9	1.7 ±1.4	1.1 ±1.0	1.2 ±1.5	0.9 ±0.9	0.7 ±0.7	1.2 ±0.9
Jumping	0.2 ±0.2	0.2 ±0.3	0.3 ±0.3	0.1 ±0.1	0.1 ±0.1	0.0 ±0.0	0.1 ±0.2
Strength training	2.2 ±0.5	2.0 ±1.0	2.3 ±0.9	1.6 ±0.7	2.0 ±0.6	1.3 ±0.9	1.9 ±0.4
Mobility training	0.5 ±0.4	0.6 ±0.7	0.4 ±0.3	0.4 ±0.3	0.3 ±0.3	0.3 ±0.3	0.4 ±0.3
Handball	**3.7 ±1.8**	**5.8 ±3.3**	**5.6 ±2.4**	**5.9 ±3.2**	**4.8 ±1.9**	**5.8 ±2.4**	**5.2 ±1.3**
Shooting practice	0.6 ±0.4	0.8 ±0.3	0.8 ±0.2	0.8 ±0.4	0.7 ±0.3	0.8 ±0.5	0.7 ±0.3
On court training	2.4 ±0.6	3.1 ±1.9	2.8 ±1.1	3.1 ±1.5	2.9 ±0.7	3.3 ±1.0	2.9 ±0.5
Games	0.7 ±0.8	1.9 ±1.1	2.1 ±1.1	2.1 ±1.3	1.2 ±0.9	1.7 ±0.8	1.6 ±0.5

† Significant higher number of weekly training hours than in week 1 (p=0.02), 5, (p=0.01) and 6 (p=0.005).

‡ Significant higher number of weekly training hours than in week 6 (p=0.05).

* Arbitrary units (1-10).

4.3.4 Relationship between overuse problems and training load

As shown in table 9, training load and intensity seems to have more effect on overuse problems and substantial overuse problems in the knees than in the shoulder and low back. Overuse problems and substantial overuse problems in the knees are significantly increased by one overall weekly training hour as well as in one hour of physical training. When observing individual training factors, running and strength training were most associated with increased prevalence of overuse problems and substantial overuse problems in the knee (Table 9). For the low back, increased prevalence of overuse problems was associated with jumping and mobility training. On the other hand, weekly increase by one training hour reduced the overuse problems in the shoulders.

Table 9. Association between the handball players reported overuse problems and training load registered from the coaches. The association is shown as Odds ratio with 95% CI.

		Shoulder		Low back		Knee	
	Av week hrs.	OP	SOP	OP	SOP	OP	SOP
Weekly training hours	9.2 ±1.3	0.90 (0.81, 0.99)*	1.04 (0.92, 1.18)	0.99 (0.90, 1.09)	1.01 (0.82, 1.22)	1.24 (1.12, 1.37)***	1.20 (1.04, 1.37)**
Weekly number of training	6.9 ±1.1	0.89 (0.79, 1.01)	0.99 (0.83, 1.16)	0.93 (0.82, 1.06)	0.97 (0.75, 1.24)	1.37 (1.20, 1.57)***	1.46 (1.22, 1.76)***
Estimated intensity†	7.6 ±0.5	0.84 (0.64, 1.08)	0.86 (0.61, 1.22)	0.92 (0.70, 1.20)	0.63 (0.37, 1.07)	0.76 (0.58, 1.01)*	0.51 (0.33, 0.77)***
Physical training hours	3.2 ±1.1	0.92 (0.81, 1.03)	1.05 (0.89, 1.22)	0.98 (0.87, 1.11)	1.02 (0.80, 1.28)	1.16 (1.03, 1.31)**	1.49 ((1.25, 1.79)***
Running	1.2 ±0.9	0.92 (0.79, 1.06)	1.03 (0.84, 1.25)	0.95 (0.81, 1.10)	0.84 (0.58, 1.14)	1.30 (1.12, 1.52)***	1.59 (1.29, 1.97)***
Jumping	0.1 ±0.2	0.90 (0.40, 2.01)	0.57 (0.16, 1.76)	4.47 (1.97, 10.25)***	3.96 (0.94, 15.34)	0.64 (0.27, 1.49)	0.06 (0.01, 0.34)***
Strength training	1.9 ±0.4	0.88 (0.70, 1.11)	1.13 (0.84, 1.53)	0.93 (0.73, 1.18)	1.39 (0.88, 2.22)	0.99 (0.78, 1.26)	1.61 (1.12, 2.34)**
Mobility training	0.4 ±0.3	0.83 (0.55, 1.24)	0.95 (0.53, 1.63)	1.81 (1.20, 2.75)**	1.26 (0.59, 2.49)	0.55 (0.34, 0.86)**	0.04 (0.01, 0.12)*
Handball training hours	5.7 ±0.8	0.99 (0.84, 1.14)	1.16 (0.96, 1.42)	0.89 (0.76, 1.03)	0.75 (0.54, 1.03)	1.16 (1.00, 1.35)	1.28 (1.03, 1.61)**
Shooting practice	0.7 ±0.3	0.68 (0.44, 1.06)	1.40 (0.81, 2.39)	0.79 (0.51, 1.24)	0.60 (0.22, 1.45)	1.82 (1.16, 2.85)**	3.22 (1.73, 5.99)***
On court training	2.9 ±0.5	1.04 (0.90, 1.21)	1.08 (0.89, 1.29)	0.96 (0.82, 1.12)	0.98 (0.69, 1.33)	1.11 (0.95, 1.29)	1.33 (1.07, 1.64)**
Games	2.1 ±0.5	0.99 (0.84, 1.16)	1.04 (0.84, 1.29)	0.94 (0.80, 1.11)	0.81 (0.57, 1.12)	0.98 (0.82, 1.15)	0.77 (0.59, 1.00)*

†Arbitrary unit (1-10). *p<.0.5, **p<.01, ***p<.001

5. Discussion

The main findings of this thesis support previous outcomes that the 9+ Screening Test cannot be used to predict injuries in handball, since no association was found between Icelandic elite male handball players score on the test and their reported overuse problems in the shoulders, low back and knees. However, the thesis provides normative functional movement screening data on elite male handball players, demonstrating differences between groups, such as age, level of play and playing positions. Youth players displayed the highest scores in tests assessing mobility, but in contrast, the lowest scores in tests measuring trunk strength and stability. National team players scored highest in tests assessing stability and neuromuscular control in the trunk. Comparing the test score according to playing positions, goalkeepers reached the highest total score, as well as the highest score in tests requiring hip mobility.

At any given time during one competitive season, one-third of Icelandic elite handball players reported overuse problems and ten percent of the players participated with overuse problems affecting their performance. The prevalence of overuse problems was higher in this thesis compared to other studies, especially in the low back (Aasheim et al., 2018; Clarsen, Bahr, Heymans, et al., 2014). During the 6-week pre-season, almost three out of four players reported overuse problems in one or more anatomical areas. The recorded training load during the pre-season had the greatest effect on increased prevalence of overuse problems in handball players' knees.

5.1 9+ Screening Test score

When looking at the players' total score, the average score is 22.2 points from ten tests, an average of 2.2 points per tests which is similar to the score for football players and recreational athletes (2.1 points) (Bakken et al., 2017; Flodstrom et al., 2016). Few studies have provided normative data and comparing the scores should be done carefully since researchers have been using the 9+ with various numbers of exercises (from 9-11). More data is needed. In this research, goalkeepers earned a higher total score (24.3 ±3.5 points) than players in other positions, where their top scores were in tests 3, 4 and 9, requiring mobility in the hips, thighs and shoulders. This is in line with the fundamental requirements of the goalkeeping position. Goalkeepers need to be flexible to react against their opponent's shots and they use a significant time during their training sessions to increase and maintain their mobility (Karcher & Buchheit, 2014).

Comparing the tests results according to level of play (Table 4), a certain pattern is displayed. Junior players earned higher scores than other groups in tests 3, 8 and 9, all requiring mobility, but lower scores in tests 5, 6 and 7, requiring trunk strength and stability as well as in test 1 which requires trunk stability among other factors. Although age-related variability in joint range of motion should be considered (Medeiros, de Araujo, & de Araujo, 2013; Soucie et al., 2011), the physical requirements of modern handball must be presumed as a key factor behind the physical difference demonstrated in table 4. According to studies, physical strength and power are, at any level, fundamental factors behind important competence in handball as well as injury prevention (Clarsen, Bahr, Andersson, et al., 2014; Wagner, Fuchs, & von Duvillard, 2018; Zapartidis et al., 2011). It seems logical to conclude that stronger muscles with more volume and rigidity can play a role in both increasing stability and strength as well as decrease range of motion. Extensive strength training with emphasis on the anterior muscle group of the shoulder girdle (Kvorning, Hansen, & Jensen, 2017; Massuca et al., 2015) tends to cause muscular imbalance and restricted movements among throwing athletes (Gillet, Begon, Blache, Berger-Vachon, & Rogowski, 2017). Association between restriction in range of motion and shoulder injuries among elite handball players has been studied, with conflicting results (Andersson et al., 2017; Andersson, Bahr, Clarsen, & Myklebust, 2018; Asker, Brooke, et al., 2018; Clarsen, Bahr, Andersson, et al., 2014; Fredriksen et al., 2020). As displayed in figure 3, age-related differences were observed on scores of strength, stability and quality of movement in muscle groups around the spine and abdomen as well as mobility in the shoulders (Frohm et al., 2013). It demonstrates that physical maturity and growth are believed to be basic factors developing physical strength and skill irrespective to anthropometrics of the individuals (Ghobadi et al., 2013; Gorostiaga et al., 2005). These notable results raise questions about possible associations between age-related differences in trunk strength and stability and high incidence of time-loss injuries in the low back region. A study on Icelandic male handball players (age. 23.4 yrs. 95%CI 22.7-24.1) revealed that one-third of overuse injuries causing absence from participation (time-loss) were located in the low back region (Rafnsson et al., 2019) (Appendix 4). Drawing conclusions should be done with care, but it raises speculations about the training culture, for example, the team's age composition and training load. It is a platform for further research.

5.1.1 Association between 9+ Screening Test and overuse problems

Until the present study, data providing an association between overuse problems and performance on functional screening tests were limited. In this study, no association was observed between the score from the 9+ test and risk for overuse problems. This finding is in line with results published on professional football players (Bakken et al., 2017), adolescent handball players (Karlsson et al., 2021) and recreational athletes (Flodstrom et al., 2016).

In general, the purpose of using screening tests is to assess quality of movement patterns by recording modifiable variables and estimating physical performance characteristics such as strength and stability (Bahr, 2016), with the total score is most often used to assess the risk of injury where a high score on the test is interpreted as a low risk of injury (Bonazza et al., 2017; Trinidad-Fernandez et al., 2019). The objective is early intervention to minimize risk factors prior to injury (Bahr, 2016). According to previous studies, two of the strongest risk factors for sport injuries are athletes rising age and injury history (Arnason et al., 2004; Fulton et al., 2014; Hagglund, Walden, & Ekstrand, 2013), factors that screening tests are not accounting for. Knowing that the risk of recurrent injury is greatest shortly after recovery, injury history and timing on full recovery should be recorded to distinguish between recurrent and new injuries in the regression (Verhagen & Bay, 2010). Even though a low number of recovery days and a high training volume were recorded as risk factors for overuse injuries in top-level endurance athletes (Ristolainen, Kettunen, Waller, Heinonen, & Kujala, 2014), such external risk factors (Figure 1), as training volume and match schedule, environment and protective equipment, can be difficult to assess.

Analysis of each of the 9+ screening tests indicates that some of them screen for various physical factors and anatomical areas. For example, test number 2 (Single leg squat) screens for stability in the ankle, knee, hip, and trunk, as well as strength in lower extremities. The participant's performance is recorded irrespective to anatomical location or a reason for it (for example, a lack of balance, strength or mobility). More accuracy when analysing the performance could make the screening test more precise by clustering higher number of tests in further analysis. The 9+ screening test can be used as a methodical approach to collect data to evaluate quality of movement patterns, asymmetries, as well as physical factors like balance, strength and mobility (Lloyd et al., 2015; V. B. Marques, Medeiros, de Souza Stigger, Nakamura, & Baroni, 2017). The dataset can be used as a pre-injury status to use in rehab as a criterion to fulfil before return to sports. However, 9+ screening test cannot be used to assess injury risk for overuse problems in elite handball players.

5.2 Prevalence of overuse problems in handball

In recent years, researchers and physicians have realized limitations in using injury incidence and absence from participation to estimate overuse problems in sports (Bahr, 2009). A new methodology has been developed to put the extent of overuse problems in sports in a new perspective, focusing on prevalence instead of incidence. Two categories, all overuse problems and substantial overuse problems, have been used to classify the extent of the problems (Clarsen et al., 2013). In this thesis, the category time-loss overuse problems have been added in the model in an attempt to add in an important dimension that analyses the general consequences regarding overuse problems in sports. Until the present study, few studies have provided prevalence on overuse problems in handball and no data is available regarding the pre-season in the sport. Comparing results from this thesis with other studies should be done carefully since the research populations differ regarding age, gender and level of play (Aasheim et al., 2018; Andersson et al., 2017; Asker, Holm, Kallberg, Walden, & Skillgate, 2018; Clarsen, Bahr, Heymans, et al., 2014).

Comparing the prevalence between the pre-season and the competitive season, the prevalence of overuse problems (40% vs. 28%) and substantial overuse problems (14% vs. 10%) was higher in the shoulder during the pre-season than in the competitive season (Table 5 and Table 7). When looking at figure 5, the prevalence was high in the first weeks of the pre-season. The majority of the players have not played handball for 8-12 weeks during their summer break. When the teams start their pre-season training, with players continuously passing and throwing the ball, many players experience symptoms in their throwing shoulder while the muscles adapt to the throwing movements by regaining strength, stamina and kinematic control (Almeida et al., 2013; Andersson et al., 2018; Andrade et al., 2013; Edouard et al., 2013; Seroyer et al., 2009). Overall, the prevalence of overuse problems in the shoulder is greater among Icelandic handball players, in both the competitive- and pre-season, than in previously published studies (17-23%) (Aasheim et al., 2018; Andersson et al., 2017; Asker et al., 2017; Clarsen, Bahr, Heymans, et al., 2014). The prevalence of substantial overuse problems is in line with the highest prevalence reported (Asker et al., 2017). Even though comparison between studies should be done with care regarding the great variability in the research population (gender, age, level of play), the results have shown that the prevalence of shoulder problems is high and more than one tenth of Icelandic male handball players are performing with overuse problems in the shoulder at any time, affecting their performance and participation. The team's coaches should note that the prevalence is highest during the first weeks of the pre-season. This is a platform for further studies.

In the low back, the prevalence of substantial overuse problems was higher in the competitive season than in the pre-season (11% vs. 6%) (Table 5 and Table 7). Considering the difference in prevalence of low back problems between pre-season and competitive season, the majority of the players seem to be without substantial overuse problems during the first weeks of the pre-season training following their summer break (Figure 5). The prevalence was higher than in other studies (2-3%) (Aasheim et al., 2018; Clarsen, Bahr, Heymans, et al., 2014). The high prevalence reported corresponds with results from a study on Icelandic handball players, where the incidence of time-loss overuse injuries in the low back among Icelandic handball players was higher than in comparable studies (Rafnsson et al., 2019). Even though more data is needed, these results raise questions regarding internal factors in Icelandic handball. The teams' squads contain relatively few players, possibly creating an external pressure, pushing players to participate with overuse problems in the low back. The teams' players are relatively young (23.8 ±4.6 years in study II and 22.5 ±4.6 years in study III). The results displayed in figure 3, demonstrating age-related increase in strength and stability in trunk raises speculations if some of the players are not physically prepared to cope with the volume and intensity required in elite male handball. It is an interesting platform for further research.

When looking at the prevalence in the knee, there was no difference between the pre- and competitive season in Iceland. One third of the players were experiencing overuse problems and one out of ten was playing with an overuse problem affecting their performance. It is higher than in other studies (Aasheim et al., 2018; Clarsen, Bahr, Heymans, et al., 2014) but there is little data available providing prevalence of overuse problems in the knees. Studies presenting incidence of injuries in handball (Bere et al., 2015; Langevoort et al., 2007; Rafnsson et al., 2019) demonstrated that the knees are susceptible for time-loss injuries and, therefore, it seems logical that a significant number of players when experiencing a high prevalence of overuse problems during their participation period.

5.3 Relationship between risk of overuse problems and training load

Until the present study, no research has been published providing data on the associations between overuse problems in elite male handball, training load, and intensity. The training load and intensity seemed mainly associated with overuse problems and substantial overuse problems in the knees. Running exercises and strength training were increasing the prevalence of substantial overuse problems by 60% for every weekly training hour (Table 8). Both running exercises with changes in speed and direction and strength training creates intensive forces on the knees of the handball players, which are relatively heavy (average; 90.0 ±9.8 kg). Jumping exercises were associated with overuse problems in the low back, where the prevalence increased 4.5 fold for every hour trained. These results should be noted in context to the high prevalence of overuse problems presented in this thesis, as well as the incidence of time-loss overuse injuries in the low back among Icelandic male handball players (Rafnsson et al., 2019).

In the shoulders, the only association found was between overuse problems and weekly training hours, with 10% decline of overuse problems for every weekly hour in training. The reason is believed to be that the increase of the training hours is highest during the first couple of weeks (Figure 5), in contrast to the declining prevalence of overuse problems (Table 8). Maybe surprisingly, no association was found between overuse problems in the shoulders and reported training load, training intensity or training factors. No direct association is provided between overuse problems in the shoulders and training volume. The numbers shown in Table 8 raise speculations about the pre-season, which starts with high training load and intensity and a great number of handball exercises. A high volume of shots and sudden increase in throwing exercises make players susceptible for shoulder injuries (Hulin et al., 2014; M. Møller et al., 2012; Wheeler, Kefford, Mosler, Lebedew, & Lyons, 2013). Coaches need to be careful and sensible when planning their teams training schedules. Awareness regarding risk factors in sports is needed.

5.4 Methodological strengths and limitations

In general, this thesis provides new knowledge on Icelandic male handball players. The data adds further information regarding the limited usability of screening tests in injury prevention in sports, as well as comprehensive data regarding injury prevalence in handball ranging from beginning of pre-season until end of the competitive season. It should be noted that the data in the thesis is limited to Icelandic elite male handball players and three anatomical areas. Therefore, comparison between gender, sports and level of play should be done carefully. In recent years the OSTRC overuse questionnaire has rapidly become an advanced method to record and define overuse problems in sports with researchers from various countries translating and adapting it (Ekman et al., 2015; Hirschmüller et al., 2017; Jorgensen, Rathleff, Rathleff, & Andreasen, 2016; Nagano, Kobayashi-Yamakawa, Higashihara, & Yako-Suketomo, 2019; Pimenta, Hespanhol, & Lopes, 2021). Although a number of studies have been published in recent years, a meta-analysis has provided variations in definitions as well as between anatomical parts, sports and level of play (Franco et al., 2021). These differences limit comparisons between studies, causing difficulties in all conclusions.

The findings from study I were based on results from elite handball players from the majority of the teams playing in Iceland. The results provided differences between groups according to age and level of play, both in total score and in tests assessing strength and stability in the trunk. Similar results have not been demonstrated before. Although the test seems usable to record and assess physical abilities of athletes and differences between groups, one should consider that the factors determining the score in a few of the 9+ tests can be related to more than one anatomical part or ability such as balance, strength or flexibility. Therefore, these tests cannot be clustered with other tests to determine. For example, trunk strength without creating sub-factors in each test to clarify the reason behind the score. It could be a valid addition to increase the test's accuracy.

In study II, a major strength is that the data was comprehensive. The research period was a full competitive season, and the participants were players from a majority of the teams in the Icelandic handball leagues, with a good response rate. The methodology used in the study created new information on overuse problems in Icelandic male handball, creating an indicative database useful for people responsible for players health and injury prevention. A limitation in the study is that the group, both performing the 9+ test and answering the questionnaire, only consisted of 130 players. Also, the response rate dropped during the research period, partially during the organization of the Icelandic tournament where the last part of the tournament is a knockout competition.

In study III, the main strength was that it is the first study to evaluate the association between overuse problems in male handball and training load in handball. The research had an acceptable response rate and gave important information about training volume, intensity and prevalence of overuse problems in the pre-season. The short research period limits this study as well as the data which only pertains to elite male players and three anatomical areas. The distribution of the first OSTRC overuse questionnaire should have been a week before the start of the pre-season to keep the first week prevalence in the average score. The training exposure, estimated training intensity and training factors recorded by the team's coaches was on a form which was convenient to use. It was not time-consuming and could therefore increase the response rate from the coaches as well as being an inexpensive method for the teams. On the other hand, the recording system was less accurate than modern GPS recording system used in grand tournaments and in professional clubs. For example, the intensity was estimated by the coaches, meaning what intensity they expect from their players during the training instead of recording the actual workout.

6. Conclusions

The findings from this thesis adds new knowledge to several aspects of overuse problems in elite male handball. The OSTRC overuse problems registration method adds a new and important dimension to recording prevalence and extent of injuries in sports, not least in overuse problems where incidence of injuries causing absence from participation seems to be an inaccurate parameter.

1. The 9+ screening test can be used to record differences between groups in both total score and in some of the ten individual tests. The test score can be used to assess differences between groups such as playing positions, level of play and age. Normative data on Icelandic male handball players were created and added into the field.

2. The 9+ screening test cannot be used to estimate risk of overuse problems in the knee, low back and shoulder in elite handball players. A significant number of Icelandic elite handball players are constantly participating with overuse problems during their pre- and competitive season. The prevalence of overuse problems in the low back is higher among Icelandic elite handball players than in comparable studies.

3. During a six-week pre-season period, handball players are most susceptible for overuse problems in the knees. The prevalence is highly associated with running exercises and shooting practice. Icelandic elite handball players start their pre-season intensively with significant increase in training volume during the first two weeks. Prevalence of overuse problems in the shoulder is high during the first weeks of the pre-season.

6.1 Future perspectives

As described in this dissertation, the 9+ screening test cannot be used to predict overuse problems in the shoulder, low back and knee in male handball players. The results showed that modifiable internal risk factors are difficult to use to estimate the risk of overuse problems. However, the test captured differences between groups, both in total score and individual tests. The most notable differences observed were the age-related increases in strength and stability in the trunk and low back. We regard these results as a positive observation, but further studies are needed. It could be an interesting perspective to observe if additional exercises or further classification inside each test (for example stiffness in upper limb or lack of strength in lower limb) could make the test more precise. The 9+ screening test can be used to reveal possible weaknesses in players' physical abilities, such as a lack of strength or mobility or imbalances between sides or between muscle groups. The results can be used to create a specified training program in order to correct the player's physical function.

The results from study II demonstrated a high prevalence of overuse problems in the low back in Icelandic handball players. This observation is interesting and should be seen as an addition to former results demonstrating a high incidence of time-loss overuse injuries among Icelandic male handball players. These results mentioned above, in perspective with the age-related increase in strength and stability in trunk and relatively low age composition in the cohort (23.4 yrs. 95%CI 22.7-24.1) can be an interesting platform for future studies. It needs to be observed with various perspectives. First, the age composition in Icelandic male handball must be investigated. Young talented players, registered in both junior and senior teams, are possibly overloaded by large number of competitive games during the season. The tight game schedule can both be aggravating overuse problems as well as occupying time of the week where young players should be performing their strength training or even resting. Secondly, the strength training culture must be inspected, according to when young players start their strength training, how they are prepared, and how they are succeeding. It should be questioned whether the young players are strong enough to participate with mature and strong senior players in this contact sport. Third, the culture in the teams should be observed. Possibly, some of the teams, with relatively thin squads may put some pressure on players with overuse problems in the low back to participate. Something that could not be possible with overuse problems in the shoulder or knee.

The prevalence of overuse problems in the shoulder and knee is high during the start of the pre-season. It should not be unexpected with the players having an intensive start following their summer break. Coaches must pay attention to this high prevalence in the shoulders during the first weeks and use the first training sessions to adapt the players shoulders to the load with a slow progression in throwing exercises. When looking at the training volume and intensity, it seems that the coaches are intentionally starting the pre-season intensively and with significant increase in training volume. The coaches must be aware of the injury risk associated with sudden increase in training load and intensity. It would be interesting to pay more attention to the first weeks of the pre-season, with more accurate recording, like GPS chips technique and start to register the prevalence of overuse problems during the last weeks of their summer break to record the status prior to the pre-season.

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Original publications

Paper I

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Original Research

Characteristics of functional movement screening testing in elite handball players: Indicative data from the 9+

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Objectives: To test 9 + screening batterie's intra-rater reliability, to provide indicative data of elite handball players, and to analyze difference between age, playing positions and level of play.
Design: Descriptive study.
Setting: Icelandic elite male handball players.
Participants: 182 elite male handball players.
Main outcome measures: Nine + screening battery.
Results: Reliability test: Intra-class correlation for the total score was 0.95. The correlation of each of the test factors varied from 0.63 to 0.91. The mean total score was 22.3 ± 2.9 (95%CI 16.7–28.1), with no difference in total score comparing players age or level of play. Goalkeepers displayed a higher total score than other players ($F_{3,151} = 5.75$, $p = 0.001$). Junior players had a lower score than senior players in tests measuring abdominal strength and core stability; Test 5; $|^2(3, 182) = 41.5$, $p < 0.0001$, Test 6; $|^2(3, 182) = 55.7$, $p < 0.0001$, Test 7; $|^2(3, 182) = 11.8$, $p < 0.005$, but higher scores in tests measuring trunk and shoulder mobility Test 8; $|^2(3, 182) = 18.2$, $p < 0.0001$, Test 9; $|^2(3, 182) = 22.2$, $p = 0.006$.
Conclusions: The 9+ intra-rater reliability was acceptable for the total score and individual tests. Age-related differences were provided in many individual tests.

1. Introduction

Handball has been a professional sport for years and an Olympic sport since 1972. The popularity has been growing fast during the last decade, with many well organized events with packed arenas and live broadcasts to 200 countries (Karcher & Buchheit, 2014). Handball has matured into a fast dynamic sport; the most significant change occurring in 2000 when teams were allowed a quick throw-off to increase the speed of the game (Karcher & Buchheit, 2014). As a result, players needed to improve their physical fitness, with obvious differences between playing positions (Haugen, Tonnessen, & Seiler, 2016; Hermassi et al., 2018; Karcher & Buchheit, 2014; Michalsik, Aagaard, & Madsen, 2013; Sibila & Pori, 2009). Even in youth handball there is a clear tendency that playing positions are determined by anthropometric and physical abilities (Zapartidis, Kororos, Skoufas, & Bayios, 2011). The physical factors are becoming more important. In a study from the men's World Cup tournament in 2013 (24 participating teams), the players from the bottom eight were shorter and had less body mass than the players from the top 16 teams (Ghobadi, Rajabi, Farzad, Bayati, & Jeffreys, 2013). In recent years, researchers have presented data on physical characteristics (body mass, height, BMI, throwing mechanism, etc.) according to playing positions, level of play and level of skill (Gorostiaga, Granados, Ibanez, & Izquierdo, 2005; Haugen et al., 2016; Karcher & Buchheit, 2014). Current handball literature aims to advance the knowledge of injuries in handball, analyze injury mechanisms as well as improve the players effort and quality in professional handball (Andrade et al., 2013; Clarsen, Bahr, Andersson, Munk, & Myklebust, 2014; Dello Iacono et al., 2017, 2018; Ghobadi et al., 2013; Gorostiaga et al., 2005; Karcher & Buchheit, 2014; Kvorning, Hansen, & Jensen, 2017;

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Manchado, Garcia-Ruiz, Cortell-Tormo, & Tortosa-Martinez, 2017; Massuca, Branco, Miarka, & Fragoso, 2015; Michalsik et al., 2013; Sibila & Pori, 2009; Sporis, Vuleta, Vuleta, & Milanovic, 2010; Wagner et al., 2010, 2014, 2018).

In recent years, functional movement tests have been popular tools to screen athletes, focusing on "dynamic“ tests to reveal possible variations in body function (Cook, 2004). One of these tools, “The 9 + Screening Battery” (9+), was developed by a Scandinavian research group as a method to screen athlete performance. It consist of five tests from the Functional Movement Screen (FMS), one from the American tennis association (USTA HPP), plus five other tests added by the group to test for mobility, dynamic trunk strength and knee control (Frohm, Heijne, Kowalski, Svensson, & Myklebust, 2012; Frohm & Kockum, 2013). In recent years, FMS has been tested for reliability (Minick et al., 2010; Teyhen et al., 2012), non-contact and overuse injuries (Warren, Smith, & Chimera, 2015), comparison with previous injuries (Letafatkar, Hadadnezhad, Shojaedin, & Mohamadi, 2014) and predictive ability for time loss or medical attention injuries (Bunn, Rodrigues, & Bezerra da Silva, 2019; Chorba, Chorba, Bouillon, Overmyer, & Landis, 2010; Kiesel et al., 2007, 2014). “High risk“ atheltes were shown to be 51% more likely to be affected by injury than “low risk“, but with very low level of evidence (Bunn et al., 2019). Studies using 9 + on athletes have failed to show association between the player's total score and lower extremity injuries (Bakken et al., 2017a, 2017b; Leandersson, Heijne, Flodstrom, Frohm, & von Rosen, 2018). as well as intraindividual variability in the total score between seasons, regardless of the players injury (Bakken et al., 2017a, 2017b). Specific exercises based on the 9 + screening battery did not reduce short-term and seasonal injury occurrence in adolescent elite athletes (Heijne, Flodstrom, & von Rosen, 2019). However, the FMS and 9 + tests have been used considerably by coaches and physical therapists to screen for asymmetries and imbalance (Marques, Medeiros, de Souza Stigger, Nakamura, & Baroni, 2017) and as a tool to measure physical capacity of athletes aimed to improve their performance (Atalay, Tarakci, & Algun, 2018), in a field where more knowledge regarding physical conditions is continually required (Kraus, Schutz, Taylor, & Doyscher, 2014; Sprague, Mokha, & Gatens, 2014).

Until now, no studies have used the 9 + screening battery to present indicative data for handball players in relation to their playing positions, level of play or different age groups. Furthermore, previous studies have only used the 9 + total score, but no study have used the scores of each of the 10 individual tests in the 9 + test battery to compare with injury risk, playing position, level of play or different age groups.

The purpose of this study was to test intra-rater reliability of the 9 + screening battery among junior handball players, to provide indicative data of junior and senior elite handball players, and to compare groups according to age, level of play and player position.

2. Methods

2.1. Participants

We contacted the male senior clubs in the two highest divisions (n = 16) in Iceland during the early pre-season with written and oral information about the study; 13 of them accepted the invitation. We also invited male junior players (16–19 yrs) from the clubs. National team players playing professionally abroad were also invited to participate during a training session in Iceland. A total of 182 players provided written consent, including parental consent for players <18 yrs. The study was approved by The National Bioethics Committee in Iceland (Andersson, Bahr, Clarsen, & Myklebust, 2018; Atalay et al., 2018; Bakken et al., 2017a, 2017b; Bland & Altman, 1986; Bunn et al., 2019; Chorba et al., 2010; Clarsen et al., 2014; Cook, 2004; Dello Iacono et al., 2017, 2018; Frohm et al., 2012; Frohm & Kockum, 2013; Gillet, Begon, Blache, Berger-Vachon, & Rogowski, 2017; Heijne et al., 2019; Kiesel et al., 2007, 2014; Kraus et al., 2014; Kvorning et al., 2017; Leandersson et al., 2018; Letafatkar et al., 2014; Manchado et al., 2017; Marques et al., 2017; Medeiros, de Araujo, & de Araujo, 2013; Minick et al., 2010; Soucie et al., 2011; Sporis et al., 2010; Sprague et al., 2014; Teyhen et al., 2012; Wagner et al., 2010, 2018; Warren et al., 2015) and reported to The Icelandic Data Protection Authority.

Of the 182 players included, 61 played in the premier division (no national team games), 44 in the second division (no national team games), 27 were Icelandic national team players, 8 of them current and 19 former professional European club players, now playing for Icelandic premier division clubs. Fifty were junior players from the teams, also playing for the senior teams or vying for a place in the senior team.

The junior players (n = 50, 16–19 yrs, mean 17.3 ± 0.7) were tested twice with the 9 + screening battery with a week interval between tests to examine the intra-rater reliability of the test, while the senior players (n = 132) were tested once.

2.2. Experimental design

All the tests were performed by the same tester (ETR), an experienced sports physical therapist. Prior to the reliability tests, the tester underwent a 2-day course supervised by two of the 9 + developers.

The 9 + screening battery consists of functional exercises and complex movements. The battery is comprised of the: 1. Deep squat test, 2. Deep single leg squat test, 3. In-line lunge test, 4. Active hip flexion test, 5. Straight leg raise test, 6. Push up test, 7. Diagonal lift test, 8. Seated rotation test, 9. Functional shoulder mobility test, and 10. Drop jump test (Frohm & Kockum, 2013). For each of the 10 tests, players received specific instructions and they were scored from 0 to 3 points on an ordinal scale according to their performance (3: correct; 2: correct, but with compensatory movement; 1: not correct; 0: if pain was present). Therefore, the maximum total score was 30. Research tools used were a standard set used for 9 + screening (Frohm & Kockum, 2013). Players were tested barefoot, wearing a t-shirt and shorts. In tests looking for side-to-side differences, the left extremity was tested first. If side differences were present, the lower score was used for data analysis. Before each test, players were shown a photo of the optimal starting and finishing position of each exercise. They received standardized verbal instructions from the tester while performing the test and verbal corrections between attempts. Every player performed each test three times and their best score was used in the analyses. The average time to complete the test was 30 min per player. Player characteristics (i.e., age, height, weight, playing position, level of play) were recorded before each player was tested.

2.3. Statistical analyses

The data were analyzed using SAS Enterprise Guide 7.1. Descriptive data are presented as the mean ± SD. In the reliability study, intra-rater reliability in the two sessions total score was analyzed using intraclass correlation coefficient (ICC (3.1)). ICC varies between 0 (no reliability) and 1 (complete reliability) (Bland & Altman, 1986). Spearman's correlation was used to calculate the intra-rater reliability of the two repeated measurements in each of the ten tests. Standard error of measurement was calculated by using the formula: $SD_{diff}/\sqrt{2}$. T-tests and ANOVA were used to test for group differences in total score, and Bonferroni post-hoc test for multiple comparisons. Chi-square was used to test for differences between groups in individual tests. Linear regression analysis was used to analyze the relationship between test scores and age. The significance level was set as $p < 0.05$.

3. Results

The 9 + screening battery total score among the 50 junior players in the reliability study varied from 16 to 30 points in both tests, with a high correlation between test sessions (ICC (3.1) = 0.95, 95%CI 0.93–0.97, $p < 0.0001$). A significant improvement (0.32, $p = 0.041$) was observed in the total score between the two test sessions (test 1: 21.6 ± 3.5; 95%CI 20.7–22.6 and test 2: 22.0 ± 3.4; 95%CI 21.0–22.9). For each of the 10 tests in the screening battery, Spearman's correlation showed that the intra-rater reliability ranged from 0.65 (test 10, Drop jump test) to 0.95 (test 1, Deep squat). The standard error of measurement ranged from 0.14 (test 10) to 0.37 (test 2).

3.1. Screening

The average total score for senior Icelandic handball players tested in the 9 + screening battery was 22.3 ± 2.9 points (95%CI 16.7–28.1). No significant difference was found in the total score between players in the two Icelandic divisions ($p = 0.26$). Fig. 1 shows the difference in total score between playing positions where goalkeepers total score (24.3 ± 3.5 points 95%CI 22.3–25.7) were 2.2–2.9 points higher than players in other positions. Examining the score for each of the ten individual tests, goalkeepers reached a higher score than other players in test 3; In-line lunge test (2.29 ± 0.9 vs 2.21 ± 0.6, $|^2(2, 155) = 6.26$, $p = 0.05$) and test 4; Active hip flexion test (2.63 ± 0.8, vs 1.70 ± 0.8, $|^2(2, 155) = 35.2$, $p < 0.0001$). Goalkeepers and wing players achieved a higher score than back court and pivot players in test 9; Functional shoulder mobility test (GK; 2.63 ± 0.7, $|^2(2, 155) = 8.9$, $p = 0.01$, WP; 2.45 ± 0.7 vs other players; 2.13 ± 0.7, $|^2(2, 155) = 9.17$, $p = 0.01$).

There was no significant difference in the total score of the 9 + screening battery between groups (junior players, premier league players, 1st division players, national team players, $p = 0.26$). But when examining the score for each of the ten tests, a significant difference was found in several tests with junior players scoring lower in tests requiring trunk strength and stability; Tests 1; Deep squat test; $|^2(3, 182) = 11.1$, $p = 0.0072$, 5; Straight leg raise test; $|^2(3, 182) = 41.5$, $p < 0.0001$); 6; Push up test; $|^2(3, 182) = 55.7$, $p < 0.0001$); and 7; Diagonal lift test, $|^2(3, 182) = 11.8$, $p = 0.006$) and higher in tests requiring hip, trunk and shoulder mobility (3; In-line lunge test, $|^2 = 13.3$, $p = 0.0018$); 8; Seated rotation test; $|^2(3, 182) = 18.2$, $p < 0.0001$); and 9; Functional shoulder mobility test; $|^2(3, 182) = 22.2$, $p < 0.0001$, (Table 1). National team players scored higher in tests requiring strength and stability in trunk and dynamic flexibility Tests 4; Active hip flexion test; $|^2(3, 182) = 10.7$, $p = 0.03$; and 5; Straight leg raise test; $|^2(3, 182) = 11.8$, $p = 0.003$) (Table 1). As seen in Fig. 2, when the results from each of the 10 tests in the 9 + was compared with age as a continuous variable, a significant age-related difference was found in tests for trunk strength and stability as well as shoulder mobility (Ghobadi et al., 2013; Haugen et al., 2016; Wagner et al., 2014; Zapartidis et al., 2011).

4. Discussion

This study provides indicative functional movement screening data on male junior, senior and national team handball players. Young players displayed lower scores in tests measuring trunk strength and stability and higher scores in tests measuring mobility. National team players scored highest in tests requiring stability and neuromuscular control in the trunk.

4.1. Screening tests

Goalkeepers scored higher than other groups of players in the 9 + screening battery due to their high scores that require mobility in hips, thighs and shoulders (Tests 3, 4 and 9). It is related to goalkeeper's requirements to be mobile to react against shots in various positions. A fundamental part of goalkeeper's training sessions consist of exercises to increase their mobility which is even more important than their strength (Karcher & Buchheit, 2014). Overall, playing handball creates muscular imbalances and tends to decrease the range of motion in the throwing shoulder compared to

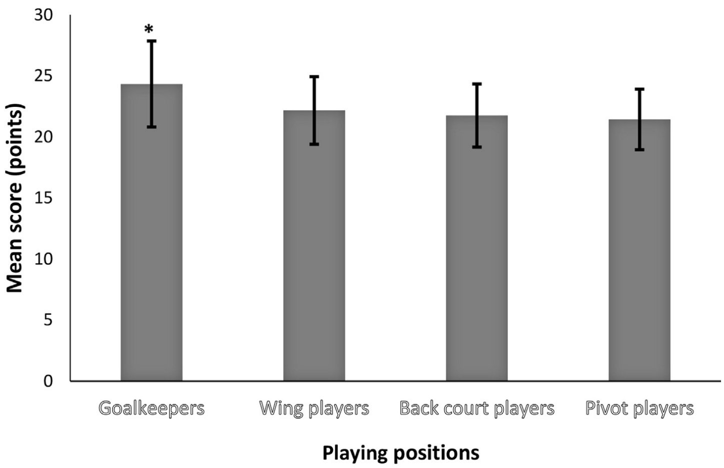

Fig. 1. The average total score of the 9 + screening battery in different playing positions. Standard deviations are shown as error bars for each playing position. *Goalkeepers had significantly higher total score than other players ($p = 0.0009$).

Table 1
The average screening test score for each test and the average total score shown for different skill levels of players.

	1	2	3	4	5	6	7	8	9	10	Total
Junior players	2.15[a]	1.32	2.39[b]	1.71	1.29[a]	2.37[a]	2.02[a]	2.39[b]	2.80[b]	2.95	21.39
Premier division	2.24	1.47[c]	2.26	1.70	2.17	2.89	2.23	2.29	2.21	2.80	22.26
Second division	2.23	1.21	2.27	1.94	2.00	2.98	2.38	2.19	2.27	2.77	22.23
National players	2.19	1.44[d]	2.11	2.07[e]	2.59[e]	2.96	2.33	2.00	2.33	2.78	22.81
Average	2.20	1.36	2.26	1.85	2.01	2.80	2.24	2.22	2.41	2.83	22.17

[a] Significantly lower score than in other groups ($p = 0.007$ (Karcher & Buchheit, 2014), $p < 0.0001$ (Haugen et al., 2016) $p < 0.0001$ (Zapartidis et al., 2011), $p = 0.006$ (Ghobadi et al., 2013)).
[b] Significantly higher score than in other groups ($p = 0.001$ (Sibila & Pori, 2009), $p < 0.0001$ (Gorostiaga et al., 2005), $p < 0.0001$ (Wagner et al., 2014)).
[c] Significantly higher score than in second division players group ($p = 0.006$).
[d] Significantly higher score than in second division players group ($p = 0.03$).
[e] Significantly higher score than in other groups ($p = 0.03$ (Hermassi et al., 2018), $p = 0.003$ (Haugen et al., 2016)).

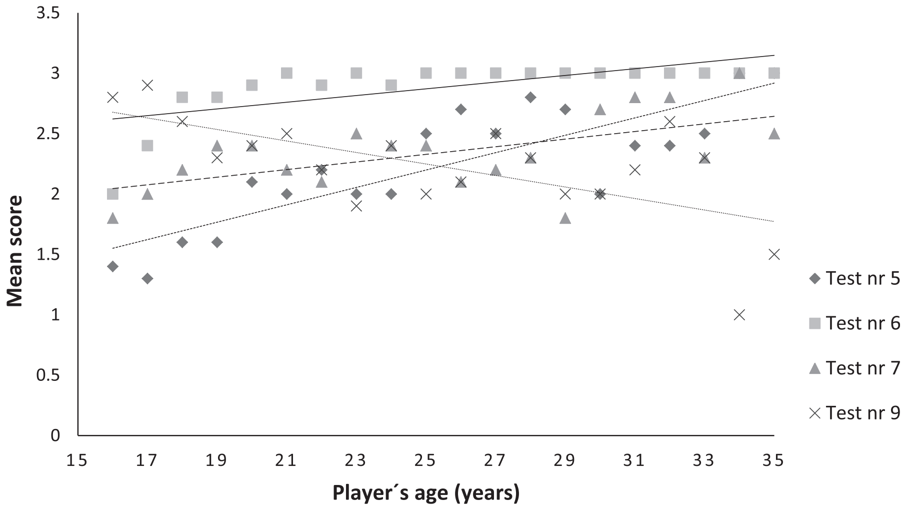

Fig. 2. The relationship between age and the mean test score of each year of age in the four tests that showed significant age-related difference (β represents estimated changes in score per year). Test 5 ($\beta = 0.14$, 95%CI: 0.10–0,19, $p < 0.0001$), Test 6 ($\beta = 0.11$, 95%CI: 0.05–0.17, $p = 0.002$), Test 7 ($\beta = 0.10$, 95%CI: 0.03–0.17, $p = 0.0068$), Test 9 ($\beta = -0.11$, 95% CI: −0.17-0.05, $p = 0.002$).

other athletes (Andrade et al., 2013; Clarsen et al., 2014). Wing players scored higher than back court and pivot players in test 9, which requires shoulder mobility. The wing players are smaller and with less body mass than other outfield players, shooting from narrow angles using various techniques requiring appropriate range of motion in the shoulder joint (Ghobadi et al., 2013; Gorostiaga et al., 2005; Massuca et al., 2015; Sibila & Pori, 2009).

As shown in Fig. 2 (Test 9), shoulder mobility declined with increased age. Researches have shown that age-related changes can be an explanation (Medeiros et al., 2013; Soucie et al., 2011). Players tend to improve their strength during their career by continuous strength training (Kvorning et al., 2017; Massuca et al., 2015). Repetitive movements and strain on the anterior part of the shoulder girdle (i.e. pushing and tackling opponents, ball throwing, weight lifting with emphasis on the protracting muscle groups) can create imbalance and reduced glenohumeral rotation among athletes (Gillet et al., 2017). This represents a risk factor for shoulder injuries among elite handball players but studies analyzing risk factors for shoulder injuries have shown conflicting results and our results should therefore be interpreted with caution and researched further (Andersson et al., 2018; Asker et al., 2018; Clarsen et al., 2014).

4.2. Level of play

In the present study, the national players scored higher than other players in tests 4 and 5, which require adequate active hamstring flexibility, trunk strength and stability. Modern handball requires a large number of high-intensity actions, leading to neuromuscular adaptation; trunk strength and stability are believed to be key performance factors (Karcher & Buchheit, 2014). Therefore, it seems logical that the most skillful group scored highest in these two tests.

Junior players scored lower than other player groups in tests 5, 6 and 7, which all require a high amount of trunk strength and stability, and in test 1, which measures trunk stability, mobility in shoulders and hips. Considering their high score in tests 3, 8 and 9 (Table 1), which all test for mobility and flexibility, it seems reasonable to suggest that lack of trunk strength and stability plays a role in their low score in test 1. Research on Icelandic elite handball players has shown that one-third of overuse injuries resulting in absence from participation were located in the low back/pelvic region (Rafnsson, Valdimarsson, Sveinsson, & Arnason, 2017). This demonstrates a need for further knowledge regarding training methods and possible risk factors. The scores in tests 5, 6, and 7 indicate age-related differences in trunk strength and stability. Age-related variability in range of motion can partially explain these differences (Medeiros et al., 2013), but physical maturity is believed to be an important factor in both strength and skill (Ghobadi et al., 2013; Gorostiaga et al., 2005). Previous studies have indicated that physical presence and strength is a fundamental factor for necessary skills as well as reducing injury risk, even at the junior level (Zapartidis et al., 2011; Clarsen et al., 2014; Wagner et al., 2018). When examining the score shown in Fig. 2, it is important to realize that it not only displays abdominal strength, but also stability and quality of movement created by the muscle groups around the spine and abdomen during flexion and extension (Frohm & Kockum, 2013). Even though some of the junior players matched the senior players in height and weight, they had lower scores irrespective to their anthropometrics. These results raise questions about possible correlations between age related differences in trunk strength and stability and the high prevalence of time loss injuries in the low back region in Icelandic male handball (Rafnsson et al., 2017). Firm conclusions are not possible, but the data represent a platform for further research.

4.3. Study limitations

The study was just performed by one tester, and therefore it was not possible to look at inter-rater reliability. It should be considered that the factors behind the score in some of the 9 + tests can be related to more than one body part, for example in test 1 (shoulders, hips and trunk). This can cause difficulties using the score to compare players without knowing which body part is responsible for the compensatory movement that determines the score. Individual factors inside each test could therefore be a valid addition to increase test sensitivity. Significant difference between groups of players do not always need to be the same as practical difference. Difference that cannot be detected in movement quality are possibly not practical. However, differences that are detectable in movement quality could be classified as practical such as the difference between skill levels in tests 5, 6 and 9, where junior players would be classified one point lower (tests 5 and 6) or higher (test 9) than other players.

4.4. Perspectives

The 9 + screening battery is reliable and usable for physical therapists. The test is easy to use, and the tools used for measurement are space demanding, which makes the test convenient to use. Some of the 10 tests seem to be useful to indicate differences between players in different playing positions, level of play and age groups. Therefore, it could be used as a tool for coaches to test players and compare to indicative data, indicating their stability, strength and flexibility. Physical therapist can use it to reveal some weak links that could be useful in rehabilitation before return to play. These results could be a platform for further research as well as to provide guidance for coaches organizing their training schedule, helping them to spot factors such as imbalance in mobility and muscle strength.

Conflicts of interest

No conflict of interest declared.

Ethical approval

The study was approved by The National Bioethics Committee in Iceland (12–043) and reported to The Icelandic Data Protection Authority. Participants got written and oral information about the study. Participants provided written consent, including parental consent for participants younger than 18 yrs.

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Paper II

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ORIGINAL ARTICLE

WILEY

No relationship between a movement screening test and risk of overuse problems in low back, shoulder, and knee in elite handball players—A prospective cohort study

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Many handball studies have reported injuries that cause absence from participation. In this prospective cohort study on elite Icelandic male players, the aim was to examine the prevalence of overuse problems in low back, knee, and shoulder. Sixteen Icelandic teams were invited. Thirteen teams agreed to participate. The OSTRC overuse questionnaire was distributed every second week during 32-week period. In addition, the 9+ Screening Test was performed on 130 players. In total, 229 players participated with a weekly average response rate of 72%. The average weekly prevalence for shoulder was 28% (95% CI 25% to 31%), for knee 33% (95% CI 30% to 36%), and for low back 32% (95% CI 29% to 35%). Substantial problems were 10% (95% CI 9% to 11%) in shoulder and knee and 11% (95%CI 10% to 12%) in low back. Only 1% (95% CI 1% to 2%) of the overuse problems caused time loss from participation. In total, 61% of the players played with at least one overuse problem and 25% with one affecting their performance. There was no association between the 9+ Screening Test score and overuse problems among Icelandic male handball players.

KEYWORDS
Handball, injuries, injury risk, overuse problems, screening test

1 | INTRODUCTION

Despite a growing research interest on handball, relatively few papers have reported on overuse injuries.[1-4] Most studies have described the incidence of injuries but using a variety of research approaches and differing injury definitions, making a comparison between studies difficult.[1,5,6] The studies show a high incidence of time-loss injuries, particularly during matches (13.3-15.0 injuries/1000 match h vs. 0.6-2.4 injuries/1000 training hrs.)[1-3,7-9] and up to 31-50 and 13-36 injuries/1000 h, respectively, for males and females in international tournaments with a congested match schedule.[6,10]

However, a limited number of studies have recorded overuse injuries and the proportion with current complaints has ranged widely.[1,2,4,11] A recent study on Icelandic elite handball players showed that the most common sites for overuse problems were the shoulder, low back, and knee.[1] Employing a time-loss injury definition may represent a significant limitation, since it may not capture injuries which still may affect performance and participation.[12] The Oslo Sports Trauma Research Center (OSTRC) Overuse Injury Questionnaire was developed to better capture the full burden of overuse injuries, and a study comparing the traditional time-loss method with the new method illustrated that the standard methodology, based on time loss, captured only 10% of overuse problems registered by the new method.[12,13]

The high number of injuries in sports havs been a source of concern for many researchers who are attempting to develop methods that may have a positive impact on injury risk. One of these methods is movement screening tests, used in various sports as tools to identify players with an increased risk for injury based on their test profile, that aim to prescribe preventive measures at the individual level.[14,15] A low score on Functional Movement Screening Test (FMS) has been claimed to be associated with a higher injury risk,[16] while other studies have failed to show a relationship between injury risk and FMS scores[17,18] or pain.[19] The 9+ Screening Test, an advanced version of the FMS, has in one study failed to show such a relationship in a study on professional footballers.[20] No studies have examined possible association between 9+ test score and the risk of overuse problems in handball.

Thus, the aims of this study were to assess the prevalence and severity of overuse problems in the dominant shoulder, low back, and knee among Icelandic male handball players using the OSTRC overuse injury questionnaire and to test whether total score on the 9+ screening battery was associated with the risk of overuse problems in these regions.

2 | METHODS

This prospective cohort study included 13 elite Icelandic male handball teams. All players with a team contract were eligible for participation (n = 229). Players who consented to participate (parents signed for those who were under 18 years of age) were asked to respond to the OSTRC Overuse Injury Questionnaire by e-mail every second week for 32 weeks (n = 16), from September 2012 to April 2013. Each questionnaire was active for a week, with two automatic reminders sent, on the third and the fifth day after distribution. Players were also informed, reminded, and encouraged to respond through a Facebook group administrated by the first author (EThR) who collected all the data. Players were asked to report on any overuse problems in the shoulder, low back, or knee during the previous week. For each anatomical area, players answered four questions to report on possible consequences of overuse problems, on the player's participation, training volume, performance, and extent of pain. Although the questions asked were related to overuse problems, the team physical therapists registered and identified the injury types (acute injuries or overuse problems). If the injury classification was not fully clear, the player was contacted for further classification. Second opinions were sought by physicians, if needed. Acute injuries, defined as injuries with a clear onset as a result of trauma,[21] were excluded from the research data.[13]

Overuse problems (OP) were defined if players reported any reduction in participation, training volume, or performance, or if pain was present. Substantial overuse problems (SOP) were defined if players reported moderate or severe reductions in participation or training volume.[13] Time-loss overuse problems (TLOP) were defined if players reported the maximum value in at least one of the first three questions in the questionnaire. As recommended by Clarsen et al (2013), the data from the first questionnaire were removed from all analyses due to answers fatigue.[13,22]

During the pre-season and the beginning of the season, the 9+ Screening Test[14] was performed on 130 of the players from the 13 teams. Their demographic values were identical to the original cohort. The players performed each of the ten tests once.[15] The 9+ tests total score was calculated for each player and used to assess possible associations with OP and SOP.

2.1 | Statistical analyses

Player age was presented as mean values with standard deviation (SD). Prevalence was calculated as the mean with 95% CI for OP, SOP, and TLOP for each anatomical area by dividing the number of players reporting a problem by the number of questionnaire respondents, multiplied by a hundred. The cumulative severity score was calculated for each of the three body parts as the sum of severity scores for each instance a player reported having a problem.[13] The time-loss/substantial overuse problem (TL/SOP) ratio was calculated by dividing the number TLOP by the number of SOP reported in the questionnaires, multiplied by a hundred.

Linear regression was performed to assess the relationship between OP reported and the player's score on the 9+ Screening Test. The significance level was set as $P < .05$.

The statistics was calculated, and figures created in Excel 2013, and SAS Enterprise guide 7.1.

The study was approved by The National Bioethics Committee in Iceland (VSN12-043) and reported to The Icelandic Data Protection Authority.

3 | RESULTS

3.1 | Participants

A total of 229 players from the 8 Premier division teams and 5 of 8 teams in the 1st division participated with participation being defined as responding to at least one questionnaire (age 23.8 ± 4.6 years, height 187 ± 7.6 cm., weight 89.7 ± 10.2 kg., BMI 25.6 ± 2.3 kg/m^2). Almost 40% of the participants had played at junior national level and 13% at full national level. The first questionnaire was completed by 205 players, and 137 completed the last one. Sixteen players dropped out, 12 due to acute injuries, two transferred to clubs abroad, and two quit playing handball. The players data were included in the analyses until the player dropped out. The overall response rate was 72%. Complete data were reported by 92 participants (40%), and 141 (62%) completed at least 13 of 16 questionnaires.

3.2 | Registered problems

During the 32-week observation period, the participants completed a total of 2590 questionnaires. The majority (68%) of problems reported were mild, not affecting performance or participation. Substantial problems affecting performance or participation occurred in 28% of cases and problems causing absence from participation (time-loss injuries) occurred in 4% of cases (Figure 1).

3.3 | Prevalence and severity score

In total, 95% of the participating players reported at least one overuse problem and 64% at least one substantial problem in one or more anatomical areas during the study period, while 4% reported problems causing absence from participation. The average prevalence of all OP during the study period was 31% (95% CI: 29% to 33%). The average prevalence of SOP during the study period was 10% (95% CI 9% to 11%). The average prevalence of TLOP was 1% (95% CI 1% to 2%), with no difference between anatomical areas.

The average ratio between TLOP and SOP was 13% (95% CI 11% to 15%), with the highest ratio for knee problems 17%.

The average severity score of the problems reported was 10 (95% CI 9% to 11%), with no difference between anatomical areas (Table 1).

The average percentage of players affected by problems from any of the three anatomical areas at any given time during the observation period was 61% (95% CI 57% to 65%) for all OP and 25% (95% CI 23% to 27%) for SOP (Table 1).

3.4 | Relationship between overuse injuries and 9+ screening test score

We observed no significant association between total score on the 9+ Screening Test and any type of overuse problems. The

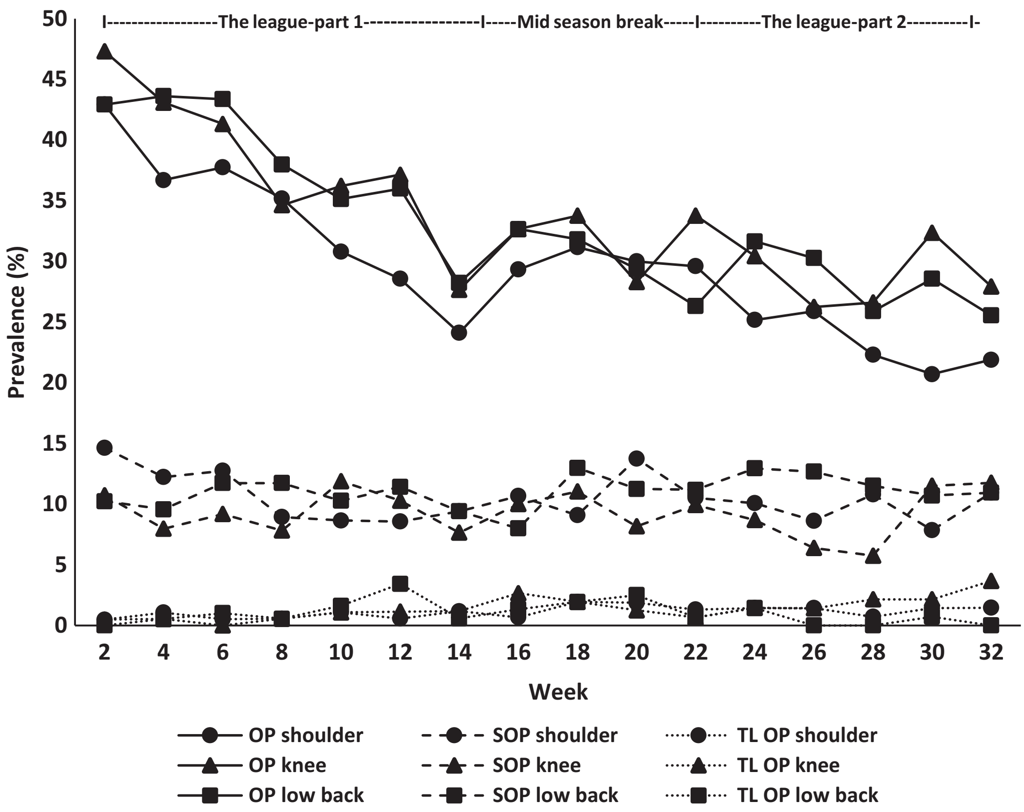

FIGURE 1 Prevalence of overuse problems in 32 weeks research period (16 questionnaires). OP = Overuse problems, SOP = Substantial Overuse problems, TL OP = Time-loss overuse problems. The bar above the chart shows the timespan during the research period

TABLE 1 Average prevalence of all overuse problems and average severity score in Icelandic handball for the 32-weeks observation period

	Knee	Low back	Shoulder	Any proportion†
All overuse problems*	33 (30-36)	32 (29-35)	28 (25-31)	61 (57-65)
Substantial overuse problems*	10 (9-11)	11 (10-12)	10 (9-11)	24 (22-26)
Time-loss overuse problems*	2 (1-2)	1 (1-2)	1 (1-2)	4 (3-5)
TL/SOP ratio*	17 (13-21)	11 (8-14)	11 (10-13)	
Severity score**	10 (9-11)	11 (10-12)	9 (8-10)	

Note: Tl/SOP ratio = Time-loss/substantial overuse problems ratio.

*Values are shown in percentages with 95% CI in parentheses.

**Values are shown as arbitrary units with 95% CI in parenthesis.

†Proportion of any overuse problems at any given time.

effect sizes found were as follows: In shoulder; OP, $R^2 = 0.008$; SOP, $R^2 = 0.03$, in low back; OP, $R^2 = 0.011$; SOP, $R^2 = 0.024$ and in knee; OP, $R^2 = 0.011$, SOP, $R^2 = 0.003$.

4 | DISCUSSION

Our main finding was that there was no association between the players score on the 9+ Screening Test and the risk of overuse problems. At any given time, one in three players reported an overuse problem and one in ten a substantial problem, affecting their performance and participation.

4.1 | Relationship between risk for overuse problems and 9+ Screening Test score

No study has provided data on the association between OP in sport and scores on movement screening tests. Furthermore, this is the first study in handball assessing the association between overuse injuries and movement screening tests.

We detected no association between the 9+ test score and the risk for OP. A re-run of the analysis in a mixed model regression, adding the teams as a cluster variable (random factor) to check for possible cluster between clubs, gave same results. This finding is comparable to results published on professional football players.[20] Most of the screening tests, including the 9+ test measure physical performance characteristics like strength, mobility, and stability[23]—all representing modifiable variables, believed to be intrinsic risk factors.[24] Most of the tests use total score to assess injury risk, where a high score (better performance) is interpreted as low risk of injury.[15-17] The screening tests do not account for factors like age and history of previous injuries—non-modifiable factors believed to be two of the strongest risk factors for injuries in sports.[21,25,26] Injury history should be recorded to clarify whether participants are newly recovered from injury, when the risk of reinjury is greatest, as well as distinguish between recurrent injuries and new ones.[27]

When assessing athlete's injury risk, it is also important to keep in mind that extrinsic factors like equipment, environment, training intensity, and athlete behavior are difficult to assess. In a study like the current, focusing on OP, training exposure and intensity are believed to be fundamental risk factors rather than physical contact and accidents.[28]

4.2 | Average overuse problems

When comparing our results with other studies, care should be taken since the research populations differ regarding age, gender, and level of play.[22,29-31] The prevalence of all reported OP for the three anatomical areas was around 30% for each area, greater than in recent studies, where 14% of Norwegian elite male junior handball players[29] and 18% of Norwegian elite handball players[22] reported OP. Even if the minor OP reported have less of an effect on player participation and performance, the overall high prevalence must be taken seriously by coaches, physical therapists, and physicians. Continuous, intensive training may be a fundamental factor in aggravating symptoms and creating SOP.

One tenth of male Icelandic handball players have SOP in these three anatomical areas and play handball with symptoms affecting their performance and participation at any given time during the observation period. Our numbers are greater than in similar studies[22,29] where the prevalence of pain in the low back in our study is the main cause for the difference. When looking at the proportion of players affected by a problem in any of the three anatomical areas, more than half of the players participated with at least on overuse problem at any given time and one out of four played with OP affecting their performance.

4.3 | Shoulder

For all OP in shoulder, the prevalence (28%) was in line with the 32% that Asker et al (2017) reported on the dominant shoulder in female handball players. It was a higher prevalence than was reported by Aasheim et al[29] (17%) and Asker et al[31] (23%). The prevalence of substantial problems (10%) is in line with what has been reported in Swedish male handball players (10%), but lower than what is reported in Swedish female players (15%).[32] Shoulder injuries in handball are well known and either caused by acute events and overuse injuries.[1,3,4,11,30,31] The fact that 10% of all players are performing every week with SOP affecting their performance demonstrates the need for this new method in injury registration as well as the need for prevention programs similar to what Andersson et al (2017) have shown in their research.

4.4 | Knee

The prevalence of all OP in the knee (33%) was higher than in other handball studies (14% and 20%)[22,29] but in line with a Norwegian volleyball study (36%).[22] The prevalence of substantial problems (10%) is in line with reports regarding Norwegian handball players (8%), but higher than what is reported in junior handball players (5%) and lower than what is reported in Norwegian volleyball players (15%).[22,29] The average prevalence of knee problems is believed to be higher among elite players than in junior players,[29] and it is understandable that the prevalence in volleyball is higher since the sport consists of intensive jumping during games and training.[33,34]

4.5 | Low back

Registered OP in the low back (32%) were higher in our study than in other studies on handball players (12%).[22,29] Only floorball (29%) is in line with our results.[22,35] The prevalence of SOP in the low back (11%) in our study is higher than presented in any other study (2%-4%).[22,29,31,35] Even though 11% of Icelandic handball players are reporting SOP, higher than in any other study published, these results correspond with the results from our previous study where the ratio of time-loss overuse injuries in low back among Icelandic handball players were higher than in similar studies.[1] Our results raise questions about internal factors in Icelandic handball, such as training culture or intensity in high quality sport environment with relatively few players in every squad, possibly pushing them to play with overuse problems without enough rest.

One limitation in this study is that the group performing the 9+ screening test only consisted of 130 players, even though the group did not differ from the whole cohort in injury prevalence and demographic values. The response rate dropped somewhat during the observation period, affecting the prevalence of minor OP, but not SOP. The players seemed to keep reporting substantial problems rather than the minor ones. The dropout during the research period can partially be explained by the manner of the Icelandic tournament, where the teams head in to knock out stages. The losing teams dropped out of the competition with many of their players taking a break for a week or two from training before starting a new pre-season. As well, it should be noted that the data pertains to elite men, not women and youth players, and collecting data on only three anatomical regions does not give a complete picture of the extent of OP in Icelandic handball as it excludes, for example, the elbow, groin and foot.

One strength of the study is that the participants were players from 13 of the 16 teams in the Icelandic handball leagues, with a decent response rate (72%). Secondly, the research period covered eight months—a full competitive season, giving comprehensive data. Another strength is that the methodology used in this study gives new information regarding OP in Icelandic male handball, creating a database useful for coaches and health teams when planning injury prevention for the players.

5 | CONCLUSIONS

There was no association between the 9+ screening battery score and reported overuse problems in shoulder, low back, or knee among Icelandic male handball players. A substantial number of players are playing with overuse problems, affecting their performance at any given time during the competitive season. The prevalence of overuse problems in low back was higher than in other studies.

6 | PERSPECTIVES

Researchers have used functional screening tests to assess possible risk of injuries in sports,[16-18,20] with different outcomes. A study on football players has failed to show an association between 9+ Screening Test total score and risk of injuries. Until now, no studies have examined possible association between 9+ test score and the risk of overuse problems in handball. The results from this study show that there is no relationship between 9+ screening test total score and the risk of overuse problems. Therefore, the test should not be used to assess injury risk in handball.

The new method to capture the full burden of overuse problems adds a new dimension to injury registration since the traditional time-loss registration, captured only 10% of overuse problems registered by the new method.[12,13] It can provide information and knowledge to clinicians and coaches, helpful to control intensity and training load during training and competition.

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DATA AVAILABILITY STATEMENT

The data supporting the findings of the study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Paper III

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ORIGINAL ARTICLE

WILEY

Association between training load, intensity, and overuse problems during pre-season in Icelandic male handball

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Abstract

In this prospective cohort study, the aim was to examine any association between pre-season training load and overuse problems (OP) in low back, knee, and shoulder in Icelandic elite male handball players. A total of 139 players participated, answering the OSTRC overuse questionnaire weekly during a 6-week period. The training volume and intensity were registered by the coaches. The average weekly OP prevalence for shoulder was 40% (95% CI 36% to 44%), for knee 33% (95% CI 28% to 38%), and for low back 31% (95% CI 26% to 36%). Substantial overuse problems (SOP) were 14% (95% CI 11% to 17%) for shoulder, 11% (95% CI 10% to 12%) for knee, and 6% (95% CI 4% to 8%) for low back. The knee was most susceptible for OP with weekly number of training and training hours associated with OP and SOP. For individual training factors, running (OP; OR = 1.30, SOP; OR = 1.59), and shooting practice (OP; OR = 1.82, SOP; OR = 3.22) had the highest associations for knee problems. Jumping was associated with OP in low back (OR = 4.55). Handball players are most susceptible for OP in knees during their pre-season. Every week, 30% participated with (SOP), affecting their performance and participation.

KEYWORDS
handball, overuse problems, training intensity, training volume

1 | INTRODUCTION

Handball is a high-speed contact Olympic team sport with increasing popularity in recent years.[1] Fundamental physical factors essential for handball players are coordination, strength, and endurance. Cognitive factors such as decision making and coping with pressure, social factors such as coaches and club efficacy, and external factors such as environmental conditions are also believed to affect both players and teams with different physical demands between playing positions and level of play.[1-5] Elite handball players run approximately 4 km per game,[6,7] where 8% of the distance is high intensity running.[1,6] Players make on average 1500 activity changes[6] and perform 7.7 ± 3.7 shots per game.[5]

The intensive nature of modern handball requires appropriate pre-season training to fulfill the physical demands of the game. Studies have shown that control of training load is a fundamental factor in reducing the risk of overuse problems (OP) during the pre-season period and protecting athletes against in-season injuries.[8-15] Optimal training methods in handball should include exercises to increase strength and power to withstand the physical demands of the game[3,16,17] and to minimize the risk of injury.[10] Studies have shown that physical performance impairs in the late stage of games.[6,18] It demonstrates the need to train intensively with position-specific exercises to maintain and improve the ability to perform with quick intensive movements throughout the game.[3,4,6,7,18]

The focus on injury data in handball has been on injuries resulting absence from participation.[19-21] In recent years, researchers and physicians have been aware of the need for a research model to register OP in sports. The Oslo Sports Trauma Research Center (OSTRC)[22] overuse injury questionnaire was designed to meet these demands. The registration model has been used on various sports[23,24] revealing unidentified data on injuries[23,24] and health-related problems.[25] Studies on handball players have shown that the prevalence of all reported OP was 14%-33% in knees,[23,24,26] 12%-32% in low back,[23,24,26] and 17%-32% in shoulders.[23,24,26-28] The prevalence of substantial overuse problems (SOP), affecting players performance or participation, was 5%-11% in knees,[23,24,26] 2%-11% in low back,[23,24,26] and 5%-15% in shoulders.[23,24,26-28]

The aim of this study is threefold: First, to investigate the prevalence and severity of OP in knees, low back, and shoulders in Icelandic male handball players during a 6-week pre-season period. Second, to register the magnitude and intensity of training/games for the same period, and third, to investigate associations between training type and overuse problems in knees, low back, and shoulders during the 6-week pre-season period.

2 | METHOD

This prospective cohort study included 10 elite Icelandic male handball teams. All players with a team contract were eligible for participation (n = 139). Players who consented to participate (parents also signed for those who were under 18 years of age) were asked to respond to the OSTRC Overuse Injury Questionnaire[22] by email weekly for 6 weeks, from the beginning of August to mid-September 2015, covering the teams pre-season. Each questionnaire was active for a week, with two automatic reminders sent, on the third and the fifth day after distribution. Players were also informed, reminded, and encouraged to respond through a Facebook group administrated by the researcher. Players were asked to report on any OP in the shoulder, low back, or knee during the previous week. For each anatomical area, players answered four questions to report on possible consequences of OP, on the player's participation, training volume, performance, and extent of pain.[23,29] Although the questions asked were related to OP, the team physical therapists registered and identified injury types. If the injury classification was not fully clear, the player was contacted for further classification. Second opinions were sought by physicians, if needed. Acute injuries, defined as injuries with a clear onset as a result of trauma,[30] were excluded from the research data.[29] OP was defined if players reported any reduction in participation, training volume, or performance, or if pain was present. SOP were defined if players reported moderate or severe reductions in participation or training volume. Time-loss overuse problems (TLOP) were defined if players reported the maximum value in at least one of the first three questions in the questionnaire.[23] As recommended by Clarsen et al (2013), the data from the first questionnaire, covering the first week of the pre-season, were removed from all analyses due to high response rate. During the research period, the team's head coaches recorded their team's weekly number of training, estimated training intensity (squad-based), using arbitrary units from 1-10, and training exposure in minutes on a special form designed by the first author in cooperation with the Icelandic national coaches, based on a review.[2] The cumulative numbers of training exposure were calculated into hours. The scheme contains two types of training: "physical" and "handball". The physical training factors were running, jumping, strength training, and mobility training. The handball training factors were shooting practice, on-court training, and games.

2.1 | Statistics

Players demographic values are presented as mean values with standard deviation (Mean ± SD).[31] Prevalence was calculated as the mean with 95% CI for OP (all reported overuse problems), SOP (overuse problems affecting players performance and participation), and TLOP (overuse problems causing absence from participation) for each anatomical area by dividing the number of players reporting a problem by the number of questionnaire respondents, multiplied by hundred. The cumulative severity score was calculated for each of the three anatomical areas as the sum of severity scores for each instance a player reported having a problem.[29] The time-loss/substantial overuse problem (TL/SOP) ratio was calculated by dividing the number of time-loss problems by the number of SOP reported in the questionnaires, multiplied by hundred.

Logistic regression analysis was performed to assess the relationship between OP reported by the handball players and the training exposure (independent variable) reported by the teams' head coaches. The significance level was set as $P < .05$.

The statistics was calculated, and figures were created in Excel 2019, and Jamovi 1.1.9.0. The jamovi project (2021). [Computer Software], Sydney, Australia. (https://www.jamovi.org).

The study was approved by The National Bioethics Committee in Iceland (VSN12-043) and reported to The Icelandic Data Protection Authority.

3 | RESULTS

3.1 | Participants

A total of 139 players from 8 of 10 Premier division and 2 of 8 first division teams participated, responding to at least one questionnaire. The players average age was 22.5 ± 4.6 yrs., height 187 ± 10 cm, weight 90.0 ± 9.8 kg, and BMI 25.7 ± 2.2 kg/m^2. They had participated in handball on average for 13.8 ± 5.6 years and for 5.0 ± 4.7 years at senior level. The first questionnaire was completed by 115 players, 87 completed the last one. Five players dropped out from the study due to serious acute injuries. The players data were included in the analyses until the player dropped out. The overall response rate was 70%. Complete data were reported by 44 participants (32%) and 93 (67%) completed at least 4 questionnaires.

3.2 | Registered problems

During the 6-week observation period, a total of 566 questionnaires were completed by the participants. The majority (69%) of the reported problems were mild, not affecting performance or participation. Substantial problems, affecting performance or participation, occurred in 28% of cases and time-loss overuse problems occurred in 3% of cases. Figure 1 shows the weekly prevalence of registered problems divided by anatomical location.

3.3 | Prevalence and severity score

In total, 69% of participants reported at least one OP and 27% at least SOP in one or more anatomical areas during the study period, while 3% reported time-loss overuse problems (Table 1). The average prevalence of the tree anatomical areas during the research period was 35% (95% CI: 32% to 38%) for all OP, 11% (95%CI 9% to 13%) for SOP, and 1% (95% CI 0% to 2%) for TLOP. The average ratio between TLOP and SOP was 7% (95%CI 3% to 12%). The average severity score of the problems reported was 10 (95% CI 9 to 12) with no difference between anatomical areas (Table 1).

The average proportion of players affected by problems from any of the three anatomical areas at any given time during the observation period was 74% (95% CI 71% to 77%) for all OP and 29% (95% CI 26% to 32%) for SOP (Table 1).

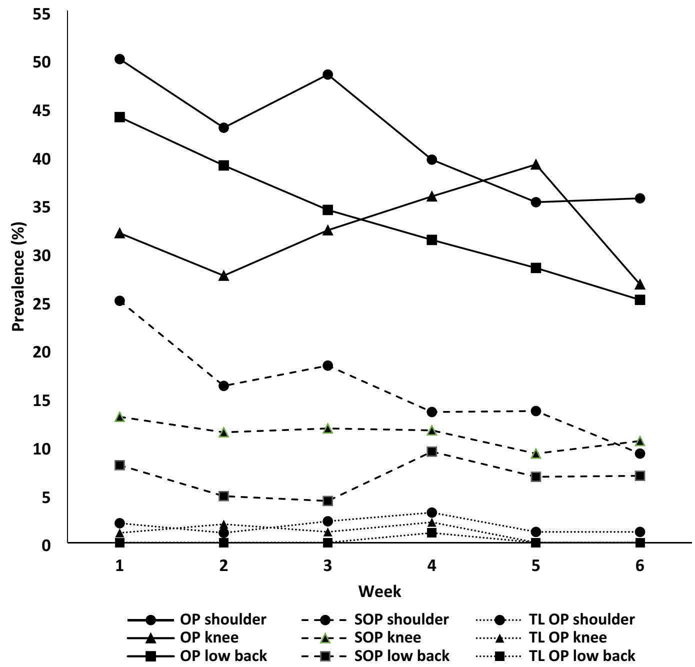

FIGURE 1 Prevalence of registered overuse problems in knee, low back, and shoulder. OP, overuse problems; SOP, substantial overuse problems; TL OP, time-loss overuse problems

TABLE 1 Average prevalence and severity score of overuse problems during pre-season in Icelandic handball

	Knee	Low back	Shoulder	Any proportion[a]
All overuse problems[b]	33 (28-38)	31 (26-36)	40 (36-44)	74 (71-77)
Substantial overuse problems[b]	11 (10-12)	6 (4-8)	14 (11-17)	29 (26-32)
Time-loss overuse problems[b]	1 (0-2)	0 (0-1)	2 (1-3)	3 (1-5)
TL/SOP ratio[b]	9 (1-17)	2 (0-4)	11 (7-15)	
Severity score[c]	10 (9-11)	8 (7-9)	13 (11-15)	

Note: Abbreviation: TL/SOP, Time loss/Substantial overuse problems.
[a]Proportion of any overuse problems registered during the research period.
[b]Values are shown in percentages with 95% CI in parentheses.
[c]Values are shown as arbitrary units with 95% CI in parentheses.

TABLE 2 Training exposure, estimated training intensity, and number of trainings during the 6-week pre-season period (values are shown as mean ±SD)

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Average
Weekly number of training	6.4 ± 1.6	8.0 ± 1.5	7.6 ± 1.6	6.9 ± 1.6	6.2 ± 1.6	6.5 ± 0.7	6.9 ± 1.3
Estimated intensity[a]	7.9 ± 0.6	7.6 ± 0.7	7.5 ± 0.6	7.7 ± 0.6	7.5 ± 0.6	7.2 ± 0.7	7.6 ± 0.5
Weekly training hours	8.2 ± 1.2	10.2 ± 2.2[†]	9.6 ± 2.4[‡]	9.1 ± 1.9	8.1 ± 1.5	8.1 ± 1.1	8.9 ± 1.3
Physical training	4.5 ± 1.6	4.5 ± 2.6	4.0 ± 2.1	3.3 ± 2.3	3.3 ± 1.6	2.3 ± 1.7	3.7 ± 1.5
Running	1.6 ± 0.9	1.7 ± 1.4	1.1 ± 1.0	1.2 ± 1.5	0.9 ± 0.9	0.7 ± 0.7	1.2 ± 0.9
Jumping	0.2 ± 0.2	0.2 ± 0.3	0.3 ± 0.3	0.1 ± 0.1	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.2
Strength training	2.2 ± 0.5	2.0 ± 1.0	2.3 ± 0.9	1.6 ± 0.7	2.0 ± 0.6	1.3 ± 0.9	1.9 ± 0.4
Mobility training	0.5 ± 0.4	0.6 ± 0.7	0.4 ± 0.3	0.4 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	0.4 ± 0.3
Handball	3.7 ± 1.8	5.8 ± 3.3	5.6 ± 2.4	5.9 ± 3.2	4.8 ± 1.9	5.8 ± 2.4	5.2 ± 1.3
Shooting practice	0.6 ± 0.4	0.8 ± 0.3	0.8 ± 0.2	0.8 ± 0.4	0.7 ± 0.3	0.8 ± 0.5	0.7 ± 0.3
On-court training	2.4 ± 0.6	3.1 ± 1.9	2.8 ± 1.1	3.1 ± 1.5	2.9 ± 0.7	3.3 ± 1.0	2.9 ± 0.5
Games	0.7 ± 0.8	1.9 ± 1.1	2.1 ± 1.1	2.1 ± 1.3	1.2 ± 0.9	1.7 ± 0.8	1.6 ± 0.5

[a]Arbitrary units (1-10).
[†]Significant higher number of weekly training hours than in week 1 ($P = .02$), 5, ($P = .01$) and 6 ($P = .005$).
[‡]Significant higher number of weekly training hours than in week 6 ($P = .05$).

3.4 | Training exposure and intensity

Of the 6-week pre-season period, the average number of training sessions per team per week was 6.9 ± 1.3. The average training exposure was 8.9 ± 1.3 training hours per week with the highest exposure in the second and third week. The average physical training hours were 3.7 ± 1.5 and handball training hours 5.2 ± 1.3 per week (Table 2).

3.5 | Relationship between overuse problems and training load

Training load and intensity seem to have less effect on OP and SOP in shoulder and low back than in knees (Table 3). In shoulders, one training hour increase per week reduced the OP by 10% ($P = .04$). In low back, one-hour increase per week in jumping ($P < .001$) and mobility training ($P = .005$) increased the OP. In knees, increase by one weekly training hour, OP increased by 24% ($P < .001$) and SOP by 20% ($P = .011$). For estimated training intensity OP reduced by 24% and SOP by 49% for increase of one arbitrary unit/week on 1-10 scale. For one-hour increase in physical training per week, OP increased by 16% and SOP by 49% while handball training increased SOP by 28% ($P = .03$). For individual training factors, running, strength training, and jumping were most associated with increased OP and SOP and mobility training with decreased OP and SOP in knees (Table 3).

TABLE 3 Association between the handball players reported overuse problems and training load registered from the coaches

	Av week hrs.	Shoulder		Low back		Knee	
		OP	SOP	OP	SOP	OP	SOP
Weekly training hours	9.2 ± 1.3	0.90 (0.81, 0.99)*	1.04 (0.92, 1.18)	0.99 (0.90, 1.09)	1.01 (0.82, 1.22)	1.24 (1.12, 1.37)***	1.20 (1.04, 1.37)**
Weekly number of training	6.9 ± 1.1	0.89 (0.79, 1.01)	0.99 (0.83, 1.16)	0.93 (0.82, 1.06)	0.97 (0.75, 1.24)	1.37 (1.20, 1.57)***	1.46 (1.22, 1.76)***
Estimated intensity[a]	7.6 ± 0.5	0.84 (0.64, 1.08)	0.86 (0.61, 1.22)	0.92 (0.70, 1.20)	0.63 (0.37, 1.07)	0.76 (0.58, 1.01)*	0.51 (0.33, 0.77)***
Physical training	3.2 ± 1.1	0.92 (0.81, 1.03)	1.05 (0.89, 1.22)	0.98 (0.87, 1.11)	1.02 (0.80, 1.28)	1.16 (1.03, 1.31)**	1.49 ((1.25, 1.79)***
Running	1.2 ± 0.9	0.92 (0.79, 1.06)	1.03 (0.84, 1.25)	0.95 (0.81, 1.10)	0.84 (0.58, 1.14)	1.30 (1.12, 1.52)***	1.59 (1.29, 1.97)***
Jumping	0.1 ± 0.2	0.90 (0.40, 2.01)	0.57 (0.16, 1.76)	4.47 (1.97, 10.25)***	3.96 (0.94, 15.34)	0.64 (0.27, 1.49)	0.06 (0.01, 0.34)***
Strength training	1.9 ± 0.4	0.88 (0.70, 1.11)	1.13 (0.84, 1.53)	0.93 (0.73, 1.18)	1.39 (0.88, 2.22)	0.99 (0.78, 1.26)	1.61 (1.12, 2.34)**
Mobility training	0.4 ± 0.3	0.83 (0.55, 1.24)	0.95 (0.53, 1.63)	1.81 (1.20, 2.75)**	1.26 (0.59, 2.49)	0.55 (0.34, 0.86)**	0.04 (0.01, 0.12)*
Handball training	5.7 ± 0.8	0.99 (0.84, 1.14)	1.16 (0.96, 1.42)	0.89 (0.76, 1.03)	0.75 (0.54, 1.03)	1.16 (1.00, 1.35)	1.28 (1.03, 1.61)**
Shooting practice	0.7 ± 0.3	0.68 (0.44, 1.06)	1.40 (0.81, 2.39)	0.79 (0.51, 1.24)	0.60 (0.22, 1.45)	1.82 (1.16, 2.85)**	3.22 (1.73, 5.99)***
On-court training	2.9 ± 0.5	1.04 (0.90, 1.21)	1.08 (0.89, 1.29)	0.96 (0.82, 1.12)	0.98 (0.69, 1.33)	1.11 (0.95, 1.29)	1.33 (1.07, 1.64)**
Games	2.1 ± 0.5	0.99 (0.84, 1.16)	1.04 (0.84, 1.29)	0.94 (0.80, 1.11)	0.81 (0.57, 1.12)	0.98 (0.82, 1.15)	0.77 (0.59, 1.00)*

Note: The association is shown as odds ratio with 95% CI.

[a]Arbitrary unit (1-10).

*$P < .0.5$.

**$P < .01$.

***$P < .001$.

4 | DISCUSSION

The main findings of the study are that the training load in the pre-season is associated with OP in knees and low back. Seventy-four percent of participants reported OP in one or more anatomical area during the observation period. On average, 40% of participants reported OP and 14% SOP in shoulder during the observation period.

4.1 | Prevalence of overuse problems

Overall, the prevalence of OP and SOP in the current study was higher than found in Norwegian elite male junior handball players (knee, OP 14%, SOP 5%; shoulder OP 17%, SOP 7%; low back, OP 12%, SOP 3%)[26] and Norwegian elite handball players (knee, OP 20%, SOP 8%; shoulder, OP 22%, SOP 6%; low back, OP 12%, SOP 3%).[32] Only Swedish youth female handball players had similar prevalence in SOP in shoulder (15%).[27] Though, it should be noted that the research populations differ regarding age, gender and level of play.[26-28,32] The prevalence is in line with results from a competitive season in Icelandic elite male handball,[23] except in low back, where the SOP prevalence was higher in the competitive season (11% vs. 6%) and in OP in shoulder where the prevalence in the current study was higher (40% vs. 28%). Considering the difference in prevalence of low back problems between pre-season and competitive season, one reason might be that most of the players are without SOP in low back following a summer break without a training schedule. It is an interesting platform for further research.

4.2 | Relationship between risk for overuse problems and training load

As far as we know, no study has provided data on the association between OP in handball training load and intensity. In general, training load and intensity mainly seem to be associated with OP and SOP in knees.

Preparing players for competitive season can be demanding, with different players in the group and a tight time frame where athletes need to train with maximal participation[13] and appropriate training load[8,11,15] in an attempt to protect athletes against in-season injuries. In contrast, high training volume,[11] intensity,[8] and sudden and great increase[10,33] in the training load during the preseason makes players susceptible for injuries, and it is recommended that coaches monitor the increase in workload carefully and avoid sudden changes.

4.3 | Shoulder

Association was found between OP in shoulder and weekly training hours, where the prevalence of OP declines by 10% for every weekly hour trained. The reason is not clear, but when looking at Figure 1, the prevalence declines during the first two weeks when number of training hours increases most (Table 2). On the other hand, no association was found between reported training load, training intensity or training factors, and OP in shoulders, the anatomical area where players reported the highest average OP prevalence (40%) during the research period (Table 3). Even though no direct association is provided, the numbers in Table 2 is interesting, where pre-season starts with high training load, intensity, and great number of handball exercises. At elite level, handball players are reported to perform on average 100 passes and 20 shots per training hour.[34] Studies have shown that a high volume of shots during training can predict shoulder soreness in throwing sports like handball[10] and water polo,[35] and sudden increase in throwing exercises made cricket players susceptible for injuries in shoulders.[36] Therefore, coaches need to be careful when planning their teams training schedules and aware of the risk of high training volume and intensity during the team's pre-season.[10,35,36]

4.4 | Low back

Association was found between jumping in pre-season and OP in low back, where one hour increase in weekly jumping increased the prevalence of OP in low back about 4.5 fold. Even though it is known that jumping is a fundamental factor when playing handball,[1,3] coaches should keep in mind that handball players are tall and heavy (187 ± 10 cm and 90.0 ± 9.8 kg), so high forces affect the players low back in each jump. The association mentioned above in context with a high prevalence and incidence of OP and time-loss overuse injuries in Icelandic handball[21,23] is a platform for further studies. The prevalence of OP in low back increases around 18% for every weekly hour of mobility training. The reason is not clear but raises speculations if players are aggravating symptoms by pushing their limits when increasing their mobility in the low back region.

4.5 | Knee

Association was found between various physical training factors and OP and SOP in knees (Table 3). Most notable, running exercises increase the prevalence of OP by 30% and SOP by 60% for every weekly hour trained (Table 3). Handball players run approximately 4 kilometers per game and the game consists of high intensity activities.[1,6,7] The players are heavy (average; 90.0 ± 9.8 kg) so running with changes in directions on a firm substance clearly creates intensive forces to their lower extremities.[17] As well, the prevalence of SOP increases of 60% for every weekly hour of strength training (Table 3). A strength training is a fundamental factor meeting handball players' physical requirements during pre- and competitive season.[16,37,38] An intensive strength training for lower body creates a great force through the knee joint, creating symptoms.[17]

Looking at the handball training factors, shooting practice are highly associated with OP and SOP in knees, as well as the on-court training which associates with SOP (Table 3). Shooting practice in handball consist of cutting movements and intensive jumping in every positions.[1] In contrast, jumping exercises seem not to have effect on prevalence of OP and SOP in knees. The reason is not clear, but jumping exercises are more controlled movement than shooting practice which can make players more susceptible for injuries. Also, is it a possibility that susceptible players are partially or totally avoiding jumping exercises to minimize the load on their knees.

Mobility training seems to have positive association with OP in knees. It seems logic that for example, stretching anterior thigh muscles tend to decrease stress on knee tendons and kneecap, relieving minor problems in the region.

A limitation in this study is that the research period only covers six weeks and the data only pertains to elite men and collecting data on only three anatomical regions does not give a complete picture of the extent of OP in Icelandic handball, excluding for example, ankle, elbow, and groin. The training exposure and squad-based estimated training intensity recorded by the team's coaches instead of a researcher can create inaccuracy. The cohort does not fully demonstrate the Icelandic male handball with players only from 10 of 18 teams of the two Icelandic handball leagues participating. The main strength of the study is that it is the first study that highlights the possible association between training load in handball and OP with an acceptable overall response rate of 70%. Another strength is that the research gives important information about prevalence of OP in pre-season, as well as training volume and intensity.

5 | CONCLUSION

Icelandic handball players are susceptible for OP in knees during their pre-season training. The prevalence of OP in shoulder is higher in pre-season than in competitive season, but SOP in low back is lower. More than a quarter of the players participated with at least one SOP in any of the three anatomical areas, at any given time during the pre-season period. Training intensity is high during the pre-season, quite from the beginning.

5.1 | Perspectives

Until recently, little knowledge has been regarding prevalence and burden caused by overuse problems in sports. As far as the authors know, no study has provided data on the association between training load and OP in handball. The registration method adds a new dimension to injury registration since the time-loss method is narrower method to capture overuse problems. The result from this study shows that handball players are most susceptible for OP in knees during their pre-season. It provides an important information and knowledge for coaches and clinicians to control their teams' training volume.

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DATA AVAILABILITY STATEMENT
The data supporting the findings of the study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Appendix 1

9+ Screening test protocol

Players ID: ______________________________

Teams ID: ______________________________

Date of test: ________________

Nr	Name		Score	Test score	Comments
1	**Deep squat**				
2	**Sigle leg squat**	left			
		right			
3	**In line lunge**	left			
		right			
4	**Active hip flexion**	left			
		right			
5	**Straight leg raise**	left			
		right			
6	**Push up**				
7	**Diagonal lift**	left			
		right			
8	**Seated rotation**	left			
		right			
9	**Shoulder mobility**	left			
		right			
10	**Drop jump**				
		Total score:			

Appendix 2

Individually based registration of overuse problems in handball created in Questback online program

You will receive this questionnaire by e-mail every second week. Please answer the questionnaire in relation to the last seven days.

Questions for possible knee problems

1. Have you had any difficulties participating in normal training and competition due to knee problems during the last week?
   - o Full participation without knee problems
   - o Full participation, but with knee problems
   - o Reduced participation due to knee problems
   - o Cannot participate due to knee problems

2. To what extent have you reduced your training volume due to knee problems during the last week?
   - o No reduction
   - o To a minor extent
   - o To a moderate extent
   - o To a major extent
   - o Cannot participate at all

3. To what extent have knee problems affected you performance during the last week?
   - o No effect
   - o To a minor extent
   - o To a moderate extent
   - o To a major extent
   - o Cannot participate at all

4. To what extent have you experienced knee pain related to handball during the last week?
   - o No pain
   - o Mild pain
   - o Moderate pain
   - o Severe pain

Questions for possible low back problems

1. Have you had any difficulties participating in normal training and competition due to low back problems during the last week?
   - o Full participation without low back problems
   - o Full participation, but with low back problems
   - o Reduced participation due to low back problems
   - o Cannot participate due to low back problems

2. To what extent have you reduced your training volume due to low back problems during the last week?
   - o No reduction
   - o To a minor extent
   - o To a moderate extent
   - o To a major extent
   - o Cannot participate at all

3. To what extent have low back problems affected you performance during the last week?
   - o No effect
   - o To a minor extent
   - o To a moderate extent
   - o To a major extent
   - o Cannot participate at all

4. To what extent have you experienced low back pain related to handball during the last week?
   - o No pain
   - o Mild pain
   - o Moderate pain
   - o Severe pain

Questions for possible problems in the dominant shoulder

1. Have you had any difficulties participating in normal training and competition due to problems in your dominant shoulder during the last week?
   - o Full participation without problems in dominant shoulder
   - o Full participation, but with problems in dominant shoulder
   - o Reduced participation due to problems in dominant shoulder
   - o Cannot participate due problems in dominant shoulder

2. To what extent have you reduced your training volume due to problems in your dominant shoulder during the last week?
   - o No reduction
   - o To a minor extent
   - o To a moderate extent
   - o To a major extent
   - o Cannot participate at all

3. To what extent have problems in your dominant shoulder affected you performance during the last week?
   - o No effect
   - o To a minor extent
   - o To a moderate extent
   - o To a major extent
   - o Cannot participate at all

4. To what extent have you experienced pain in your dominant shoulder related to handball during the last week?
   - o No pain
   - o Mild pain
   - o Moderate pain
   - o Severe pain

Appendix 3

Registering form for handball coaches

Teams code: ____________________

Week: ____________________

		Mon	Tue	Wed	Thu	Fri	Sat	Sun	W average
Physical training									
Running (total)	**(min)**								
Jumping	**(min)**								
Strength training	**(min)**								
Mobility training	**(min)**								
Other factors:									
Leiklíkir þættir									
Shooting	**(min)**								
On court training	**(min)**								
Fast breaks	(min)								
Tactic (6 meters)	(min)								
Play (2:2, 3:3, 4:4)	(min)								
Play (full teams)	(min)								
Games	**(min)**								
Other factors:	**(min)**								
Total training time:									
Total number og players in training.									
Total intensity in the training (1-10)									

1 = min intensity, 10 = max intensity

Appendix 4

Injury pattern in Icelandic Elite Male handball players Rafnsson et al. 2017.

Original Research

Injury Pattern in Icelandic Elite Male Handball Players

Elis Thor Rafnsson, PT, MSc,*† Örnólfur Valdimarsson, MD, PhD,† Thorarinn Sveinsson, PhD,* and Árni Árnason, PT, PhD*‡

Abstract

Objective: To examine the incidence, type, location, and severity of injuries in Icelandic elite male handball players and compare across factors like physical characteristics and playing position. **Design:** Prospective cohort study. **Setting:** The latter part of the preseason and the competitive season of Icelandic male handball. **Participants:** Eleven handball teams (185 players) from the 2 highest divisions in Iceland participated in the study. Six teams (109 players) completed the study. **Variables Measured:** Injuries were recorded by the players under supervision from their team physiotherapists or coaches. Coaches recorded training exposure, and match exposure was obtained from the Icelandic and European Handball Federations. The players directly recorded potential risk factors, such as age, height, weight, previous injuries, and player position. **Main Outcome Measures:** Injury incidence and injury location and number of injury days. **Results:** Recorded time-loss injuries were 86, of which 53 (62%) were acute and 33 (38%) were due to overuse. The incidence of acute injuries was 15.0 injuries/1000 hours during games and 1.1 injuries/1000 hours during training sessions. No significant difference was found in injury incidence between teams, but number of injury days did differ between teams ($P = 0.0006$). Acute injuries were most common in knees (26%), ankles (19%), and feet/toes (17%), but overuse injuries occurred in low back/pelvic region (39%), shoulders (21%), and knees (21%). Previous knee injuries were the only potential risk factor found for knee injury. **Conclusions:** The results indicate a higher rate of overuse injuries in low back/pelvic region and shoulders than in comparable studies.

Key Words: overuse injuries, acute injuries, incidence, epidemiology

(*Clin J Sport Med* 2017;0:1–6)

INTRODUCTION

Despite growing interest in international handball, limited research exists on injuries in handball players. Previous studies have shown a high incidence of time-loss injuries (ie, causing absence from trainings and/or games) among elite male handball players, (eg, 13.3-14.3 injuries/1000 hours during games and 0.6-2.4 injuries/1000 hours during training sessions).[1,2] Much higher incidences have been detected in large international tournaments such as the World cup or Olympic Games, (eg, 31-50.5 injuries/1000 game hours for males and 13-36 injuries/1000 hours for females).[3,4] Studies that report locations and types of injuries are conflicting because of different injury definitions, registering methods, as well as differences in age and level of play.[1,2,5–11] However, studies have shown a high proportion of injuries in the lower (40%-69%) and upper extremities (17%-40%), followed by the head/face (4%-32%) and the trunk (2%-17%).[2–4] A German study on 186 male handball players found that 20% of acute time-loss injuries occurred in knees, followed by fingers (18%), ankles (15%), and shoulders (14%). The most common time-loss overuse injuries were located in the shoulders (19%), low back (17%), and knees (16%).[2] Ligament sprains (35%-46%) and muscle strains (26%) have been shown to be the most common types of time-loss injuries.[2,5]

Most previous studies registered only time-loss injuries,[1,2,7,10,11] but studies were also found that registered all injuries that needed medical attention.[6,8] In 2006, Fuller et al[12] published a new consensus on definition of injuries and data collection in football (soccer) that can be used in other types of sport. Unfortunately, since 2006, few studies have been published in which injuries in general are registered in handball players.[3,4,13] During the past 20 years, the intensity of handball has increased, with increased game speed and higher total game scores, most likely resulting from the fast throw-off rule introduced in the year 2000.[14] As a result, training habits and intensity have also increased[15] and could affect the injury profile of the sport.

Therefore, the aim of this study was to examine the incidence, type, location, and severity of acute and overuse time-loss injuries in Icelandic elite male handball players and compare across factors like physical characteristics and playing position.

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Statement Summarizing The Clinical Relevance Of The Study

Handball is a growing sport in many countries worldwide. However, studies on injuries in elite handball are relatively few and most of them are relatively old. We found only 5 original studies published during the last 10 years on injuries in handball in general (junior and elite) and a few studies on specific injury types in handball (eg, Anterior Cruciate Ligament (ACL) and shoulder injuries). It seems that there is a lack of studies about injuries in elite handball. The aim of this prospective cohort study was to examine the incidence, type, location, and severity of injuries in Icelandic elite male handball players and compare across factors like physical characteristics and playing position.

MATERIALS AND METHODS

The study was approved by The National Bioethics Committee in Iceland (07-089) and reported to The Icelandic Data Protection Authority. Fourteen of 16 male handball teams, participating in the 2 highest handball divisions in Iceland during the handball season 2007 to 2008, were invited to participate in this prospective cohort study. Two teams were excluded because of a high level of player variability, caused by partial participation in training by junior team members and those players not under contract. This made it difficult to register injuries and exposure factors.

Of the 14 teams invited, 11 teams with 182 players agreed to participate. Five of these teams (73 players or 40%) ended up not meeting the requirements of registration of injuries or training exposure (noncompliant group). The remaining 6 teams (109 players or 60%) finished the study (compliant group) (Figure 1). The study period was 10 months, consisting of the latter part of the preseason period (July 20-September 15) and the competition period (September 15-May 8). All players were followed up until May 20 and injured players until they had recovered from their injuries.

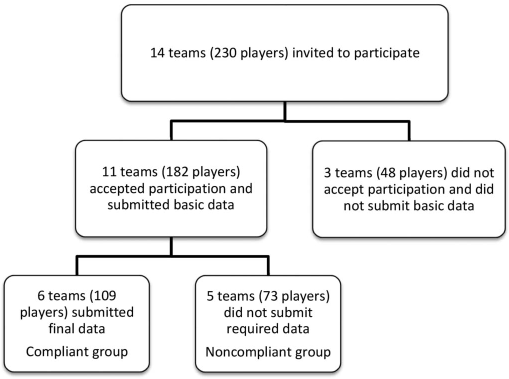

Figure 1. Flow diagram of team recruitment and drop out.

Injury Registration

Participants completed a questionnaire about their playing position, age, height, weight, and previous injuries. Injuries were defined as any physical complaint sustained by a player during handball training or a game, resulting in the player being unable to play a game or participate in a training session. The player was defined as injured until he was able to fulfill the sports requirements of at least 1 practice session or a game.[16] This injury definition is in accordance with Fuller et al,[12] except that only time-loss injuries were registered. Acute injures were defined as injuries with a clear onset as a result of trauma. Overuse injuries were defined as injuries with an insidious onset with gradually increasing intensity of discomfort without an obvious trauma.[16] Recurrent injuries were defined as injuries of the same type and location as a previous injury that had healed with the player returning to full activity (training or game). Injuries were further classified by duration as slight (1-3 days), minor (4-7 days), moderate (8-28 days), and severe (>28 days).[12] The number of injury days was defined as the number of days from injury onset until the players were able to fulfill the sports requirements of at last 1 practice session or a game.

Injuries were recorded shortly after occurrence on a special form by the players under supervision from their team physiotherapist or coach. The registration form included the date the injury occurred, type and location of the injury, whether the injury was acute or overuse, whether it was a recurrent injury, as well as the date of return to play. Exact diagnosis was obtained from the team physiotherapist or an orthopedic surgeon.

Game and Training Exposure

Information about playing time in games played in Iceland was retrieved from the electronic database of The Icelandic Handball Federation (Handknattleikssamband Íslands), and, for games played in European Championship, similar information was retrieved from The European Handball Federation. Time exposure for each team per game was calculated as the total time of each game (2 × 30 minutes) multiplied with the number of players on the court per team (n = 7), minus all 2-minute suspensions players received during the game. When calculating training exposure, coaches submitted the training schedule with information on the date of training and its duration, as well as number of players per training session. Training exposure was calculated for each team as hours of training multiplied by the average number of players per training.

Statistics

Comparison of basic data between the compliant and noncompliant group was made by 2 sample t tests for parametric data and the Wilcoxon test for nonparametric data. Incidence of acute injuries was calculated as the number of injuries per 1000 game or training hours. The 95% confidence interval (CI) for injury incidence was calculated as

$$\text{incidence} \pm 1.96 \times \left(\frac{\text{SD}}{\sqrt{(\text{number of injuries})}} \right).$$

SAS Enterprise Guide 4.3 (SAS Institute Inc, Cary, North Carolina) was used for the following statistics: analysis of variance to test possible difference in age, height, weight, and body mass index between player positions. Chi-square test was used to calculate differences in injury incidence and number of injury days between teams and months. Logistic regression was used to compare uninjured and injured groups of players treating potential risk factors as continuous variables. Injury rate differences between groups were presented at a 95% CI. Significance level was set as $P < 0.05$.

RESULTS

Comparison in basic factors between compliant and noncompliant groups at the beginning of the study, as well as classification with respect to playing position combined for both groups are shown in Table 1.

Injury Incidence and Severity

Of the 109 players who completed the study, 62 players (57%) incurred 86 time-loss injures, of which 53 were acute injuries (62%) and 33 were overuse injuries (38%). Of the 53 acute injuries, 22 (42%) occurred during games and 31 (58%) during training sessions. The total exposure time for all participating players was 30 737 hours (1465 hours during games and 29 272 hours during training). The incidence of acute injuries during games and during trainings was 15.0 and 1.1 injuries/1000 player-hours, respectively (Table 2). This corresponds to 0.2 acute injuries per game (or 1 injury per 4.75 games) and 0.03 per training session (or 1 injury per 36 training sessions). No significant difference was found in the total acute injury incidence between the 6 teams [incidence (95% CI): 2.2 (1.0-3.4), 1.4 (0.4-2.4), 2.7 (1.2-4.1), 1.4 (0.4-2.3), 1.8 (0.6-2.9), and 0.7 (−0.09-1.4)]. Of all injuries, 13 (15%) were classified as slight, 23 (27%) as minor, 28 (32%) as moderate, and 22 (26%) as severe injuries. When corrected for number of players in each player position, no significant difference was found in either the number of injuries or severity categories between different playing positions (Table 3). During the 10-month study period, the average number of injury days per month varied significantly ($P <$ 0.007), peaking in April, which represents the final competition (Figure 2). The Tukey post hoc test showed that number of injury days in April was significantly higher than those in August ($P = 0.009$) and December ($P = 0.01$). There was also a difference in the total number of injury days between teams that varied from 177 to 479 during the 10-month study period ($P = 0.0006$). Each team had between 17.7 and 47.9 injury days per month which means that between 0.6 and 1.6 players were on the injury list every day.

Injury Types and Locations

The most frequent types of injuries were ligament sprains (n = 23; 27%), followed by muscle strains (n = 13; 15%), tendinopathies (n = 12; 14%), contusions (n = 10; 12%), injuries in joint cartilage, and meniscus (n = 9; 10%) and bone fractures (n = 6; 7%). Most acute injuries occurred in the lower extremities. Overuse injuries were most common in the low back/pelvis region (Table 4). Of 53 acute injuries, 34 (64%) occurred without contact with other players, mostly during landing (n = 13; 38%) or cutting (n = 11; 32%). Eighteen (34%) acute injuries occurred in contact with other players, and 1 (2%) in contact with the ball. Of all injuries, 36 (42%) were recurrent injuries. One-third of recurrent injuries were to the low back/pelvis region (n = 12; 33%), of which overuse injuries were 10 (28% of all recurrent injuries). Recurrent injuries occurred in the following areas: knee (10 or 28%; 5 acute and 5 overuse); shoulders (7 or 19%; 2 acute and 5 overuse), and ankle sprains (only 3 or 8%). Players with a history of previous knee injuries incurred higher knee injury rate than players without a history of previous knee injuries (odds ratio: 3.5, 95% CI: 1.1-11.4, $P = 0.04$).

DISCUSSION

The main results were high incidence of acute time-loss injuries during games and high number of injury days, peaking at the final competition. Of acute injuries, the knee was the most common injury location, followed by the ankle. Of

TABLE 1. Players Classified Into Compliant and Noncompliant Groups, by Playing Position in Relation to Number of Players, Average Age, Height, Weight, and Body Mass Index, as well as Average Number of National Team Games and National Junior Team Games (U21, U19, U17 Combined)

	Number (n)	Age (yrs)	Height (cm)	Weight (kg)	Body Mass Index (kg/m^2)	No. of National Team Games	No. of National U Team Games
Average	182	23.4 (22.7-24.1)	186.4 (185.4-187.4)	88.3 (86.8-89.8)	25.4 (25.5-25.7)	7.4 (2.9-11.9)	16.5 (12.8-20.2)
Compliant group	109	23.6 (22.6-24.5)	187.9 (186.4-189.3)*	90.3 (88.1-92.5)†	25.6 (25.1-26.0)	9.4 (2.4-16.5)	23.1 (16.6-29.5)
Noncompliant group	73	23.2 (22.1-24.3)	184.8 (183.3-186.4)	86.0 (83.5-88.5)	25.1 (24.5-25.8)	5.1 (−1.7-11.9)	9.0 (4.8-13.2)
Goalkeepers	27	24.1 (21.8-26.4)	188.9 (186.5-191.3)	91.0 (86.6-95.4)	25.5 (24.3-26.7)	9.5 (1.0-19.8)	18.5 (6.5-30.5)
Wing players	49	23.4 (22-24.8)	181.0 (179.6-182.4)‡	80.3 (78.0-82.5)‡	24.5 (23.8-25.3)	1.1 (−0.2-2.1)	11.1 (6.3-15.9)
Backcourt players	81	23.4 (22.4-24.4)	187.9 (186.5-189.3)	89.7 (87.9-91.5)	25.4 (25.0-25.8)	12.8 (3.4-22.2)	20.9 (14.7-27.1)
Line players	25	23.0 (21.3-24.7)	190.1 (187.6-192.6)	96.8 (92.2-101.4)	26.7 (25.7-27.7)§	0.4 (−0.3-1.1)	11.2 (3.6-18.8)

95% CI is presented in parenthesis.
** Players in the compliant group were significantly higher than players in the noncompliant group (P = 0.005).*
† Players in the compliant group were significantly heavier than players in the noncompliant group (P = 0.01).
‡ Significantly lower height and weight than in other player groups (P < 0.0001).
§ Significantly higher body mass index than wing players (P < 0.006).

TABLE 2. The Incidence (Injuries/1000 Player Hours) of All Acute Injuries, as well as the Incidence of the Most Common Locations of Acute Injuries During Games, Training, and Total (Games and Training Combined)

	Acute Injury Incidence (Injuries/1000 Hours)		
	Games	Training	Total
All acute injuries	15.0 (8.7-21.3)*	1.1 (0.7-1.4)	1.7 (1.3-2.2)
Knee	4.1 (0.8-7.4)	0.3 (0.1-0.5)	0.5 (0.2-0.7)
Ankle	2.7 (1.3-5.4)	0.2 (0.04-0.4)	0.3 (0.1-0.5)
Foot/toe	2.0 (−0.3-4.4)	0.2 (0.04-0.4)	0.3 (0.1-0.5)

95% CI is presented in parenthesis.
**Significant higher incidence of injuries during games than during training ($P < 0.001$).*

overuse injuries, the low back/pelvis region was the most common injury site, followed by the shoulder and knee. Recurrent injuries were common, and a third of these injuries were in the low back/pelvis region. The only potential risk factor found for knee injury was previous knee injuries.

Injury Incidence

In this study, injury incidence is only calculated for time-loss acute injuries. Overuse injuries can develop over a period of time and affect the player's participation, training volume, and performance long before they will be defined as time-loss injuries.[17] Therefore, calculations of injury incidence for time-loss overuse injuries do not give an accurate picture of the number of these injuries. In this study, acute injury incidence during games was a little higher than in the studies by Seil et al[2] and Nielsen and Yde[1] that used similar injury definition, methods, and age, but level of play was higher in this study, indicating higher injury incidence.[2] On the other hand, Moller et al[13] found much higher injury incidence, representing a weekly injury registration by SMS, where all players who reported injuries were contacted through telephone for further information. Therefore, one could expect more accurate injury registration and follow up, especially for slight or minor injuries.

In this study, the peak of average number of injury days occurred during the final competition where multiple games were played in a short period of time. On the other hand, there was a reduction in the average number of injury days in December when games and training session were fewer because of the Christmas break. In some of the teams, severe injuries occurred early during the season and players were out for the rest of the season, increasing the total number of injury days. Different training methods and preparation of the players before the season, as well as different playing style and medical support could also affect the number of injury days per team.

Injury Location

In this study, a much higher injury rate was found in the trunk (22%) than was reported in previous studies (2%-10%).[1,2,8,13] However, Langevoort et al[4] and Bere et al[3] found that 11% to 17% of injuries in international tournaments were located in the trunk. This high rate of trunk injuries in this study can be explained by an extremely high rate of overuse injuries located in the low back/pelvis region (39% of all overuse injuries), compared with other handball studies (5%-17%).[2,8,13] This raises a question about the preparation of the Icelandic players for this challenging sport. The average age of the players in this study was 23.6 years, which is similar to a study on Danish senior elite handball players,[13] but lower than was seen in studies on other professional handball players.[18,19] Therefore, it could be possible that the Icelandic players are not trained properly to meet the demanding biomechanical load or that they start heavy training before they have sufficient strength, stability, and movement control in the low back. Weightlifting is used significantly in handball training and it could be possible that some of them have not learned the adequate lifting technique before they start lifting heavy loads. Another possibility is that promising junior players start training too early and even play with senior teams, which include stronger and heavier players, while simultaneously playing with their junior teams, raising the potential for overload and increased risk of overuse injuries.

The rate of injuries in the upper extremities was lower in this study (14%) than in previous studies (17%-47%).[1–4,8,13] The

TABLE 3. The Type and Severity of Injuries Shown as Numbers and Percentage in Parenthesis

	All Players (n = 109)	Goalkeepers (n = 14)	Wing Players (n = 27)	Back Court pl. (n = 53)	Line Players (n = 15)
Type of injuries, n (%)					
Overuse	33 (38)	6 (67)	8 (50)	19 (38)	0 (0)
Acute	53 (62)	3 (33)	8 (50)	31 (62)	11 (100)
Severity of injuries, n (%)					
1-3 d	13 (15)	1 (7)	3 (11)	8 (15)	1 (7)
4-7 d	23 (27)	2 (14)	2 (7)	17 (33)	2 (13)
8-28 d	27 (31)	1 (7)	8 (29)	13 (25)	5 (33)
>28 d	23 (27)	5 (36)	3 (11)	12 (23)	3 (20)

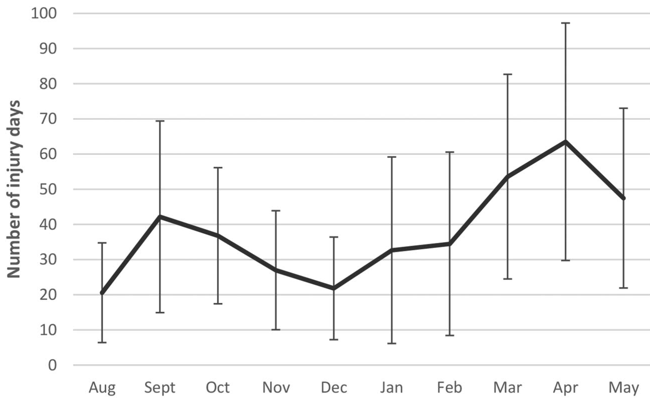

Figure 2. The average number of injury days per team for each month during the 10-month study period. The number of injury days in April was significantly higher than those in August ($P = 0.009$) and December ($P = 0.01$). SDs are shown as error bars. (Injury days: number of days from injury onset until the players were able to fulfill the sports requirements of at last 1 practice session or a game).

rate of shoulder overuse injuries is much higher in this study (21%) than in most comparable studies (4%-6%).[8,13] Only Seil et al[2] found a similar rate (19%). The results of this study indicated that one-fourth of all acute injuries are located in the knee, which is the same as Olsen et al[8] found in their study of Norwegian junior handball players, but higher than Moller et al[13] found in senior Danish handball players (15%). As described earlier, this could possibly indicate that the Icelandic players were not prepared enough for high load training and competition and need more stability and movement control training.

Most of the recurrent injuries were located in the low back/pelvis region and the knee, indicating more need for follow-up with controlled rehabilitation after injuries. Because of financial reasons, the medical staff for the Icelandic handball teams is usually not involved in training sessions. This makes it difficult to protect players who overestimate their ability to tolerate high biomechanical loads after recovery from injury and return to heavy training or participate in a game before being ready. Such behavior could easily lead to increased amount of recurrent injuries.

TABLE 4. Number and Percentage of Acute and Overuse Injuries in Different Locations

	Acute		Overuse		Total	
	Number	%	Number	%	Number	%
Head, neck	3	5.7	1	3.0	4	4.7
Trunk	6	11.3	13	39.4	19	22.1
Sternum/rib/thorax	3	5.7	0	0.0	3	3.4
Abdomen	1	1.9	0	0.0	1	1.1
Low back/pelvis	2	3.8	13	39.4	15	17.2
Upper extremity	4	7.5	8	24.2	12	13.9
Shoulder	1	1.9	7	21.2	8	9.3
Upper arm	0	0.0	0	0.0	0	0.0
Elbow	0	0.0	1	3.0	1	1.2
Forearm	1	1.9	0	0.0	1	1.2
Hand/finger	2	3.8	0	0.0	2	2.3
Lower extremity	40	75.5	11	33.3	51	59.3
Hip/groin	3	5.7	3	9.1	6	7.0
Thigh	2	3.8	0	0.0	2	2.3
Knee	14	26.4	7	21.2	21	24.4
Leg	2	3.8	0	0.0	2	2.3
Ankle	10	18.9	0	0.0	10	11.6
Foot/toe	9	17.0	1	3.0	10	11.6
Total	53	100	33	100	86	100

Methodological Consideration

During the first months of the study period, 5 of 11 teams dropped out. Three of them replaced their coach, and the new coaches were not interested in continuing to participate in the study. Two other coaches did not follow up with registration from the start of the study, despite encouragement from the researchers. Although there was no significant difference in injury incidence between the compliant teams, we could not rule out the possibility of some skewed injury incidence estimate because of the high dropout rate. Because of this drop out, the statistical power was relatively low, leading to less power for identifying potential risk factors, and therefore it was only possible to include 1 risk factor in each regression model.

Match and training exposure was calculated for each team, but not individually for each player. This method was used to decrease the workload on the coaches in an attempt to reduce the dropout rate, but could possibly affect the accuracy of estimating the injury incidence. The players were all contracted to the clubs, meaning that they were not allowed to drop out of training sessions unless they were injured or sick. Therefore, the squads were relatively constant during training and consisted of the same number of players.

In this study, only time-loss injuries were registered, which differs from the recommendation from Fuller et al[12] but is in accordance with Moller et al.[13] Because physiotherapists are usually not present during trainings; they could easily miss injuries that did not cause time loss, or even slight injuries lasting 1 to 3 days. Also, players may not necessarily notify the team physiotherapist of such injuries. Moreover, coaches are not always focusing on injury registration, meaning that injuries not causing time loss or even slight injuries could easily be missed. For this reason, it was decided to register only time-loss injuries. However, it is possible that slight or even minor injuries are underestimated in this study.

This study is primarily a descriptive study on injury incidence, location, type, and severity of injuries in Icelandic elite male handball. Some comparisons were done, but no corrections were made for conducting multiple significance tests.

CONCLUSION

The results indicated a high rate of time-loss overuse injuries in the low back/pelvis region and the shoulder. A high number of injury days were found during the final competition. Studies that investigate overuse problems in handball that do not necessarily cause time loss from training or games are needed.

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