

DAUGAVPILS UNIVERSITĀTE
DAUGAVPILS UNIVERSITY

DAUGAVPILS UNIVERSITĀTES ZINĀTŅU DAĻA
SCIENCE DEPARTMENT OF DAUGAVPILS UNIVERSITY

**DAUGAVPILS UNIVERSITĀTES
64. STARPTAUTISKĀS ZINĀTNISKĀS
KONFERENCES RAKSTU KRĀJUMS**

**PROCEEDINGS OF THE 64th
INTERNATIONAL SCIENTIFIC CONFERENCE
OF DAUGAVPILS UNIVERSITY**

A. DAĻA. DABASZINĀTNES

PART A. NATURAL SCIENCES

DAUGAVPILS UNIVERSITĀTE
AKADĒMISKAIS APGĀDS „SAULE”
2022

Apstiprināts Daugavpils Universitātes Zinātnes padomes sēdē 2022. gada 21. decembrī, protokols Nr. 15. /
Approved in the meeting of Daugavpils University Science Council on December 21, 2022; minutes No 15.

Kokina I., red. *Daugavpils Universitātes 64. starptautiskās zinātniskās konferences rakstu krājums. A. daļa "Dabaszinātnes" = Proceedings of the 64th International Scientific Conference of Daugavpils University. Part A "Natural Sciences"*. Daugavpils: Daugavpils Universitāte, 2022.

***Daugavpils Universitātes 64. starptautiskās zinātniskās konferences Programmas komiteja /
Programme Committee of the 64th International Scientific Conference of Daugavpils University***

Dr. psych., prof. **Irēna Kokina** (Daugavpils University, Latvia, Latvia, Chairman of Scientific Committee)
Dr. biol., prof. **Arvīds Barševskis** (Daugavpils University, Latvia, Vice Chairman)
Dr. habil. art., prof. **Romualdas Apanavičius** (Vytautas Magnus University, Lithuania)
Dr. habil., prof. nazw. **Jakub Bartoszewski** (State University of Applied Sciences in Konin, Poland)
Dr. philol., prof. **Maija Burima** (Daugavpils University, Latvia)
Dr. paed., asoc. prof. **Sergejs Čapulis** (Daugavpils University, Latvia)
PhD, prof. **Yesudas Choondassery** (Berkeley College, USA)
Dr. art., prof. **Ēvalds Daugulis** (Daugavpils University, Latvia)
Dr. paed., prof. **Jelena Davidova** (Daugavpils University, Latvia)
Dr. habil. philol., prof. **Ina Druviete** (University of Latvia)
PhD, prof. **Ulla Harkonena** (Joensuu University, Finland)
Dr. habil. philol., prof. **Zaiga Ikere** (Daugavpils University, Latvia)
PhD, prof. **Dzintra Iliško** (Daugavpils University, Latvia)
Dr. hum., prof. **Genovaitė Kačiuškienė** (Siauliai University, Lithuania)
Dr. biol., prof. **Inese Kokina** (Daugavpils University, Latvia)
PhD, prof. **Enne Koresaare** (University of Tartu, Estonia)
Dr., assist. prof. **Detlev Lindau-Bank** (University of Vechta, Germany)
Dr. habil. sc. soc., prof. **Antanas Makštutis** (The General Jonas Žemaitis Military Academy of Lithuania, Lithuania)
Dr. sc. soc., prof. **Vladimirs Menšikovs** (Daugavpils University, Latvia)
Dr. habil. sc. ing., prof. **Sławomir Partycki** (The John Paul II Catholic University of Lublin, Poland)
Dr. med., asoc. prof. **Anatolijs Požarskis** (Daugavpils University, Latvia)
Dr. hist., prof. **Irēna Saleniece** (Daugavpils University, Latvia)
Dr. habil. biol., prof. **Yarosław Skłodowski** (Warsaw University of Life Sciences, Poland)
Dr. theol., prof. **Anita Stašulāne** (Daugavpils University, Latvia)
Dr. paed., prof. **Małgorzata Suswillo** (University of Varmia and Mazuri in Olsztyn, Poland)
PhD, prof. emeritus **Geoffrey R. Swain** (University of Glasgow, United Kingdom)
Dr. philol., prof. **Vilma Šaudiņa** (Daugavpils University, Latvia)
Dr. biol., prof. **Ingrīda Šauliene** (Šauļu Universitāte, Lietuva)
Dr. biol., prof. **Artūrs Škute** (Daugavpils University, Latvia)
Dr. biol., prof. **Natalja Škute** (Daugavpils University, Latvia)
Dr. phys., prof. **Edmunds Tamanis** (Daugavpils University, Latvia)
Dr. oec. **Manuela Tvaronavičiene** (The General Jonas Žemaitis Military Academy of Lithuania, Lithuania)
Dr. habil. paed., Dr. habil. psych., prof. **Aleksejs Vorobjovs** (Daugavpils Universitāte, Latvija)
Dr. iur., prof. **Vitolds Zahars** (Daugavpils University, Latvia)
Dr. paed., asoc. prof. **Edgars Znuņiņš** (Daugavpils University, Latvia)

***Daugavpils Universitātes 64. starptautiskās zinātniskās konferences Rīcības komiteja /
Organizing Committee of the 64th International Scientific Conference of Daugavpils University***

Dr. biol., prof. **Arvīds Barševskis** (Chairperson of Organizing Committee)

Ludmila Aleksejeva, Zeltīte Barševska, Jana Butāne-Zarjuta, Ēvalds Daugulis, Armands Gricāns, Inese Hodanova, Dzintra Iliško, Irēna Kaminska, Jānis Kudiņš, Miervaldis Mendriks, Olita Miglāne, Sergejs Osipovs, Andrejs Radionovs, Matīss Ruskulis, Aleksejs Ruža, Henrihs Soms, Juris Soms, Jānis Teivāns-Treinovskis, Uldis Valainis, Anna Vanaga, Elīna Vasiļjeva

***Daugavpils Universitātes 64. starptautiskās zinātniskās konferences rakstu krājuma redakcija /
Editorial staff of the 64th International Scientific Conference of Daugavpils University***

Dr. psych., prof. Irēna Kokina – redaktore / editor

Dr. oec., asoc. prof. Ludmila Aleksejeva

Dr. biol., doc. Līga Antoņeviča

Dr. art., Mg. paed., doc., pētn. Zeltīte Barševska

Dr. philol., prof. Maija Burima

Dr. oec., asoc. prof. Aina Čaplinska

Dr. paed., prof. Jeļena Davidova

Dr. biol., vad. pētn., doc. Pēteris Evarts-Bunders

PhD, vad. pētn. Ilona Fjodorova

Ph.D., pētn., doc. Maija Grizāne

Dr. biol., prof. Inese Kokina

Dr. iur., asoc. prof. Anatolijs Kriviņš

Dr. philol., doc. Ilze Oļehnoviča

Ph.D., doc. Anna Rubika

Dr. paed., pētn. Astrīda Skrinda

Dr. philol., prof. Anna Stankeviča

Dr. philol., prof. Elīna Vasiļjeva

Dr. iur., prof. Vitolds Zahars

Dr. paed., pētn. Gaļina Zavadska

Atbildīgās par izdevumu / Responsible for the Edition

Olita Miglāne (olita.miglane@du.lv)

Anna Vanaga (anna.vanaga@du.lv)

Daugavpils Universitātē docētāju un studējošo zinātniskās konferences notiek kopš 1958. gada. Konferencēm ir starpdisciplinārs raksturs un tajās piedalās gan studējošie, gan docētāji, gan arī ievērojami zinātnieki no dažādām pasaules valstīm. Daugavpils Universitātes 64. starptautiskās zinātniskās konferences pētījumu tematika bija ļoti plaša – dabas, veselības aprūpes, humanitāro un mākslas un sociālo zinātņu jomās.

Zinātnisko rakstu krājumā *Daugavpils Universitātes 64. starptautiskās zinātniskās konferences rakstu krājums = Proceedings of the 64th International Scientific Conference of Daugavpils University* apkopoti 2022. gada 21.–22. aprīlī konferencē prezentētie materiāli.

Daugavpils Universitātes 64. starptautiskās zinātniskās konferences rakstu krājums tiek publicēts 3 daļās: A. daļa. *Dabaszinātnes*; B. daļa. *Sociālās zinātnes*; C. daļa. *Humanitārās zinātnes*.

The annual scientific conferences at Daugavpils University have been organized since 1958. The themes of research presented at the conferences cover all spheres of life. Due to the facts that the conference was of interdisciplinary character and that its participants were students and outstanding scientists from different countries, the subjects of scientific investigations were very varied – in the domains of natural sciences, health care sciences, humanities and art, and social sciences.

The results of scientific investigations presented during the conference are collected in the collection of scientific articles *Proceedings of the 64th International Scientific Conference of Daugavpils University*.

Proceedings of the 64th International Scientific Conference of Daugavpils University are published in three parts: part A. *Natural sciences*; part B. *Social Sciences*; part C. *Humanities*.

SATURS / CONTENTS

VESELĪBAS APRŪPES ZINĀTNE / HEALTH CARE SCIENCE

<i>Teodora Asenova, Ivet Koleva, Jelena Buiko, Vesela Eneva, Borislav Yoshinov</i>	IMPACT OF PHYSICAL MODALITIES IN THE COMPLEX TREATMENT OF LIPOATROPHIA SEMI-CIRCULARIS (WITH A CASE REPORT)	6
<i>Ivet Koleva, Borislav Yoshinov, Irena Kaminska, Alexander Alexiev, Teodora Asenova</i>	CONTEMPORANEOUS OPINIONS ON CARDIOPREVENTION AND CARDIOREHABILITATION (AND OUR OWN EXPERIENCE)	16
<i>Borislav Yoshinov, Ivet Koleva, Jelena Buiko, Nadezhda Tsvetkova, Radoslav R. Yoshinov</i>	IMPACT OF DIGITALIZED BALANCE ASSESSMENT FOR REVISION OF THE COORDINATIVE TRAINING IN CEREBELLAR ATAXIA (CLINICAL CASE PRESENTATION)	26
<i>Matīss Dravnieks, Arnolds Jezupovs</i>	IS PROLONGED PREOPERATIVE ANTIMICROBIAL PROPHYLAXIS AFTER MAJOR LOWER EXTREMITY AMPUTATION NECESSARY? A FOUR-YEAR SINGLE INSTITUTION TRIAL	33
<i>Agnese Ričika, Aleksejs Zavorins, Anna Ramata-Stunda</i>	IMPACT OF A COSMETIC PRODUCT CONTAINING DRACOCEPHALUM RUYSCHIANA EXTRACT ON BIOPHYSICAL PARAMETERS OF THE SKIN	39
<i>Diāna Pabērza, Monta Dancēte, Undīne Skujiņa, Anna Marija Skudra, Jeļena Reste</i>	TENSION AND ACTIVITY IN NECK EXTENSOR MUSCLES DEPENDING ON THE HEAD POSITION WORKING ON COMPUTER	46
<i>Undīne Čeire, Aivars Kaupužs, Līga Antoņeviča</i>	REDUCTION OF THE MUSCLE IMBALANCE FOR SOCCER PLAYERS BETWEEN FOUR-HEADED THIGH MUSCLE AND TWO-JOINT EXTENSOR WITH BIODEXSYSTEM ISOKINETIC DYNAMOMETRY AND POST-ISOMETRIC RELAXATION	54

BIOLOĢIJA / BIOLOGY

<i>Veneranda Stramkale, Larisa Černova, Inga Morozova, Aldis Stramkalis</i>	EVALUATION OF YIELD FOR HEMP VARIETIES	62
<i>Guna Petaja, Viktorija Vendiņa, Sindija Žīgure</i>	SHORT-TERM IMPACT OF FERTILIZATION ON WOOD VOLUME INCREMENT DEPENDING ON DOMINANT TREE SPECIES AND FOREST SITE TYPE	69

VESELĪBAS APRŪPES ZINĀTNE / HEALTH CARE SCIENCE

IMPACT OF PHYSICAL MODALITIES IN THE COMPLEX TREATMENT OF LIPOATROPHIA SEMI-CIRCULARIS (WITH A CASE REPORT)

Teodora Asenova¹, Ivet Koleva², Jelena Buiko³, Vesela Eneva⁴,
Borislav Yoshinov¹

¹Medical Faculty of Sofia University

²Department of Physiotherapy, Medical University of Sofia, Bulgaria

³Department of Anatomy and Physiology, Daugavpils University, Latvia

⁴Esthetic center “Derma Pro” – Sofia, Bulgaria, Sofia 1606, Dospat 6, dr.yvette.5@gmail.com

Abstract

Impact of physical modalities in the complex treatment of lipoatrophia semi-circularis (with a case report)

Key Words: *Lipoatrophy, lymphatic drainage, LPG, massage, analytic exercises*

Lipoatrophy (LA) is a loss of fat, with subsequent depression in the skin. It is considered as a condition, result of other conditions. Can occur at any age. LA is most common in females (because they have fewer muscles under the subcutaneous layer). Different types of lipoatrophy are described: localized, partial or total.

Semicircular LA (lipoatrophia semi-circularis) is a rare disorder, increasingly detected amongst female office workers, characterized by the appearance of indentations in one or both thighs (as result of localized loss of subcutaneous fat). Authors consider that this condition is caused by various mechanisms, generated in the workspace: interactions with electro-magnetic fields (electrostatic hypothesis), localized pressure (micro-traumatization).

Traditionally, every type of LA is treated by: Collagen, Hyaluronic acid, Calcium hydroxyapatite (injections), or Surgery. We consider that some physical modalities can be useful in the complex treatment of LA.

We present a case of a 32 years woman, office worker, suffering of “ribbed thighs” with horizontal bands (indentations) in the anterior, antero-medial and antero-lateral areas of the thigh, at the office desk height (approximate height 70 cm from the ground). We applied a rehabilitation complex of regular physical activity (including swimming), analytic exercises, manual massage, lymphatic drainage, endermology and endermotherapy (LPG), diet (rich in fibers, fruits and vegetables, poor in lipids), mineral water. After a period of 45 days we observed a re-sculpture of the lower extremities with decrease of the “ribbed zones”, reduction of the lobular panniculitis, improvement of the skin tonus and elasticity.

1. Introduction

1.1. Lipoatrophy

Lipoatrophy (LA) is a loss of fat, with subsequent depression in the skin. It is considered as a condition, result of other conditions. LA can occur at any age. LA is most common in females (because they have fewer muscles under the subcutaneous layer). Different types of lipoatrophy are described: localized, partial or total.

1.2. The condition “Lipoatrophy semicircularis”

Semicircular LA (lipoatrophia semi-circularis) is a rare disorder, increasingly detected amongst female office workers, characterized by the appearance of indentations in one or both thighs (as result of localized loss of subcutaneous fat). Many authors consider that this condition is caused by various mechanisms, generated in the workspace: interactions with electro-magnetic fields (electrostatic hypothesis) or localized pressure (micro-traumatization). SL is a benign and

reversible pathology, characterized by subcutaneous tissue atrophy, which affects subcutaneous adipose tissue and related structures, and is located mainly in the thigh region [Nogue, Sanz, Tomas, Farrús; 2008]. Commonly known as “ribbed thighs”.

Semicircular LA was first described in 1974 (Gschwander and Munzberg, 1974; Bachmeyer and Haddad, 2011) and is characterized by the appearance of semicircular bands, unilateral or bilateral, depressed, usually located in the anterior and lateral region of the thigh, and at an approximate height of 72 cm from the ground. It affects women more frequently than men, having a ratio of 6:1 (Hodak et al., 1990).

The origin of semicircular LA is not yet clear. Some hypotheses are that it is caused by localized pressure or by electromagnetic fields (Hodak, David, Sandbank, 1990).

1.3. Treatment of Lipoatrophia

Traditionally, every type of LA is treated by: Collagen, Hyaluronic acid, Calcium hydroxyapatite (injections), or Surgery (Silva and Filoni, 2014). We consider that some physical modalities can be useful in the complex treatment of LA (Asenova, Koleva, 2020).

2. Aim of the article

The goal of current article is to present the potential of physical and rehabilitation medicine for treatment of semicircular lipoatrophy.

3. Clinical case presentation

3.1. We present a case of a 32 years woman, office worker, suffering of “ribbed thighs” with horizontal bands (indentations) in the anterior, antero-medial and antero-lateral areas of the thigh, at the office desk height (approximate height 70 cm from the ground). We observed localized adiposity, skin flaccidity, and some depressed lesions and dimples on the found of lipomatosis and cellulite. (Figure 7-a)

In this case, we applied a rehabilitation complex of regular physical activity (including swimming) and analytic exercises; manual massage; lymphatic drainage; endermology and endermotherapy (LPG); diet (rich in fibers, fruits and vegetables, poor in lipids); mineral water.

3.2. The “Endermologie” Technique (LPG-Endermology and endermotherapy)

In 1986 the French engineer Louis Paul Guitay (LPG) developed a system to help care for the fibrosis he developed as a result of violent trauma. This resembled the movement performed by his therapist’s fingers, including additional effects. Sophisticated software allows for possible phases of continuous and sequential aspiration with mobilization of the tissues, offering the therapist an endless range of possible interventions appropriate for various pathologies. So began a true revolution in physiotherapy.

The LPG company developed the science of endermology concerning dermal tissue response targeted using a mechanical stimulation with LPG's patented head (i.e., a combination of dosed

vacuum and grasped skinfold stimulation with LIPO motorized rollers or LIFT motorized flaps), based on the personal experience of the founder and developer of the patented ROLL technology. (Figures 1 & 2).



Fig. 1. The LPG-endermologie

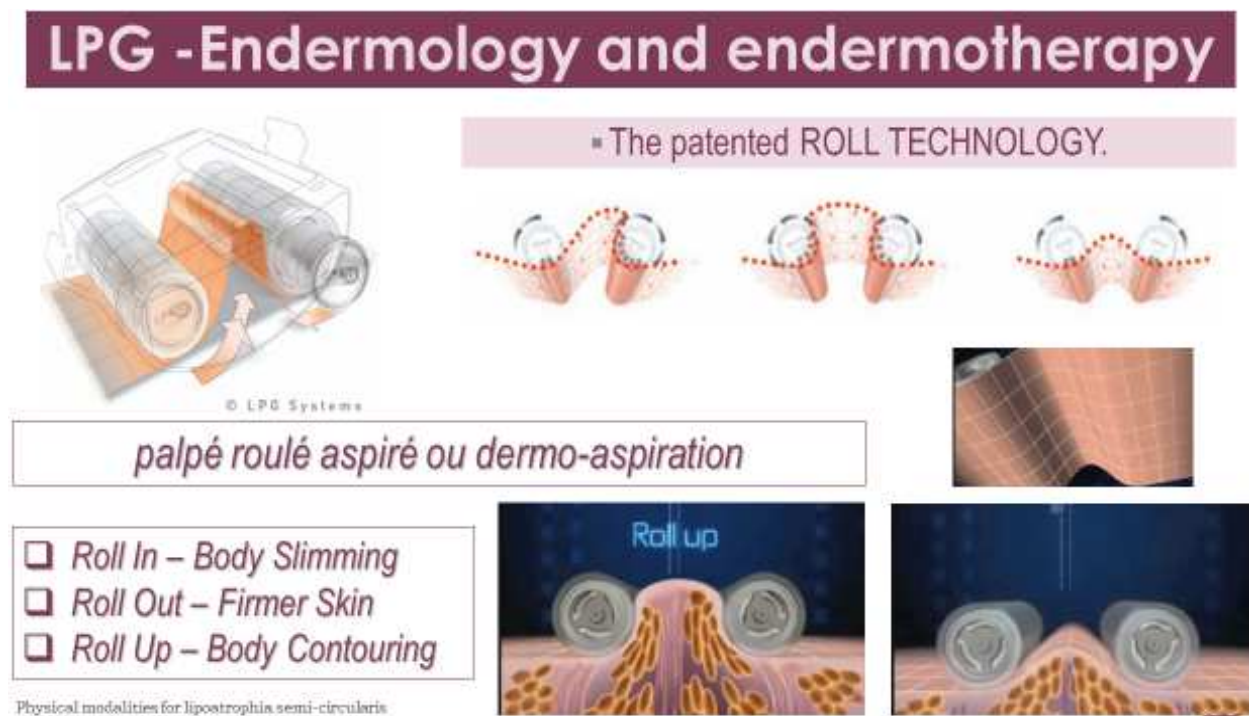


Fig. 2. The patented ROLL technology

LPG-endermotherapy is a non-surgical and thus non-invasive, painless and entirely natural technique, which consist in the natural stimulation of dermal tissue using motorized flaps in a

horizontal and vertical sequential grip supported by a dosed vacuum (patented head with rollers, which stimulate the skin using 3 rotation directions depending on the required effect). Different directions of the rotation facilitates different activities (Fig. 2). Using Key Module we obtain active action for connective tissue, vascular system, metabolic function, adipose tissue, status of the skin, collagen production, lymphatic drainage.

Such induced tissue gymnastics results in a response at the cellular level (fibroblast activation), lymphatic and circulatory system stimulation, oxygenation improvement, and subcutaneous sediment flushing, and it leads to the formation of new fibrous structures – collagen and elastin and extracellular matrix, which improves skin tonus and elasticity (Foldesova and Drvota, 2015).

Endermologie® possesses some complementary actions that allow treatment of different types of tissues. Effects include: Mobilization of the tissues that characterize the different structures with consequent activation of the arteriolar microcirculation; Traction of the connective tissue with exercise of the skin; Activation of the reflected arcs and stimulation of fibrous banding; Neurometabolic regulation with metabolic activation; Rhythmic compression of the tissues with lymph drainage.



Fig. 3. LPG-ergo-drive

Practically Endermologie technique treats *the superficial muscular fascia*.

Surgeons and anatomists have often ignored or denied the importance of the superficial fascia of the body – the systemic bandage: SFS (superficial fascial system). An interesting anatomical and

histological examination of the inferior limbs has shown the presence of the “superficial fascia” as responsible for numerous aesthetic alterations of the skin surface (Bacci. 2000). The depressions and elevations of the contour of the body are explained by the anatomy of the superficial fascia and from its relationships with the skin, the fat and the musculo-skeletal system. The study of anatomy and the understanding of physio-pathological exchanges of the superficial bandage system are the basis for cosmetic therapeutic or surgical correction of the silhouette. An anatomical study of the Argentinians, Moretti, Schapira and Kaplan finds the presence of a net of connective tissue that extends from the subdermal plane to the muscular aponeurosis (Moretti, Schapira, Kaplan et al., 1993).

This net constitutes a true superficial band, formed from various horizontal septa of collagen and elastic fibers separated by fat lobules and always crossed vertically by septa-type fibers. At the subdermal level, the presence of the superficial fascia also constitutes a connection with the deep dermis with bigger fibrous septa woven among them in such way to provoke the separation of adipose tissue in small compartments that organize the superficial adipose tissue with the classic structure of a honeycomb of bees. This structural configuration constitutes the “bundle-dermal system”, of great functional importance. Even if anatomically a real plane of separation is not observed among the superficial muscular fascia and the connective fibers of the deep dermis we can deduce that, functionally and histologically, the continuous imbrications of fibers collectively constitute this “hypodermic superficial fascia”. In thin patients the superficial band is well delineated and of whitish color. In obese patients the great quantity of adipose tissue stretches the superficial fascia and attenuates the end making it difficult to recognize. The connective and elastic fibers are diluted in the fat fabric and this can explain the error of some studies, ones that put doubts on the existence of this superficial band. Without doubt, in the facial zone over the iliac crest in men appears as a deep band that is not found in the female sex. In the women, instead, the fibrous band appears with the muscular aponeurosis at a level of the subgluteous that constitutes the base for the adipose tissue situated in this zone. This difference explains the difference in the contour of the gluteus among the two sexes. The skin, the superficial fascia and the superficial fat must to be considered as a system of protection and functional support. This functional unity constitutes the support of the adipose fabric and helps to prevent the abnormal location of this fabric in other anatomical regions. The traction and stretching of the superficial facial band and the superficial muscular fascia with Endermologie is essential in the treatment (Bacci 2003).

3.3. Regular physical activity (including swimming) and analytic exercises

Physical activity, sports and exercises are considered as obligatory element in the treatment algorithms of every condition of the adipose tissue, including cellulite and lipoatrophy (Goldman and Hexsel, 2003; Asenova and Koleva, 2020). We adapt the physical rehabilitation programme to

the needs of the concrete patient, using the FITT principle: Frequency, Intensity, Time and Type of exercises.

A. Regular physical activity

Recommendations of many scientific societies are oriented to healthy adults and to patients. We recommended to our patient to strive for at least 150–300 minutes a week of moderate intensity or 75–150 minutes a week of vigorous intensity aerobic physical activity, or an equivalent combination. Many sports can be applied: walking, swimming, tourism. In this case, we insist on swimming, 3 times a week.

B. Analytic exercises

Analytic exercises for body sculpture were oriented to the tight muscles: quadriceps femoris (especially vastus lateralis and vastus medialis) and hamstring muscles (especially biceps femoris and semi-membranosus). Our recommendations included practice of analytic exercises every day, 10–15 repetitions for every muscle, total duration 10–30 minutes.

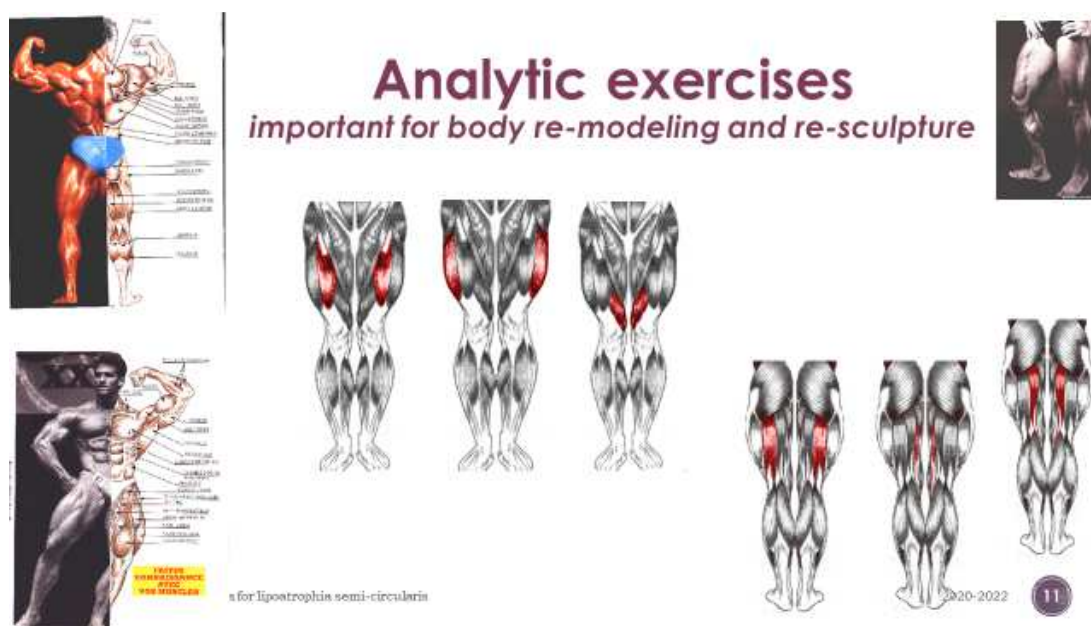


Fig. 4. Analytic exercises of tight muscles

C. Exercises in water immersion (Starkey, 2013)

The physical characteristics of water, buoyancy, resistance, and hydrostatic pressure, create a good supportive medium for active range-of-motion (ROM) exercises. These benefits can be obtained in exercise therapy pools and swimming pools. For all immersion treatments the temperature of the water is important, in this case must be hypothermal (28–32 degrees). Buoyancy describes the lifting force (thrust) provided by water and is explained by Archimedes's principle. If the body's specific gravity is equal to that of the water (1.0 for pure water), it floats just beneath the surface. If the body's specific gravity is greater than water, it sinks; if it is less, it floats.

Therapeutically, buoyancy is used to reduce compressive forces on weight-bearing joints and assist in anti-gravity motions. Movements of lower extremities in the water during swimming increase blood flow, decrease pain (if present) and reduce oedema. During immersion, patients can realize analytic exercises for some muscles.

3.4. Manual massage

Massage is one of the oldest forms of healing techniques. Using therapeutic touch, the body's tissues are manipulated to reduce muscle spasm, promote relaxation, improve blood flow, and increase venous drainage. The scope of massage theories, techniques, and effects is broad. Massage is a skill- and knowledge-based technique (Gordon, 2013)

Massage is an art, more than a therapeutic action that comprises a feeling between the hand of the operator and the tissues of the patient that must not be traumatized, but instead revascularized, stimulated and cleansed. A well-done massage has to relax the body and the mind to increase the skin temperature with stimulation of the microcirculation which favors intercellular exchange. A global massage of the body can have a sedative action and, at the same time, stimulate the nervous system. But massage doesn't have to be violent or prolonged to avoid provoking lymphatic congestion. (Starkey, 2013)

Principal techniques, applied during classical manual massage in this case, included effleurage, petrissage, friction, tapotement and vibration strokes. Our objective was to achieve some physiological effects, as follows: stimulation of blood flow, oedema reduction, separation of muscle fibers and fasciae, providing systemic invigoration of tissues. In this case we applied too *muscle stripping* or exertion of sustained pressure along the muscle fibers, from the insertion (distal) to the origin (proximal) and parallel to the muscle fibers of the tight (quadriceps and hamstrings). We used too myofascial release (massage strokes with simultaneous stretching of the muscles and fasciae of the tights – the goal was to restore tissue mobility.

3.5. Lymphatic drainage

Lymphatic massage targets the lymphatic system and attempts to remove edema, waste products, and toxins from the body using light, rhythmic strokes. This is one of few techniques that can be used for acute musculoskeletal injuries. Activation of the lymphatic system may limit acute inflammation (Gordon 2013).

Lymphatic drainage is a physical method to reduce the stasis of the lymphatic fluid and the toxic substances in the tissues. Lymphatic drainage is not traumatic, but a gentle massage technique. Manual lymphatic drainage has its scientific basis in the study and teachings of Foldi and Leduc (Foeldi, 1983; Leduc, 1980). It deals with a series of grazing and compressions on the lymphatic system to improve lymphatic flow. In the Vodder technique, lymphatic drainage becomes less physical and more aesthetic in nature. Periodic cycles of manual lymphatic drainage are

recommended according to Emile Vodder, particularly to maintain the tissues free from lymphatic congestion. Some authors believe that manual lymphatic drainage performed with the hands is the only one that can give acceptable results on lymphatic pathology (Bacci, Klein, Izzo et al., 1996).

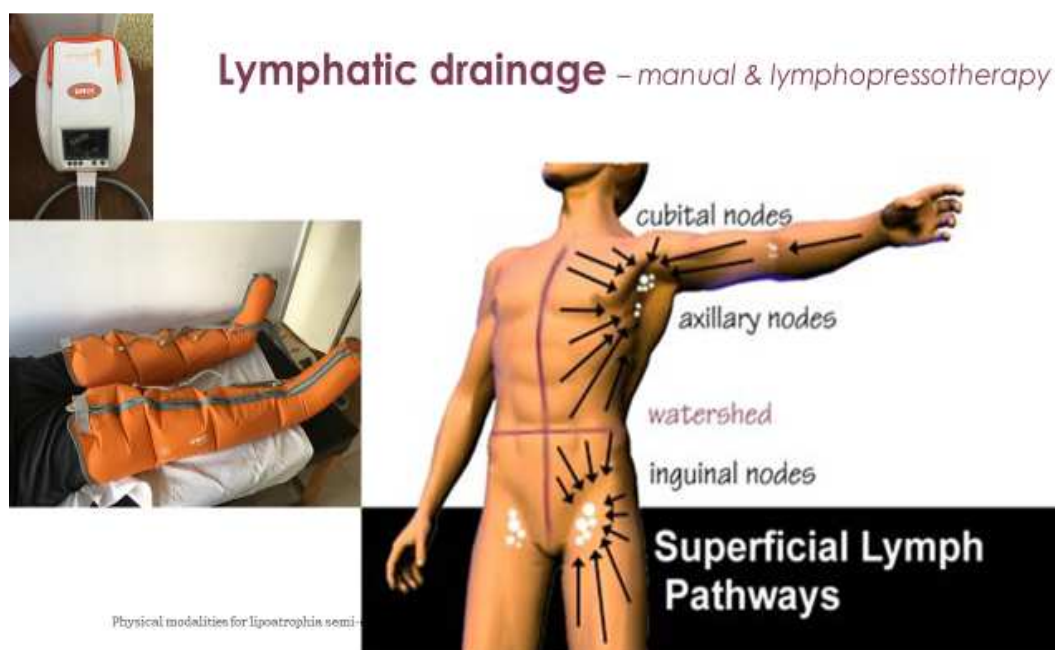


Fig. 5. Lymphatic drainage

3.6. Mineral water and specific diet

During the LPG procedures the water uptake was increased to 2.5 liters per day. Diet was rich in fibers, fruits and vegetables, poor in lipids (according the USDA food pyramid (Fig. 6).

Diet

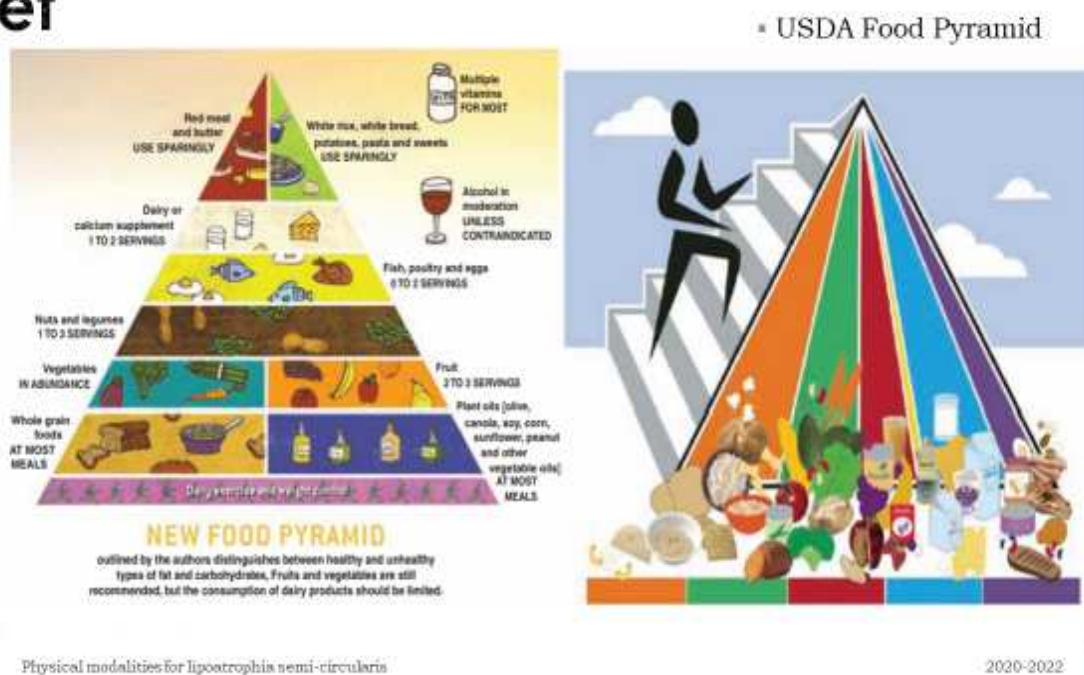


Fig. 6. Diet – USDA food pyramid

3.7. Results of the rehabilitation

After a period of 45 days we observed a **re-sculpture of the lower extremities** with: decrease of the “ribbed zones”, reduction of the lobular panniculitis, improvement of the skin tonus and elasticity (Fig. 7).



Fig. 7. Comparison of the patient's signs: a – before treatment, b – after treatment

We obtained some anthropometric changes, as weight reduction (from 72,1 kg to 69,3 kg) and decrease of the Body Mass Index (BMI – from 28,4 to 26,1 kg/cm²). The dynamics of centimetry indices is presented on Table 1 and includes: reduction of the waist circumference, hip tour and hip circumferences (10 cm and 20 cm over the superior board of the patella).

	<i>Before treatment</i>	INDICES	<i>After Treatment</i>	Difference
<i>kg</i>	72.1 kg	Weight	69.3	<i>2.8 kg</i>
<i>kg/ cm²</i>	28.4	BMI	26.1	<i>2.3 kg / cm²</i>
	98.5	Waist circumference	96.3	<i>2.2 cm</i>
	117.3	Hip tour	112.6	<i>4.7 cm</i>
<i>Centimetry (centimeters)</i>	52.1	Hip circumference – 10 cm over the patella	49.4	<i>2.7 cm</i>
	62.3	Hip circumference – 20 cm over the patella	59.5	<i>2.8 cm</i>

4. Discussion

Practically, our rehabilitation programme was based on principles of healthy lifestyle: regular physical activity (swimming), hydration (with mineral water) and diet. We applied systematically manual massage, lymphatic drainage, LPG Endermologie.

5. Conclusion

Physical modalities can be very useful in the complex treatment of lipoatrophy, especially in cases with Semicircular lipoatrophy. The most important elements of the rehabilitation complex are: Regular physical activity (including swimming) and Analytic exercises; Manual massage, Lymphatic drainage, Endermologie and endermotherapy (LPG), Mineral water.

References

- Asenova T., Koleva I. 2020. Potential of physical modalities in lipoatrophia. In: *Clinical cases of the rehabilitation practice. Practicum physiotherapeuticum*. Pr I.Koleva Editor. Sofia: SIMEL print, pp. 68–74. [In Bulgarian]
- Bacci P.A. 2000. La fascia superficiale. – In: Bacci P.A. Le celluliti. Arezzo: Alberti & C Editori, Parte 4.
- Bacci P.A. 2003. Endermologie-LPG systems after 15 years. In: *Cellulite – Pathophysiology and Treatment*. Second edition. M.P. Goldman and D. Hexsel Editors. Informa Healthcare, pp. 91–99.
- Bacci P.A., Klein D., Izzo M. et al. 1996. La patologia linfatica nel Thigh Lifting, Atti Congresso Nazionale SICPRE, Vol. 10, 323–31, Ribuffo.
- Bachmeyer C., Haddad A. 2011. Lipoatrophia semicircularis of the thighs. *Presse Med*; 40: 980–981.
- Gschwander W.R., Munzberg H. 1974. Lipoatrophia semicircularis – linear circular atrophy of subcutaneous fat on extremities. *Hautarzt*; 25: 222–227.
- Foldesova J., Drvota V., Meluzinova E. 2015. Effect of LPG-endermologie on skin changes resulting from longterm treatment with Glatiramer acetate. *Neurologie pro praxi*: 16 (1), 44–47.
- Foeldi M. 1983. Symposium ueber die sogenannte Zellulitis. Feldberg, 1–2 Juni 1983.
- Goldman M.P., Hexsel D. Editors. 2003. *Cellulite – pathophysiology and treatment*. Second edition. – New York: Informa Healthcare, 224 pp.
- Hodak E., David M., Sandbank M. 1990. Semicircular lipoatrophy – a pressure-induced lipoatrophy? *Clin. Exp. Dermatol.* 15 (6): 464–5.
- Kutlubat Z., Songur A., Engin B. 2013. An alternative treatment modality for cellulite: LPG endermologie. *Journal of Cosmetic and Laser Therapy*, 2013; 1–5.
- Leduc A. 1980. *Le drainage lymphatique, Theorie et pratique*, Masson; 1980.
- Mezencevová V., Torok J. 2017. Endermologie – new approach in the medicine treatment. *Technological engineering*, volume XIV, number 1, pp. 27–30.
- Moretti E., Schapira A., Kaplan G. et al. 1993. La fascia superficiale, *Revista panamericana de flebologia y linfologia*, n. 9.
- Nogue S., Sanz P., Tomas X., Farrús X. 2008: Lipoatrophy semicircularis. *Med Clin (Barc)*; 130: 360–360.
- Silva J., Filoni E. 2014. Physical Therapy in the treatment of body aesthetics dysfunctions. *Manual Therapy, Posturology and Rehabilitation Journal*, 12, 230–240.
- Starkey Ch. 2013. *Therapeutic modalities*. Fourth edition. Philadelphia: F.A. Davis Company, 449 pp.

CONTEMPORANEOUS OPINIONS ON CARDIOPREVENTION AND CARDIOREHABILITATION (AND OUR OWN EXPERIENCE)

Ivet Koleva¹, Borislav Yoshinov², Irena Kaminska³, Alexander Alexiev⁴,
Teodora Asenova²

¹Professor in Physical Medicine, Medical University of Sofia, Bulgaria

²Student in Medicine, Medical Faculty of Sofia University

³Department of Anatomy and Physiology, Daugavpils University, Latvia

⁴Medical Center “Cardio” – Sofia

Abstract

Contemporaneous opinions on cardioprevention and cardiorehabilitation (and our own experience)

Key Words: *cardioprevention, cardiorehabilitation, rehabilitation team, European Society of Cardiology*

The goal of current article is to present contemporaneous aspects of cardioprevention and cardiorehabilitation: principles, algorithms, benefits of application.

According American Heart association, Cardiac rehabilitation (CR) is a professionally supervised program to help people recover from heart attacks, heart surgery and percutaneous coronary intervention (PCI) procedures, such as stenting and angioplasty.

Authors discuss some contemporaneous documents: Global burden of diseases study 2019, ESC guidelines 2021, Global Action Plan of Physical Activity 2018–2030.

In 2021 the European Society of Cardiology (ESC) published Guidelines on cardiovascular prevention in clinical practice; elaborated by representatives of the ESC and 12 medical societies. According these data, participation in a medically supervised, structured, comprehensive, multidisciplinary evidence-based cardiac rehabilitation and prevention programme is very important, as recommendation of high class (I or II) and high levels of evidence (A or B). Some recommendations for cardio-vascular diseases risk modifiers are included: stress, plaque detection by carotid ultrasound, RR control). The role of physical activity and exercise is underlined, with recommendations of class I, level A and B.

Physical inactivity is considered as the fourth leading cause of death in the world.

The events for stimulation of physical activity are systematized in the Global Action Plan on Physical Activity (GAPPA 2018–2030), developed by the World Health Organization and the Pan-American Health Organization (PAHO), with an important goal: 15% relative reduction in the global prevalence of physical inactivity in adults and adolescents. Principal initiatives include: create active societies, active people, active environments, active systems.

Results of CR of different types of patients are presented.

1. Goal of the article

The goal of current article is to present contemporaneous aspects of cardioprevention and cardiorehabilitation: principles, algorithms, benefits of application.

2. Principles of cardioprevention and cardiorehabilitation

2.1. Definitions

Cardiac rehabilitation (CR) is the integrated treatment of individuals after cardiac events or procedures with the goal of maximizing physical function, promoting emotional adjustment, modifying cardiac risk factors, and addressing return to previous social roles and responsibilities (Frontera, Silver, Rizzo, 2020).

According American Heart association, CR is a professionally supervised program to help people recover from heart attacks, heart surgery and percutaneous coronary intervention (PCI) procedures, such as stenting and angioplasty.

CR programs usually provide education and counseling services, to help heart patients increase physical fitness, reduce cardiac symptoms, improve health and reduce the risk of future heart problems, including heart attacks. The CR-team include medical doctors (general practitioner, cardiologist, surgeon, physiatrist), nurses, exercise specialists, physical and occupational therapists, dietitians or nutritionists, psychologists, specialists in Adapted physical activity (APA).

Indications for CR include cardio-respiratory functional deficiency or cardiac insufficiency in cases of:

- **Heart attack;**
- **Heart condition**, such as *coronary artery disease (CAD)*, *angina* or *heart failure*;
- **Heart procedure or surgery**, including *coronary artery bypass graft (CABG) surgery*, *percutaneous coronary intervention (PCI)*, including *coronary angioplasty (balloon angioplasty)* and *stenting*, *valve replacement*, or a *pacemaker* or *implantable cardioverter defibrillator (ICD)*;
- Heart or **hearth & lung transplant**;
- **Peripheral artery disease.**

The CR-team include: *medical doctors* (general practitioner, cardiologist, cardio-surgeon, physiatrist), *nurses*, *exercise specialists*, *physical and occupational therapists*, dietitians or nutritionists, psychologists, specialists in Adapted physical activity (APA).

Basic elements of CR-programme are: Pharmacological therapy; Behavior; Patients' education; Diet; Smoking cessation; Exercises.

CR has 4 principal phases: *Phase 1* – in-patient phase; *Phase 2* – immediate out-patient; *Phase 3* – intermediate out-patient; *Phase 4* – maintenance out-patient.

Ultimately, we have some important *documents*, concerning CR: Global burden of diseases study 2019, ESC guidelines 2021, Global Action Plan on Physical Activity 2018–2030.

2.2. Global burden of diseases study 2019

In 2019, approximately *18.6 million deaths were attributed to CVD* globally. The age-adjusted death rate per 100,000 population was 239.8. The *highest mortality rates attributable to CVD* in 2019 were in *Eastern Europe* and *Central Asia* (GBD, 1990–2019).

Globally, it was estimated that *in 2019, 197.2 million people were living with ischemic heart disease (IHD)*, and it was more prevalent in males than in females (113.7 and 83.6 million people, respectively).

North Africa, Middle East, Central Asia, and *Eastern Europe* had the *highest prevalence rates of IHD* in the world (Fig. 1).

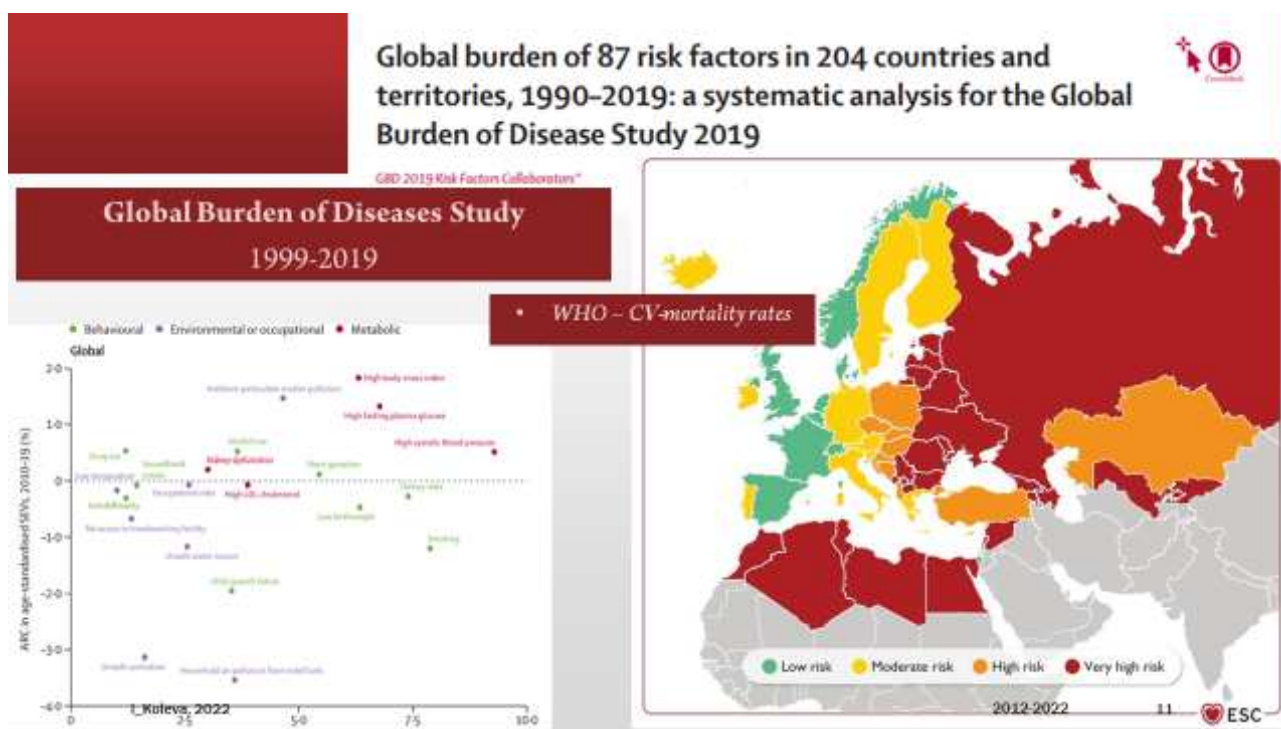


Fig. 1. Global burden of diseases study – cardio-vascular mortality rates

2.3. ESC guidelines 2021

In 2021 the **European Society of Cardiology (ESC)** published *Guidelines on cardiovascular prevention in clinical practice*; elaborated by representatives of the ESC and 12 medical societies (ESC, 2021).

According to these data, participation in a *medically supervised, structured, comprehensive, multidisciplinary evidence-based cardiac rehabilitation and prevention programme* is very important, as a recommendation of high class (I or II) and high levels of evidence (A or B).

Some recommendations for cardio-vascular disease risk modifiers are included: stress, plaque detection by carotid ultrasound, RR control).

The *role of physical activity and exercise* is underlined, with recommendations of class I, level A and B.

Recommendations for C-rehab have a high level of evidence (Fig. 2):

- *For all patients after CV-event or revascularization – level I-A;*
- *Class II-a, Level B – for CR after discharge;*
- *Class II-b, Level B – for home-based CR, or tele-rehab.*

RECOMMENDATIONS for C-rehab:

For all patients after CV-event or revascularization – level I-A

Class II-a, Level B – for CR after discharge

Class II-b, Level B – for home-based CR, or tele-rehab

ESC European Society of Cardiology
European Heart Journal (2021) 42, 3227–3337
doi:10.1093/eurheartj/ehab484

ESC GUIDELINES

2021 ESC Guidelines on cardiovascular disease prevention in clinical practice

Developed by the Task Force for cardiovascular disease prevention in clinical practice with representatives of the European Society of Cardiology and 12 medical societies

With the special contribution of the European Association of Preventive Cardiology (EAPC)

Recommendations for cardiac rehabilitation

Recommendations	Class ^a	Level ^b
Participation in a medically supervised, structured, comprehensive, multidisciplinary EBCR and prevention programme for patients after ASCVD events and/or revascularization, and for patients with HF (mainly HFrEF), is recommended to improve patient outcomes. ^{638–642}	I	A
Methods to increase CR and prevention referral and uptake should be considered (i.e. electronic prompts or automatic referrals, referral and liaison visits, structured follow-up by nurses or health professionals, and early programme initiation after discharge). ^{643–646}	IIa	B
Home-based CR, telehealth, and mHealth interventions may be considered to increase patient participation and long-term adherence to healthy behaviours. ^{647,648}	IIb	B

2012-2022 21

© ESC 2021

Fig. 2. ESC recommendations for cardiac rehabilitation

Same document include *recommendations for physical activity (PA)*, as follows (Fig. 3):

- Class I, Level A – for 150–300 minutes / a week PA of moderate intensity – for patients of every age;
- Class I, Level B – for reduction of sedentary lifestyle – in adults;
- Class I, Level B – for resistance exercises & aerobic activity, at least twice a week;
- Class II-a, Level B – for lifestyle interventions, oriented to intensification of PA.

RECOMMENDATIONS FOR PHYSICAL ACTIVITY

Class I, Level A – for 150-300 minutes / a week PA of moderate intensity – for patients of every age

Class I, Level B – for reduction of sedentary lifestyle – in adults

Class I, Level B – for resistance exercises & aerobic activity, at least twice a week

Class II-a, Level B – for lifestyle interventions, oriented to intensification of PA

ESC European Society of Cardiology
European Heart Journal (2021) 42, 3227–3337
doi:10.1093/eurheartj/ehab484

ESC GUIDELINES

2021 ESC Guidelines on cardiovascular disease prevention in clinical practice

4.3. Optimizing lifestyle

4.3.1. Physical activity and exercise

Recommendations for physical activity

Recommendations	Class ^a	Level ^b
It is recommended for adults of all ages to strive for at least 150–300 min a week of moderate-intensity or 75–150 min a week of vigorous-intensity aerobic PA, or an equivalent combination thereof, to reduce all-cause mortality, CV mortality, and morbidity. ^{373,372}	I	A
It is recommended that adults who cannot perform 150 min of moderate-intensity PA a week should stay as active as their abilities and health condition allow. ^{373,374}	I	B
It is recommended to reduce sedentary time to engage in at least light activity throughout the day to reduce all-cause and CV mortality and morbidity. ^{375–377}	I	B
Performing resistance exercise, in addition to aerobic activity, is recommended on 2 or more days per week to reduce all-cause mortality. ^{378,379}	I	B
Lifestyle interventions, such as group or individual education, behaviour-change techniques, telephone counselling, and use of consumer-based wearable activity trackers, should be considered to increase PA participation. ^{380–382}	IIa	B

CV = cardiovascular; PA = physical activity.
^aClass of recommendation.
^bLevel of evidence.

2012-2022 23

© ESC 2021

Fig. 3. ESC recommendations for physical activity

WHO consider reduced PA (sedentary lifestyle) as the fourth leading cause of death in the world. Physical inactivity is considered as the fourth leading cause of death in the world.

2.4. Global Action Plan on Physical Activity 2018–2030 (GAPPA 2018–2030)

The events for stimulation of physical activity are systematized in the *Global Action Plan on Physical Activity* (GAPPA 2018–2030), developed by the World Health Organization and the Pan-American Health Organization (PAHO), with an important goal: *15% relative reduction in the global prevalence of physical inactivity in adults and adolescents* (World Health Organization, 2019). Various reasons may explain this habit: perceived limitations in PA and effort; lack of time, fun, and motivation; economic problems; misconceptions of the minimal volume of PA necessary for cardiovascular health benefits; and unfavorable environments (lack of sports facilities, lack of walking or cycling lanes, dangerous boroughs because of crime, etc.). Considering these difficulties, more attention has been paid recently to sedentary behaviour (more than physical inactivity), which has been defined as an energy expenditure ≤ 1.5 METs, while in seated, reclined, or lying posture for several hours a day (Organización Panamericana de la Salud, 2019).



Fig. 4. Global action plan on physical activity (GAPPA 2018–2030)

GAPPA 2018–2030 includes initiatives in four principal fields (Fig. 5): creation of active societies, active people, active environments, active systems. Examples: “Active cities” – bicycle lanes & walking paths; Media & Educational campaigns (incl. in the social media); Initiatives of Sport medicine societies; PA prescriptions from the general practitioners; Wellness programmes at the work place; Fitness-centers – for the workers; Educational campaigns at school; For old people – programmes of adapted PA (Amini, Habibi, Islamoglu et al., 2021).

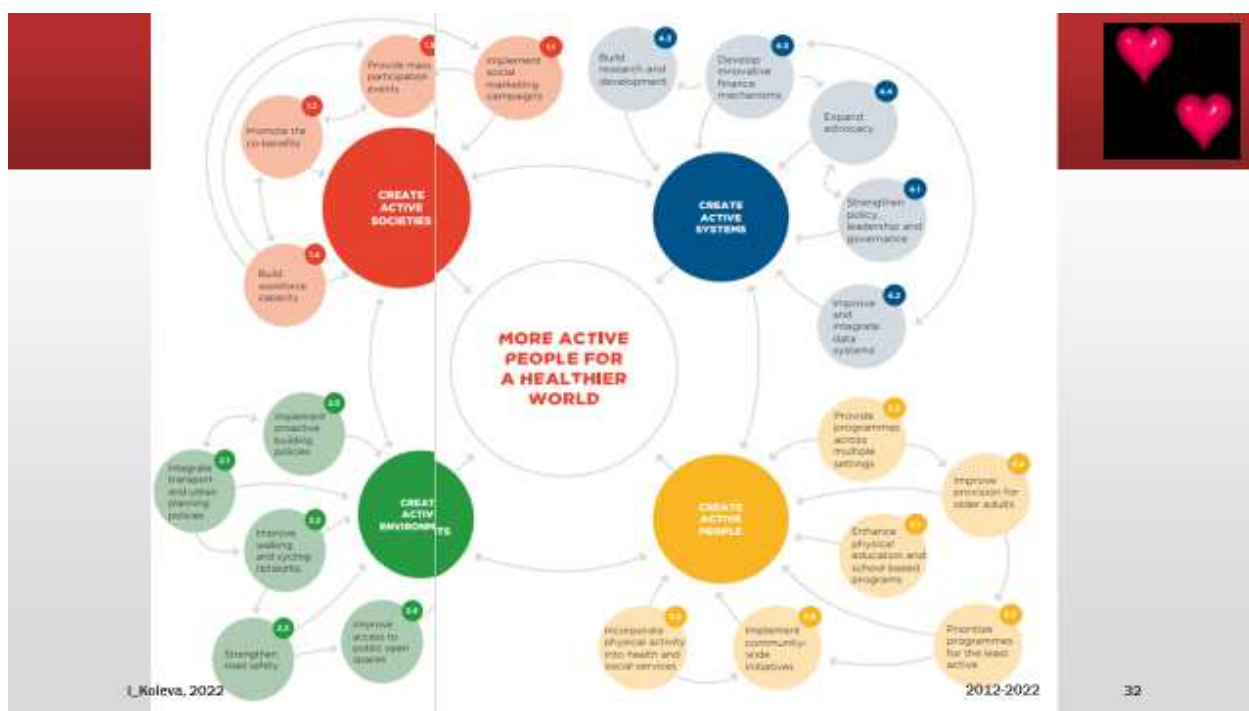


Fig. 5. GAPPA (2018–2030) initiatives

3. Cardioprevention & cardiorehabilitation algorithm

CR must be individually dosed, adapted and controlled. The programme includes: Physical Activity Counseling: Motivation to a Physically Active Lifestyle; Perception Training, Body Awareness, and Practical Skills of Self-Control; Aerobic Endurance Training.

CR algorithm includes Functional assessment and Functional therapy.

For *functional evaluation*, we apply: Sitting – Rising test; Timed Up and Go test, 10 meters walk test, 6-minutes walk test.

The CR programme includes basic physical activity, exercises, analytic exercises, balance & walking exercises; mechanotherapy, magnetic field, ergotherapy (American College of Sports Medicine. 1994).

An individualized exercise prescription should include parameters for intensity, duration, frequency, and mode. Progression should include an initiation stage of 3 to 6 weeks, an improvement stage of 4 to 5 months, and a maintenance stage aimed at the adoption of a lifetime exercise habit (O’Connell & Bezner, 2013).

First phase of the inpatient CR must include:

- STEP 1: *Sitting in bed, Respiratory exercises, Ankle & foot exercises; wrist & hand exercises;*
- STEP 2: *Exercises for proximal joints of extremities;*
- STEP 3: *Plus walking;*
- STEP 4: *Augmentation of the duration & the intensity of the physical load – of exercises, walking up to 10 minutes or as tolerated.*

Stages of exercise training in CR are:

- **Initial stage** – with 4–6 exercise units during 1–2 weeks, short exercise duration (15–30 minutes) and low exercise intensity.
- **Improvement stage** – exercise duration gradually prolonged up to 30–60 minutes and intensity gradually increased;
- **Maintenance stage** – gradually increase of exercise intensity and exercise time (as tolerated).

The dosage of physical load can be measured using: Karvonen formula, Borg scale or Metabolic equivalents (METs).

Physical activity protocols use Bicycle ergometry or Treadmill (with variations – walking, running, for geriatric patients – Nordic walking).

We apply aerobic endurance training and dynamic resistance training, in some ambulatory patients – High-intensity interval training (HIIT)

Finally, we prepare a scheme of home-based exercise training programme, adapted to the needs of every patient.

4. Benefits of systematic cardioprevention & cardiorehabilitation

Regular exercises decrease fatigue; improve performance in work- and sports-related activities; recover blood lipid profile; enhance immune reaction; ameliorate glucose tolerance and insulin sensitivity; upgrade body composition; enhance sense of well-being; decrease risk of coronary artery disease, cancer of the colon and breast, hypertension, type 2 diabetes mellitus, osteoporosis, anxiety and depression; ameliorate quality of life (Pate et al., 1995).

Systematic cardiorehabilitation presents many benefits (Collins, 2013), as follows (Fig. 6): reduction of total and cardio-vascular mortality and of hospitalization, amelioration of cardiac function, improvement of ejection fraction, improvements in self-reported health status.

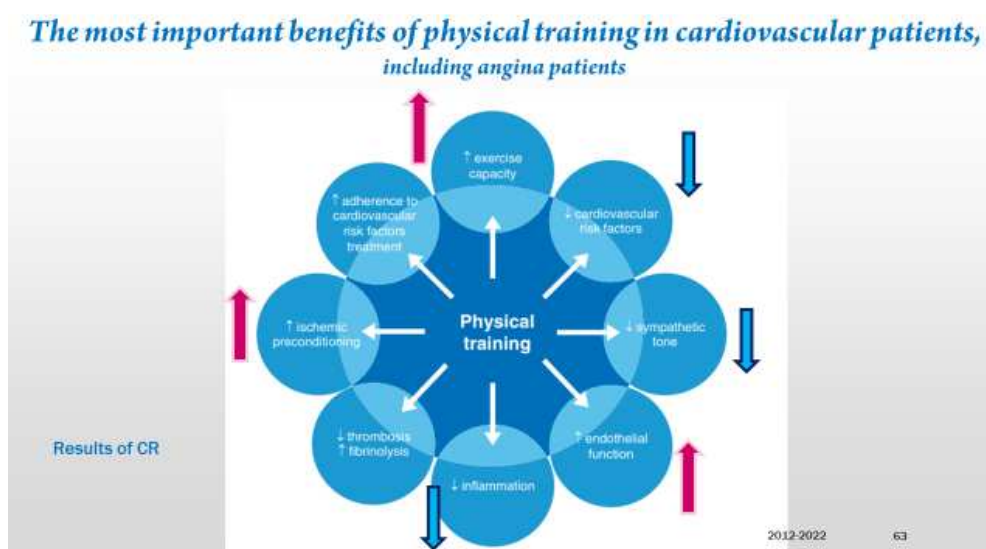


Fig. 6. Benefits of systematic CR

Our own results on cardiologic and cardio-surgical patients

During last 10 years, we explore the effects of systematic cardio-rehabilitation on cardiologic and cardio-surgical patients, in the sub-acute phase – after cardiac event due to coronary artery disease (CAD), after percutaneous cardiac intervention (PCI) and stenting, and after cardio-surgery (coronary artery bypass graft /CABG/, valvular replacement). Our patients enter into the department of early CR at the day 5 to 7 after the respective procedure. For a period of 10 days of CR, we observe significant effects, as follows: stabilization of the functional status, amelioration of physical performance, reduction of depression and anxiety, decrease of risk factors, amelioration of the quality of life. Next figures present some results of the inpatient CR (Figures 7–10), as follows: results of the 6 minutes' walking test (6-MWT) – systolic blood pressure (Fig. 7), walking distance (Fig. 8), effects on the heart rate (Fig. 9); results of the Minnesota quality of life questionnaire (Fig. 10).

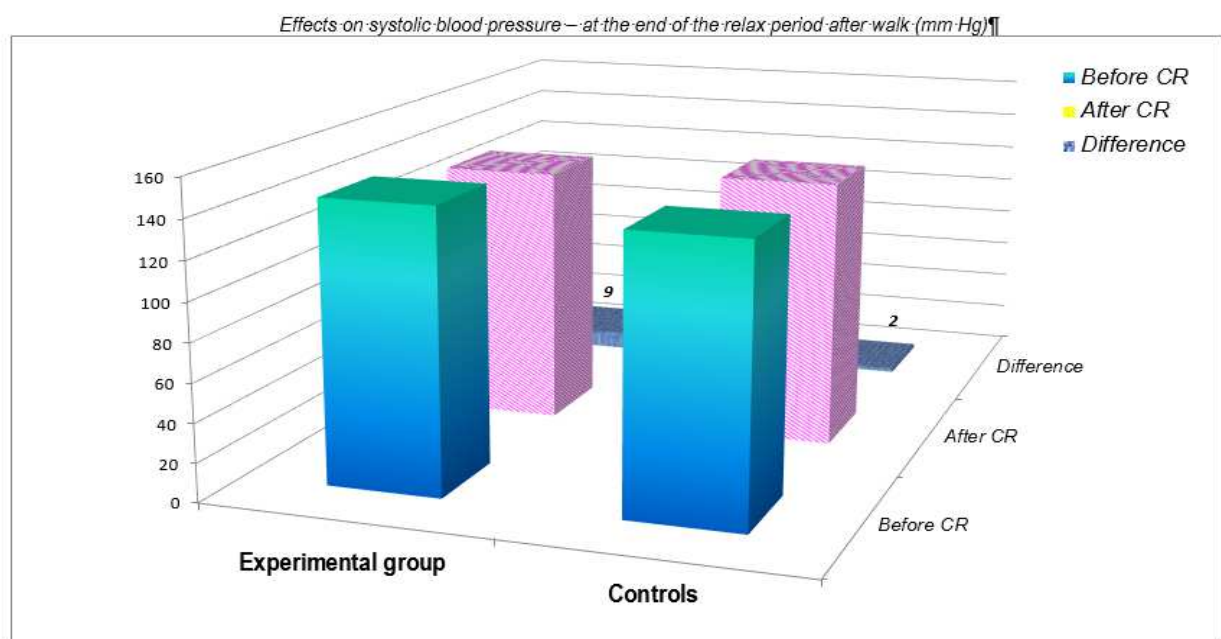


Fig. 7. Results of 6-MWT – effects on systolic blood pressure

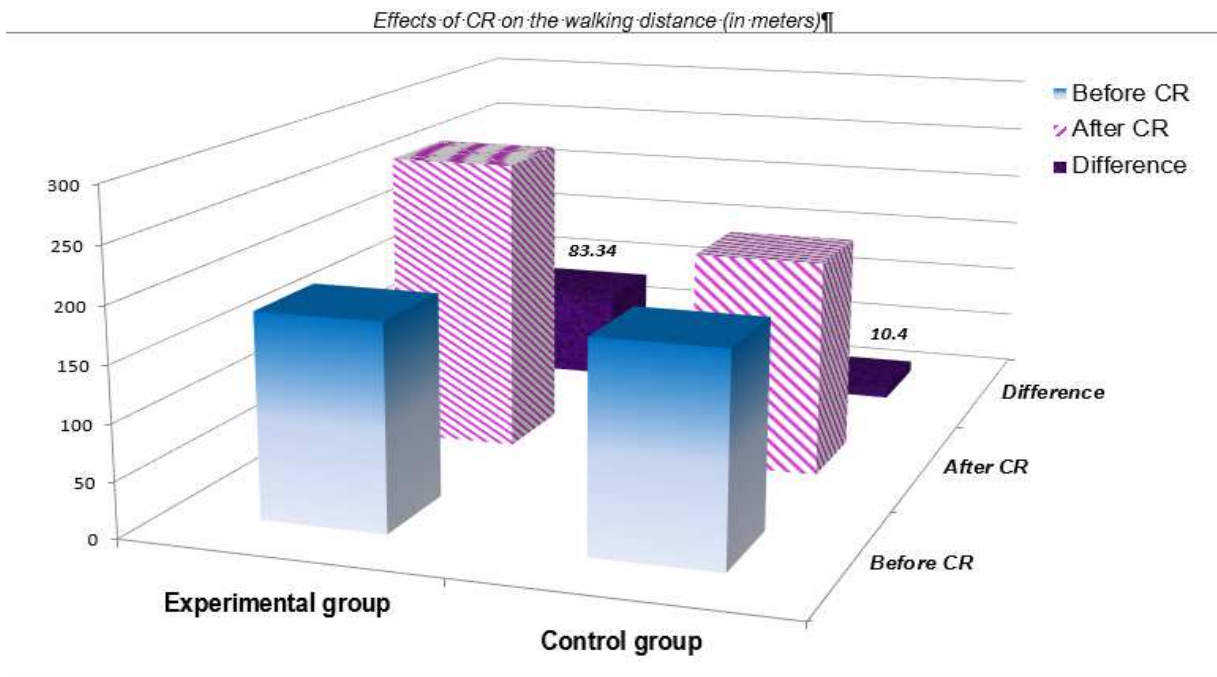


Fig. 8. Results of 6-MWT – effects on the walking distance

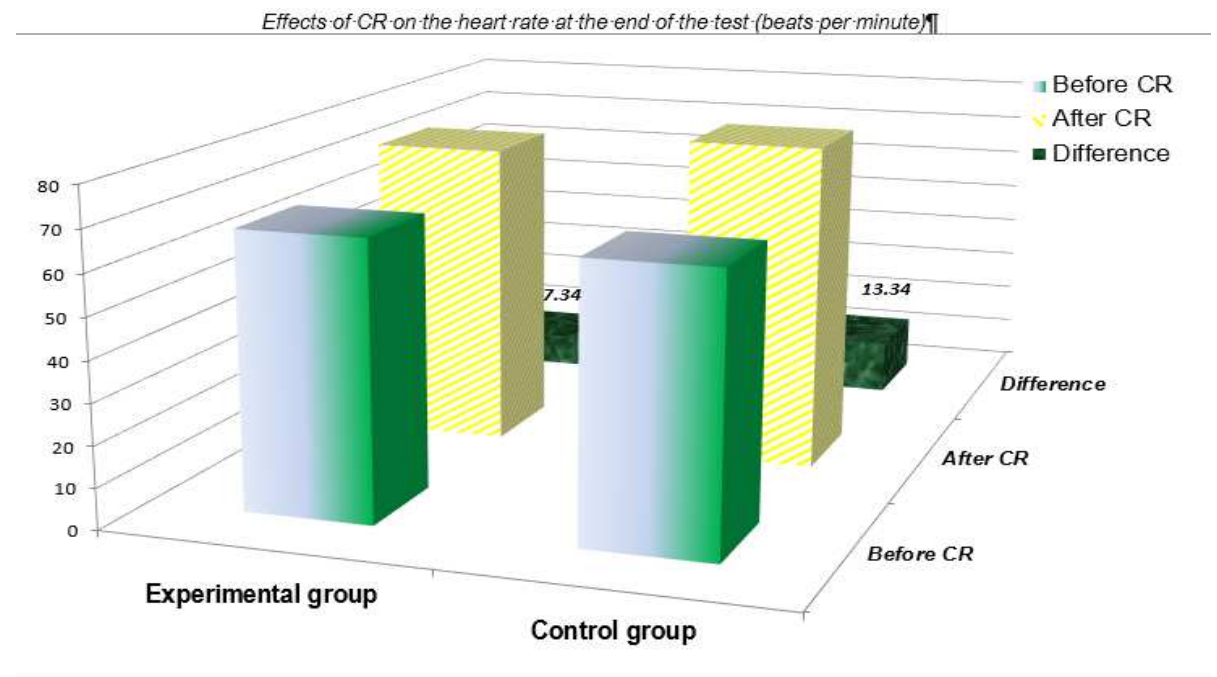


Fig. 9. Results of 6-MWT – effects on the heart rate

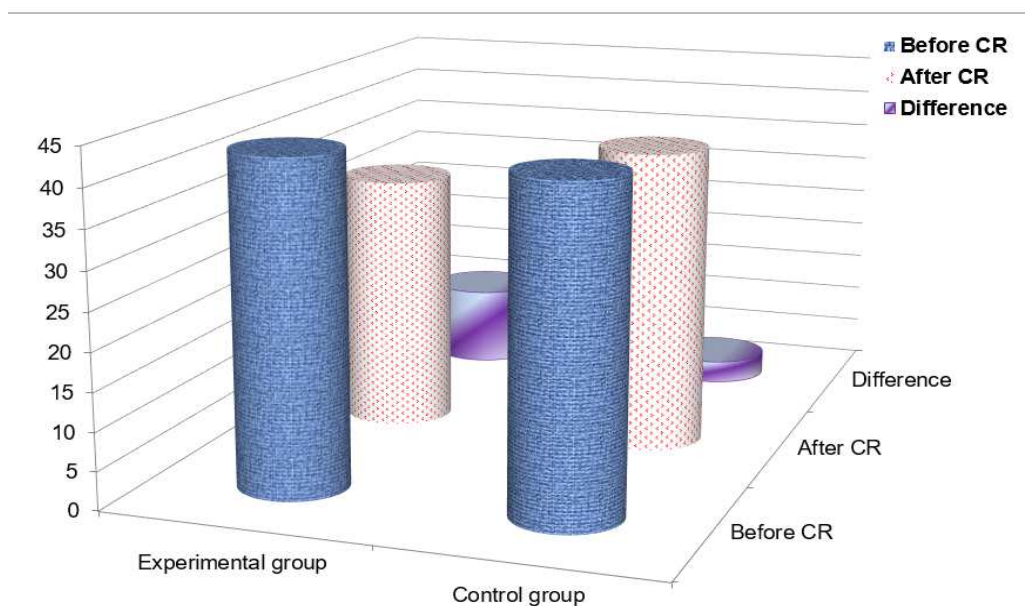


Fig. 10. Results of Minnesota quality of life questionnaire

5. Conclusion

In conclusion, we must underline the clinical importance of systematic cardiorehabilitation – with significant benefits on physical performance and quality of life of patients – after cardiac event or cardiac surgery. Effects of CR on reduction of mortality rate and hospitalization rate are important too.

References

- American College of Sports Medicine. 1994. Ejercicio para pacientes con enfermedad de las arterias coronarias. *MSSE*, 26: 3, 1994, pp. i–v.
- Amini H., Habibi S., Islamoglu A.H. et al. 2021. COVID-19 pandemic-induced physical inactivity: the necessity of updating the Global Action Plan on Physical Activity 2018–2030. *Environ Health Prev Med* 26, 32. <https://doi.org/10.1186/s12199-021-00955-z>
- Collins J.A. Editor. 2013. *Encyclopedia of cardio-vascular research*. – New York: Nova Biometrical, 944 pp.
- ESC. 2021. European Society of Cardiology (ESC) Guidelines on cardio-vascular disease prevention in clinical practice. 2021. *European Heart Journal*, 42: 3227–3337.
- Frontera W., Silver J.K., Rizzo T.D. *Essentials of Physical medicine and Rehabilitation*. Saunders Elsevier, pp. 615–666.
- Murray et al. 2020. Global Burden of Diseases Study 1990–2019. *Lancet*, 396: 1223–49.
- O’Connell D., Bezner J. 2013. Principles of aerobic conditioning and cardiac rehabilitation. Third edition. – In: Bandy W.D., Sanders B. *Therapeutic exercise for physical therapist Assistants. Techniques for intervention*. Philadelphia – Baltimore – New York – London – Buenos Aires – Hong Kong – Sidney – Tokyo: Wolters Kluwer Health, Lippincott Williams & Wilkins, pp. 300–339.
- Organization WH. 2019. Global action plan on physical activity 2018–2030: more active people for a healthier world. *World Health Organization*; No. WHO/NMH/PND/18.5.
- Organización Panamericana de la Salud. 2019. Plan de acción mundial sobre actividad física 2018–2030. Más personas activas para un mundo sano. PAHO, Washington, D.C. Licencia: CC BY-NC-SA 3.0 IGO.
- Pate R.R., Blair S.N. et al. 1995. Physical activity and public health. *JAMA*, 273: 402–407.

IMPACT OF DIGITALIZED BALANCE ASSESSMENT FOR REVISION OF THE COORDINATIVE TRAINING IN CEREBELLAR ATAXIA (CLINICAL CASE PRESENTATION)

Borislav Yoshinov¹, Ivet Koleva², Jelena Buiko³, Nadezhda Tsvetkova⁴, Radoslav R. Yoshinov⁵

¹Student in Medicine, Medical Faculty of Sofia University

²Professor in Physical Medicine, Medical University of Sofia, Bulgaria

³Department of Anatomy and Physiology, Daugavpils University, Latvia

⁴Hospital for long-term care and rehabilitation “Serdika” – Sofia

⁵University of Information Technologies UNIBIT – Sofia

Abstract

Impact of digitalized balance assessment for revision of the coordinative training in cerebellar ataxia (clinical case presentation)

Key Words: COVID, complications, ataxia, coordination, balance test, training

The goal of current article is to present a post-COVID-19 clinical case of cerebellar ataxia.

Corona-virus disease 2019 (COVID-19), caused by the newly emerged coronavirus [severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)], affected the public health in the world. Many acute and chronic neurological issues were considered as consequences of COVID-19: ischaemic stroke, inflammatory and neurodegenerative disorders (encephalomyelitis, leucoencephalitis, Guillain-Barre syndrome and chronic demyelinating polyneuropathy, relapses of Multiple sclerosis, Parkinsonism; cognitive impairment, post-intensive care syndrome (PICS), Memory, attention and sleep problems; Brain fog, Post-traumatic stress syndrome, Depression and Anxiety.

Cerebellar degeneration and subsequent cerebellar ataxia (CA) include a group of disorders, affecting coordination, balance and speech. The outlook for ataxia vary considerably, but most adult onset ataxias will get progressively worse over many years. A multidisciplinary approach is necessary in CA.

We present a case of a woman of 51 years, with CA, developed progressively for a period of 7–8 months; the onset was 25 days after a Corona-virus disease (fever up to 38°C, headache, fatigue, myalgia and arthralgia, without pneumonia). At the entry in our department, she presented vertigo, balance and gait instability, dysmetria and dysdyadochokinesia, muscular cramps in both legs, ataxic dysarthria. During the TYMO Balance test (TyroMotion system), we obtained oscillations of the center of pressure and extended sway area, with considerable anterior-posterior displacement. The instability increases on instable surface and after eyes' closure. Romberg index 0.74.

Many studies provide Class III evidence that coordinative training improves motor performance and reduces ataxia symptoms in patients with progressive CA.

The detailed digitalized evaluation of the equilibrium was the base for structuration of a complex training of the balance, gait and coordination, adapted to the needs to the concrete patient.

1. Introduction and goal of the article

The goal of current article is to present a post-COVID-19 clinical case of cerebellar ataxia. During the assessment of the patient's static balance, we applied a detailed digitalized equilibrium assessment. Detailed evaluation help us to adapt the standard coordinative training to the individual needs of the concrete patient in the concrete moment of development of the disease.

2. Covid-19 and some neurological consequences

Corona-virus disease 2019 (COVID-19), caused by the newly emerged coronavirus [severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)], affected the public health in many countries, including Bulgaria.

Clinical manifestations include fever, cough, shortness of breath, headache, fatigue, myalgia and arthralgia, in some cases – anorexia, ageusia and anosmia (loss of taste and smell). Consequences of severe and critical forms of COVID include Respiratory insufficiency,

Deconditioning, Dysphagia, Joint stiffness and pain, critical-illness related Myopathy and Neuropathy, and complications of the central and peripheral nervous system.

Ultimately post-COVID or long COVID-19 syndrome was described, including: Fatigue, Difficulty breathing; Shortness of breath, Cough; Joint pain; Chest pain; severe acute respiratory syndrome (SARS); Fast or pounding heartbeat; Muscle pain or headache; Loss of taste and/or smell; Rash or hair loss.

Many acute and chronic neurological issues were considered as consequences of COVID-19: ischaemic stroke, inflammatory and neurodegenerative disorders (encephalomyelitis, leucoencephalitis, Guillain-Barre syndrome and chronic demyelinating polyneuropathy, relapses of multiple sclerosis, Parkinsonic syndrome); post-intensive care syndrome (PICS), Memory, attention and sleep problems; cognitive impairment; Brain fog, Inability to concentrate; Post-traumatic stress syndrome, Depression and Anxiety; Sleep issues.

3. Cerebellar ataxia

3.1. Cerebellum – anatomo-physiological correlations

The anatomy of the cerebellum in the posterior fossa of the intracranial cavity is complex, but it can be separated into three major structures:

- The midline cerebellum, which includes the cerebellar vermis, the fastigial and interposed nuclei (globus and emboliform), the vestibulo-cerebellum (composed of the flocculus and nodulus), and the paravermis / intermediate zone;
- The two large cerebellar hemispheres, including the dentate nuclei.

Cerebellar syndromes can be divided into symptoms arising from damage to the midline structures or hemispheric structures, although there is significant clinical overlap between these syndromes (Grimaldi, Manto, 2012).

Function of the cerebellum include: Control of balance and ocular movements; Planning of movements that are about to occur; Coordination of complex and sequential movements; Maintenance of muscle tone.

3.2. Cerebellar degeneration and subsequent cerebellar ataxia include a group of disorders, affecting coordination, balance and speech. Although cerebellar degeneration may be chronic and slowly progressive, acute cerebellar swelling due to infarction, edema, or hemorrhage can have rapid and catastrophic effects and is a true neurologic emergency.

3.3. Types of ataxia

Ataxia is usually caused by damage to the cerebellum, but it can also be caused by damage to the spinal cord or other parts of the nervous system. Damage can occur as a result of injury or illness (acquired ataxia) or because the cerebellum or spinal cord degenerates because of an inherited faulty gene (hereditary ataxia) (Timmann, Diener, 2007). Sometimes there's no clear reason why the cerebellum and spinal cord become damaged. This is the case for people with idiopathic late-onset cerebellar ataxia.

There are many different types of ataxia, which can be divided into three broad categories (Winchester, Singh, Mikati, 2013):

- *Acquired ataxia* – Alcohol, stroke, medications (Benzodiazepines, phenytoin; some types of chemotherapy, Vitamin B deficiencies (B1, B6, B12), Multiple sclerosis, Autoimmune diseases (Sarcoidosis, encephalomyelitis), Infections (HIV, Lyme, COVID-19), Paraneoplastic syndromes, Cerebral abscess, benign or malignant tumors, head trauma and others;
- *Hereditary ataxia* – Autosomal recessive ataxias (Friedreich's ataxia, Wilson's disease, Ataxia-telangiectasia), Autosomal dominant ataxias (Spinocerebellar ataxias, Episodic ataxia);
- *Idiopathic late-onset cerebellar ataxia (ILOCA)* – where the brain is progressively damaged over time for reasons that are unclear.

3.4. Clinical Features of cerebellar ataxia include (de Bot, Willemsen, Vermeer et al. 2012; Fogel and Perlman, 2006): Gait ataxia – abnormal wide-based, unsteady gait; Truncal ataxia; Limb ataxia with dysmetria; Dysarthria; Dysdiadochokinesia; Tremor; Oculomotor dysfunction (including nystagmus).

3.5. Outlook

The outlook for ataxia can vary considerably and largely depends on the type of ataxia. Some types may remain relatively stable or even improve with time, but most will get progressively worse over many years.

Life expectancy is generally shorter than normal for people with hereditary ataxia, although some people can live well into their 50s, 60s or beyond. In more severe cases, the condition can be fatal in childhood or early adulthood. For acquired ataxia, the outlook depends on the underlying cause. Some cases may improve or stay the same, while other cases may get gradually worse over time and reduce life expectancy (Benussi, Cantoni, Manes et al., 2021).

3.6. Treatment of ataxia

A multidisciplinary approach is necessary in cases with Cerebellar Ataxia.

In most cases, there is no cure for ataxia and supportive treatment to control the symptoms is necessary. This may include: medication to control muscle, bladder and eye problems; physiotherapy to help with coordination and enhance mobility; occupational therapy to help the patient cope with the activities of daily life (ADL) problems; speech and language therapy to help with speech and swallowing problems.

In a few cases, it is possible to improve ataxia or stop it getting worse by treating the underlying cause (Ilg, Synofzik, Brötz, Burkard, Giese, Schöls, 2009).

4. Case presentation

51 year old female with CA, with progressive development for a period of 7–8 months; the onset was 25 days after an acute COVID-19 infection (fever up to 38°C, headache, fatigue, myalgia

and arthralgia, without pneumonia). At the beginning, the patient suffered of vertigo, balance and gait instability, cramps in both legs. Upon entry in our clinic, she presented vertigo, balance and gait instability, dysarthria, dysmetria, dysdiadochokinesia, muscular cramps in both legs. Difficulties in gait in stable floor and upstairs.

Clinically diagnosed syndromes: static, locomotory and dynamic ataxia; central oto-neurological syndrome.

No significant deviations in the laboratory results.

Computer tomography (CT) and Magnetic resonance imagery (MRI) demonstrate cerebellar degeneration and cerebellar atrophy; supratentorially – in the right parieto-occipital region – presence of small hypodense zones in the subcortical white substance.

Auditory evoked potentials – without alteration of the auditory afferentation at the level of truncus cerebri.

Visual evoked potentials – without alteration of the visual afferentation.

Electroneurography and electromyography of lower extremities – normal values.

Otoneurological exam: positive Romberg, Central type of vertigo. Central oto-neurological syndrome.

We realized digitalized equilibrium assessment, using the Thyro Motion system, with Thymo platform. During the TYMO Balance test, we obtained oscillations at the center of pressure (CoP) and extended sway area, with considerable anterior-posterior displacement (Fig. 1 and Fig. 3). The instability increases on an unstable surface and after eye closure (Fig. 2 and Fig. 3). The CoP parameters with medio-lateral and antero-posterior displacements and deformation of the sway area are presented on Figures 3 and 4. Frequency analysis reported a Romberg index at 0.74.

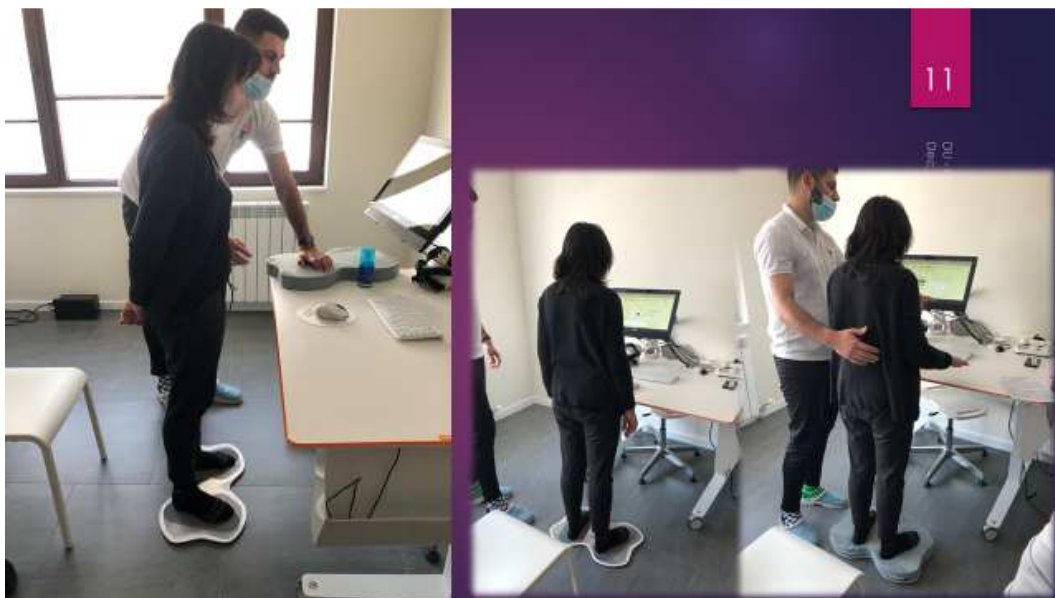


Fig. 1. Balance assessment on the Thymo-stable platform



Fig. 2. Balance assessment on the Thymo-unstable platform

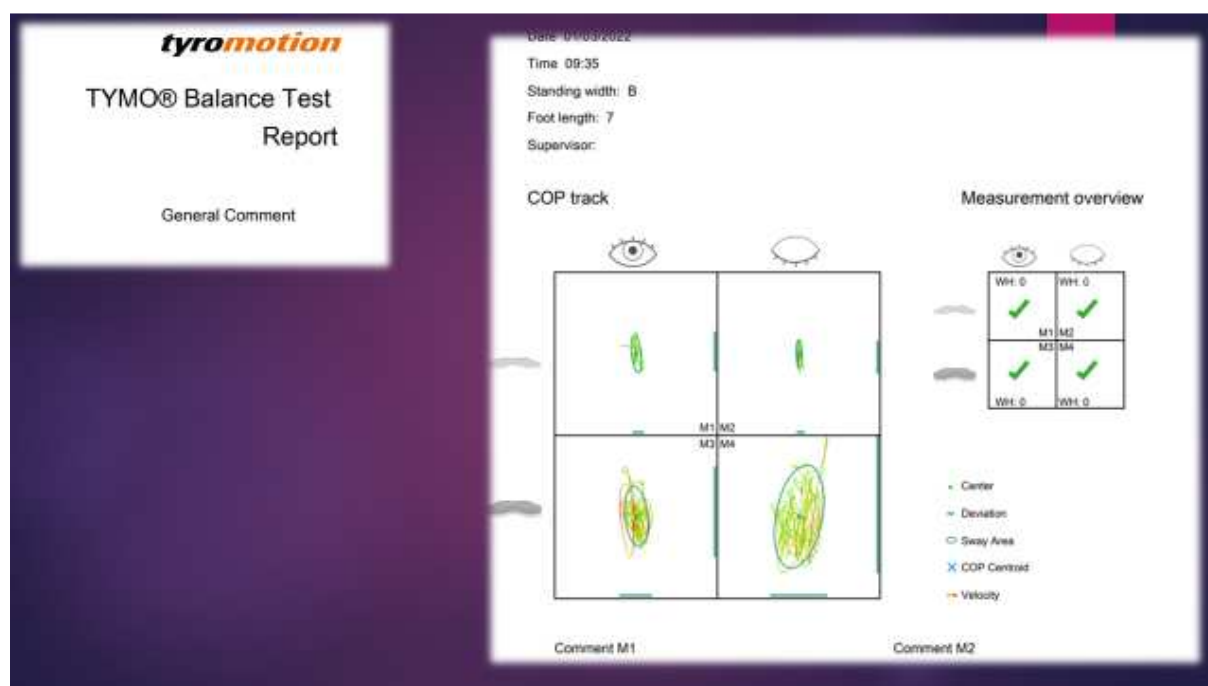


Fig. 3. Balance test report – oscillations of the center of pressure (CoP) – with open eyes and closed eyes, on stable and unstable platform

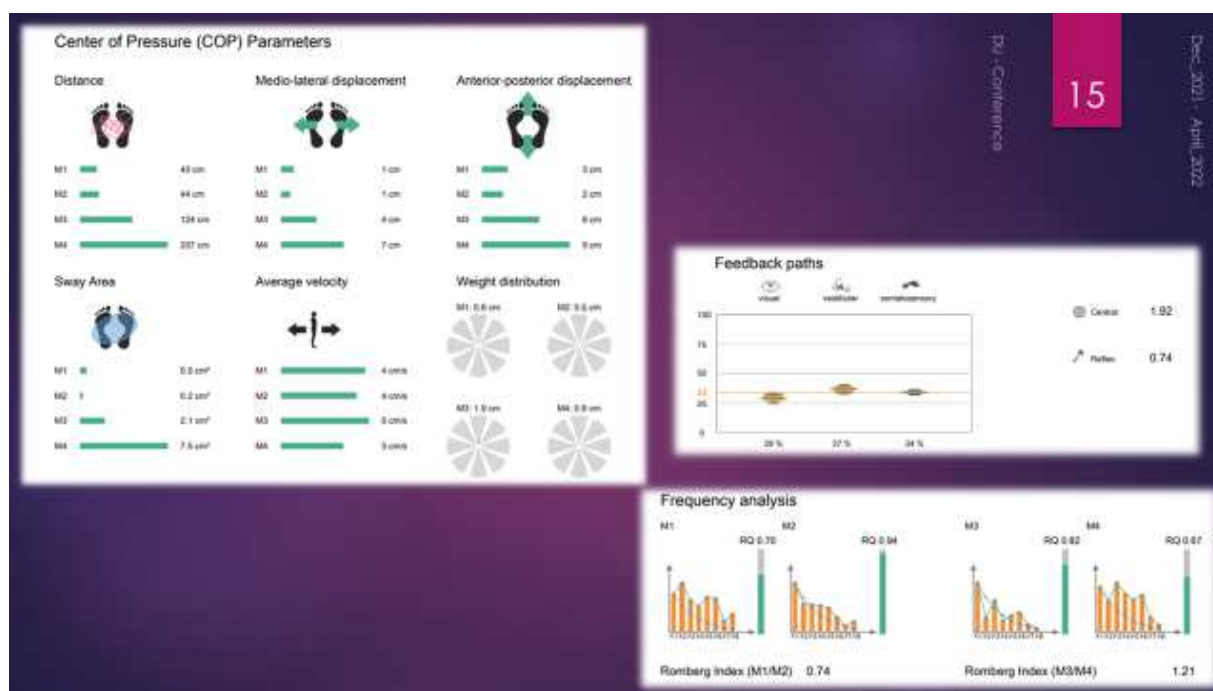


Fig. 4. Balance test report – center of pressure (CoP) parameters and Romberg index

The detailed digitalized evaluation of the equilibrium was the base for elaboration of a complex rehabilitation programme, emphasizing on balance, gait and coordination training; adapted to the clinical specificity of the concrete patient. We included physiotherapeutic and ergotherapeutic procedures, e.g.: balance training in sitting and in straight position; training of core-muscles; exercises on weight distribution with alternative weight transfer between both legs; balance training on stable and unstable platforms; gait training; coordination exercises for the whole-body (in different positions) and for extremities – with small objects, medical balls, Swiss ball and different gadgets. We included exercises for training of eye-hand coordination. We consider necessary neuro-muscular coordination exercises, as well as exercises for cerebellar coordination.

The complex neurorehabilitation (NR) programme was elaborated for a month, including physiotherapy, ergotherapy, electrical stimulations on muscles – ankle extensors (for stabilization of the feet), psychological intervention (for reaction time, for reactive depression and anxiety), training of abilities in activities of daily life. The coordinative training (of 15 sessions) was distributed for 3 times weekly.

5. Discussion and conclusion

Physical activity in adults has numerous benefits, including improvement of physical health and fall prevention (Poduri, 2017). Several practitioners recommend aerobic exercises, resistive exercises, flexibility exercises, physical fitness and balance training (McKeown, Crawford, 2017). Many authors consider that balance and coordination exercises can ameliorate motor performance in degenerative cerebellar disease.

Ilg, Synofzik, Brötz, Burkard, Giese and Schöls (2009) from the Departments of Cognitive Neurology, Hertie Institute for Clinical Brain Research and Center of Neurology in Tübingen (Germany) examined the effectiveness of a 4-week intensive coordinative training for 16 patients with progressive ataxia due to cerebellar degeneration (n = 10) or degeneration of afferent pathways (n = 6). As results they reported significant improvements in motor performance and reduction of ataxia symptoms were observed in clinical scores after training and were sustained at follow-up assessment. Patients with predominant cerebellar ataxia revealed more distinct improvement than patients with afferent ataxia in several aspects of gait like velocity, lateral sway, and intra-limb coordination. Consistently, in patients with cerebellar but without afferent ataxia, the regulation of balance in static and dynamic balance tasks improved significantly. Authors conclude that in patients with cerebellar ataxia, coordinative training improves motor performance and reduces ataxia symptoms, enabling them to achieve personally meaningful goals in everyday life. This study provides Class III evidence that coordinative training improves motor performance and reduces ataxia symptoms in patients with progressive cerebellar ataxia.

In conclusion, we must underline that multidisciplinary approach is necessary in cerebellar ataxia, due to the multitude of progressive motor and non-motor symptoms. Physical rehabilitation should be offered to all patients with ataxia. Continuous exercise programs have shown positive results. Coordination training improves motor performance and reduces ataxia symptoms in patients with progressive Cerebellar Ataxia. The digitalized equilibrium evaluation is useful for the elaboration of a complex rehabilitation programme, adapted to the individual patient with cerebellar ataxia.

References

- Benussi A., Cantoni V., Manes M. et al. 2021. Motor and cognitive outcomes of cerebello-spinal stimulation in neurodegenerative ataxia. *Brain*; 144: 2310.
- de Bot S.T., Willemsen M.A., Vermeer S. et al. 2012. Reviewing the genetic causes of spastic-ataxias. *Neurology*; 79: 1507.
- Fogel B.L., Perlman S. 2006. An approach to the patient with late-onset cerebellar ataxia. *Nature Clinical Practice Neurology*; 2 (11): pp. 629–635.
- Grimaldi G., Manto M. 2012. Topography of cerebellar deficits in humans. *Cerebellum*; 11: 336.
- Ilg W., Synofzik M., Brötz D., Burkard S., Giese M.A., Schöls L. 2009. Intensive coordinative training improves motor performance in degenerative cerebellar disease. *Neurology*; 73(22): 1823.
- Manto M. 2009. Mechanisms of human cerebellar dysmetria: experimental evidence and current conceptual bases. *J Neuroeng Rehabil*; 6: 10.
- McKeown C.B., Crawford P. Movement Disorders. – In: Paulman P.M., Taylor R.B. Editors. 2017. Family Medicine: Principles and Practice. Seventh Edition. New York: Springer–Verlag, pp. 851–860.
- Poduri K.R. 2017. Geriatric Rehabilitation: from Bedside to Curbside. – Boca Raton – London – New York: CRC Press, Taylor and Francis Group, 713 pp.
- Timmann D, Diener HC. 2007. Coordination and ataxia. In: *Textbook of Clinical Neurology*, 3rd ed., Goetz C. (Ed.), Saunders, p. 307.
- Winchester S., Singh P.K., Mikati M.A. 2013. Ataxia. *Handb Clin Neurol*; 112: 1213.

IS PROLONGED PREOPERATIVE ANTIMICROBIAL PROPHYLAXIS AFTER MAJOR LOWER EXTREMITY AMPUTATION NECESSARY? A FOUR-YEAR SINGLE INSTITUTION TRIAL

Matīss Dravnieks¹, Asoc. prof. Arnolds Jezupovs^{1,2}

¹University of Latvia, Raiņa bulvāris 15, Rīga, Latvia, dravnieks.matiss@gmail.com, arnolds.jezupovs@lu.lv

²Riga East Clinical University Hospital, Rīga, Latvia

Abstract

**Is prolonged preoperative antimicrobial prophylaxis after major lower extremity amputation necessary?
A four-year single institution trial**

Key Words: preoperative antimicrobial prophylaxis, cefazoline, major lower extremity amputation, peripheral artery disease, gangrene

Introduction: Surgical site infection (SSI) is one of the leading surgical complications. SSI increases hospital stay and mortality. SSI is preventable with preoperative antibiotic prophylaxis. There is an ongoing discussion about prolonged preoperative antimicrobial prophylaxis for certain types of surgery.

Objective: Compare 7-day cefazoline (cef.) treatment plan vs cef. one day preoperative prophylaxis in preventing SSI and systemic infection after major lower extremity amputation.

Methods and materials: Trial was conducted in Riga East clinical university hospital from 2018 to 2022. Before major lower extremity amputation patients were randomly assigned to one of the two study groups. Prophylaxis group received 1 dose cef. preoperatively. 7-day treatment plan received preoperative dose and additionally two doses for next 6 days. Data was acquired about infection risk factors. Pearson Chi square, logistical regression and Mantel-Haenszel test was used for data analysis. Level of statistical significance: $p < 0.05$. Data analysis performed with IBM SPSS 23.

Results: 191 patients admitted to study. Average age: 77 y. (SD \pm 9.8). 22 patients were excluded. Prophylaxis group had 81 patients, seven-day course group had 88. Pearson Chi square test found no statistical significance between treatment group and SSI ($p = 0.2$). Amputation stump hematoma or trauma had a greater chance of SSI ($p = 0.048$, OR = 4.4, 95% CI = 1-16.9). Mantel-Haenszel test found no significance between age and SSI ($p = 0.2$) or systemic infection ($p = 0.8$) and risk factors (≤ 1 un ≥ 2 risk factors) and SSI ($p = 0.1$) or systemic infection ($p = 0.8$).

Conclusion: In lower limb amputation antibiotic prophylaxis is not inferior to prolonged antibiotic treatment.

Kopsavilkums

**Vai paildzināta preoperatīva antimikrobiālā profilakse ir nepieciešama
pēc apakšējās ekstremitātes amputācijas?**

Atslēgvārdi: preoperatīva antimikrobiālā profilakse, cefazolīns, apakšējo ekstremitāšu amputācija, perifēro artēriju slimība, gangrēna

Ievads: Eiropā ķirurģiskā brūces infekcija (ĶBI) veido lielu daļu no ķirurģisko pacientu pēcoperācijas komplikācijām. ĶBI pagarina pacientu stacionēšanās laiku un palielina nepieciešamību pēc papildus ķirurģiskas iejaukšanās. Preoperatīvā antibiotiku profilakse (PAP) novērš ĶBI. Pastāv diskusija par pagarinātas PAP izmantošanu dažādās ķirurģiskās operācijās.

Mērķis: Izvērtēt cefazolīna (cef.) septiņu dienu kursa plānu un cefazolīna vienas dienas preoperatīvās prevencijas plānu lokālu un sistēmisku infekciju prevencijā pacientiem pēc aterosklerotiskās gangrēnas kājas amputācijas.

Metodes: Pētījums veikts Rīgas Austrumu klīniskās universitātes slimnīcā no 2018. gada līdz 2022. gadam. Pirms apakšējās ekstremitātes amputācijas pacienti tika iekļauti vienā no divām pētījumu grupām. Profilakses grupa saņēma 1 cef. preoperatīvu devu. 7-dienu ārstēšanas plāna grupa saņēma vēl papildus divas devas nākamās 6 dienas. Tika ievākti dati par infekcijas riska faktoriem. Datu analīzei izmantots Pīrsona Hī kvadrāta tests, loģistiskā regresija un Mantela-Henzela tests. Būtiskuma līmenis izvēlēts $p < 0,05$. Datu analīze veikta ar IBM SPSS 22.

Rezultāti: Pētījumā piedalījās 191 pacients, vidējais vecums 77 gadi (SD \pm 9.8). No pētījuma izslēdza 22 pacientus. Cefazolīna profilakses grupā bija 81 pacients, cefazolīna ārstēšanas grupā bija 88 pacienti. Izmantojot Pīrsona Hī kvadrāta testu neapstiprinājās statistiski ticama saistība starp cefazolīna 7 dienu kursu un ĶBI ($p = 0.2$). Amputācijas stumbra hematoma vai trauma ir saistīta ar lokālu infekciju ($p = 0.048$, OR = 4.4, 95% CI = 1-16.9). Mantela-Henzela tests neatrada statistiski ticamu asociāciju starp vecumu un ĶBI ($p = 0.2$) vai sistēmisku infekciju ($p = 0.8$), starp amputācijas veidu (transtibiāla un transfemorāla amputācija) un ĶBI ($p = 0.22$) vai sistēmisku infekciju ($p = 0.77$), starp infekcijas riska faktoru skaita (≤ 1 un ≥ 2 infekcijas riska faktori) un ĶBI ($p = 0.1$) vai sistēmisku infekciju ($p = 0.8$).

Secinājums: Cefazolīna pagarināts 7 dienu kurss nav pārāks par cefazolīna profilakses kursu brūces infekcijas prevencijā.

Introduction

Surgical site infection (SSI) is third most frequent intrahospital infection. SSI increases hospital stay and increases chance of additional surgical intervention. According to ECDC from all intrahospital infections SSI is ranked third (ECDC 2013). SSI is preventable with preoperative antibiotic prophylaxis (PAP). It is an important part of modern surgery. Correct type, dosage and timing prevents SSI (Bowater et al. 2009). Unnecessary and prolonged PAP increases chance of antimicrobial resistance. It is an important and global public health concern. According to ECDC data yearly epidemiological report on antimicrobial resistance in Europe – Baltic region had higher rates of antimicrobial resistance than average in Europe (ECDC 2019). Almost 15 percent of all used antibiotics in hospital are for preoperative antimicrobial prophylaxis (Ansari et al. 2009). There is discussion whether implement prolonged preoperative antimicrobial prophylaxis for certain types of surgery.

Throughout 1950s and 1960s PAP was prescribed at prolonged courses globally – seven to eight days (Nichols et al. 2005). In the following years prolonged PAP showed no reduction at SSI rate (McDonald et al. 1998). Benefits have been observed in patients for elective hip endoprosthesis surgery (Engesaeter et al. 2003). Study on cardiovascular surgery had different findings. Prolonged PAP didn't reduce SSI rate, but raised the chance for infection of multiresistant bacteria (Harbarth et al. 2000). European multicenter study performed in 2006 observed that 60 percent of surgery patients receive prolonged antimicrobial preoperative prophylaxis longer than 24 hours (Ansari et al. 2009). The goal of the study is to evaluate cefazoline seven-day plan vs cefazoline one day preoperative antimicrobial prophylaxis at reducing postoperative local and systemic infection rate in patients after major lower leg amputation due to atherosclerotic gangrene.

Material and methods

Study was done in Riga East clinical university hospital from 2018. to 2022. Study is accepted in University of Latvia “Kardioloģijas un reģeneratīvās Medicīnas institūta zinātniskās izpētes” Ethical committee. Patients were introduced to study methods, its goals, duration, risks and gains. Study organizers replied to patients' questions. Patients were informed that they may quit the trial at any time. Study design: prospective, randomized trial.

Patients were enrolled in the study according to following criteria:

- Patient gives informed consent to the study,
- Age 18–95 years old,
- No data for an active infection,
- Patient has indications for major lower extremity amputation due to gangrene caused by peripheral artery disease.

Patients were excluded from the study if:

- Patient declines to take part or study or is unable give an informed consent,
- Patient is allergic to cephalosporin group antibiotics,
- Recently (less than two weeks) received antimicrobial therapy,
- Has postoperative amputation necrosis due to ischemia (inadequate blood flow to the amputation stump).

After confirming their participation in the study patients were randomly assigned to one of the two study groups. Randomization was done by giving participants even or uneven number therefore maintaining group ratio 1:1. Patients with even number were assigned to cefazoline prophylaxis group. Patients with uneven number were assigned to prolonger cefazoline prophylaxis. Cefazoline prophylaxis group (cef. pr. gr.) group received 2 g cefazoline intravenously 30 to 45 minutes before operation. Cefazoline treatment (cef. tr. gr.) group patients received cefazoline 2 g intravenously 30 to 45 minutes before operation and continued receiving cephalosporin 4 g per day for next 6 days.

Data was acquired about patient duration of hospitalization, recent use of antibiotics, hyperglycemia, hemotransfusion, anemia, amputation stump hematoma/seroma, MSSA/MRSA material in patients' nasal material, use of immunosuppressive drugs, local infection and systemic infection. Pearson-Chi square test was used to identify association between study groups and the outcomes. Logistical regression was used to estimate other factor influence. Mantel-Haenszel test analyzed association between local and systemic infection rates in different patients with different age and amount infection of risk factors. Study significance set at $p < 0.05$. Data analysis performed using IBM SPSS 22.

Results

191 patients admitted to study. Average age: 77 y. (SD \pm 9.8). 22 patients were excluded. Prophylaxis group had 81 patients, seven-day course group had 88 (see Table No 1).

Table No. 1. Patient demographical data, type of amputation, average hospital stay, local and systemic infection cases in study group

	Cef. prof. gr. (n = 81)	Cef. treatm. gr. (n = 88)
Average age	76,9 SD \pm 9,8	77,4 SD \pm 9,6
Gender: male/female	56/25	34/54
Amputation level: crural/femoral	14/67	16/71
Local	6 (7.4%)	4 (4.5%)
Systemic infection	8 (9.8%)	10 (11.3%)
Average hospitalization stay (days)	17,4	18,3

Study had 10 cases of SSI and 18 cases of systemic infection. 6 SSI and 8 systemic infection cases were in cefazoline prophylaxis group (see Fig. 1 and Fig. 2). 4 SSI cases and 10 systemic infection cases were in cefazoline treatment group. Despite prolonged hospital stay in cefazoline prolonged treatment plan group both study groups had similar systemic infection case proportion. Both groups have similar ratio between surgery amputation levels. In both groups more than a half of the patients spent more than three days in hospital before surgery. In both groups more than a third of patients had type 2 diabetes. Hyperglycemia was observed 13 patients in prophylaxis group and 14 patients in treatment group. Almost half of patients in both study groups had anemia. Hemotransfusion was done for 6 patients in each of the study groups (see Table No. 2).

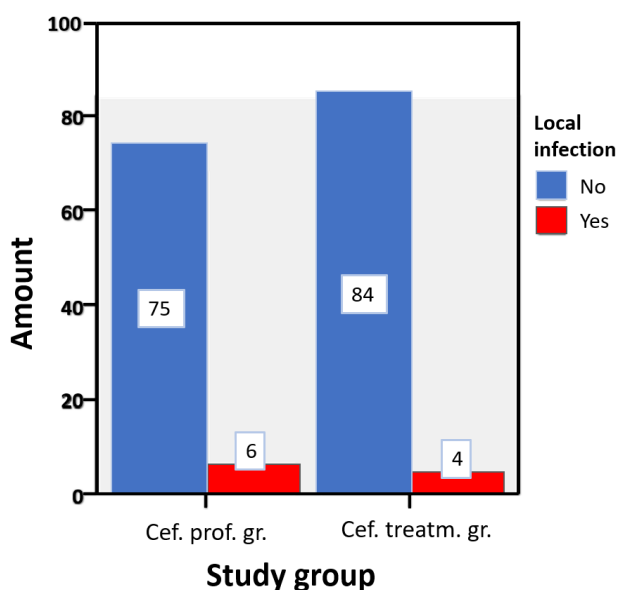


Figure 1. SSI count in study groups

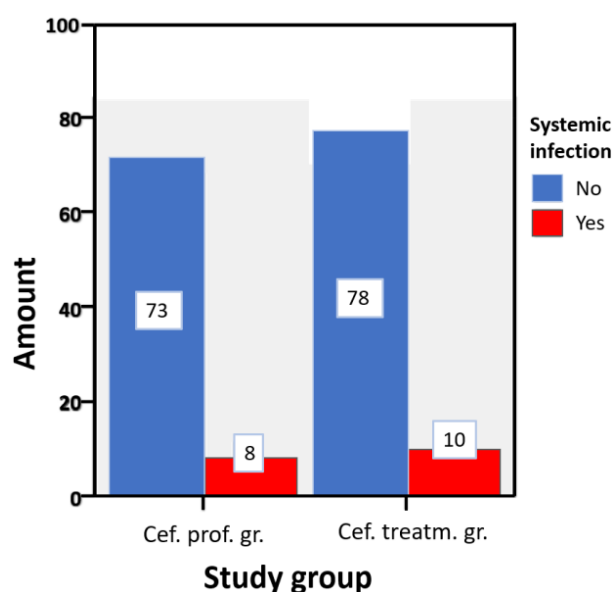


Figure 2. Systemic infection difference in study groups

Table No. 2. Infection risk factors between study groups

	Cef. prof. gr. (n = 81)	Cef. treatm. gr. (n = 88)
Patients has been hospitalized during last three months	32	33
>3 days in hospital before surgery	43	57
Hyperglycemia	13	14
Hemotransfusion	6	6
Anemia	35	40
Amputation stump trauma, seroma or hematoma	9	10
MSSA or MRSA enucleation in patient's nasal material	19	20
Cardiovascular disease	60	69
Chronic renal disease	11	17
Diabetes	29	31

Pearson Chi square test found no statistical significance between treatment group and SSI ($p = 0.2$). Same test didn't find statistical significance between duration of cefazoline use and systemic infections. Amputation stump hematoma or trauma had a greater chance for SSI ($p = 0.048$, OR = 4.4, 95% CI = 1-17.9). Staying in hospital more than 3 days before surgery was associated with a higher chance for systemic infection ($p = 0.01$, OR = 5.4, 95% CI = 1.5-20; $p = 0.02$, OR = 12.3, 95% CI = 1.6-88). Mantel-Haenszel test found no significance between age and SSI ($p = 0.2$) or systemic infection ($p = 0.8$) and risk factors (≤ 1 un ≥ 2 risk factors) and SSI ($p = 0.1$) or systemic infection ($p = 0.8$).

Discussion

Pearson-Chi statistical analysis found a statistically insignificant difference between prolonged use of cefazolin and local or systemic infection. Stratifying patients by age, amputation type and amount of infection risk factors. In patients with amputation stump hematoma, seroma or trauma logistical regression found an increased chance of local infection. Because the odds ratio had a wide confidence interval it may only be considered as a tendency. Staying in hospital more than three days before surgery or receiving hemotransfusion increased the chance of systemic infection. Tough study analyzed multiple risk factors, peripheral artery disease itself is an infection risk factor.

Despite patients receiving different doses of cefazoline there was not a difference in systemic infection between the study groups.

Postoperative infection is a significant burden in global healthcare. It increases hospital stay length and mortality. According to World Health Organization the amount of surgical manipulations increases by the year (Weiser et al. 2016). Rise of global antibiotic use and following antimicrobial resistance is expected. There is scarce data on amputations due to peripheral artery disease and postoperative antimicrobial prophylaxis (McIntosh et al. 2009). Therefore, infection risk factor identification and infection prevention in peripheral artery disease patients after major lower extremity amputation is perspective and necessary future study field.

Conclusions

1. Study hypothesis was confirmed: in preventing postoperative infections cefazoline seven-day course is not superior to cefazoline as one day preoperative antimicrobial prophylaxis.
2. Amputation stump trauma, hematoma or seroma increases local infection risk.
3. Patients receiving hemotransfusion or staying more than three days in hospital before surgery increased systemic infection risk.
4. Stratifying patients according to age, amputation type and amount of infection risk factors no statistically significant association was found between prolonged cefazoline use and SSI or systemic infection.

5. The study may be prone to type II error due to limited amount of study subjects. To reach necessary statistical power the study ought to be continued.

Acknowledgments and Disclosure Statements

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors have no conflicts to disclose.

References

- Ansari, F., Erntell, M., Goossens, H., & Davey, P. (2009). The European surveillance of antimicrobial consumption (ESAC) point-prevalence survey of antibacterial use in 20 European hospitals in 2006. *Clin Infect Dis*, 49(10), 1496–1504. <https://doi.org/10.1086/644617>
- Bowater, R. J., Stirling, S. A., & Lilford, R. J. (2009). Is antibiotic prophylaxis in surgery a generally effective intervention? Testing a generic hypothesis over a set of meta-analyses. *Ann Surg*, 249(4), 551–556. <https://doi.org/10.1097/SLA.0b013e318199f202>
- ECDC (2013). Systematic review and evidence-based guidance on perioperative antibiotic prophylaxis. Technical report, 2013. <https://www.ecdc.europa.eu/sites/portal/files/media/en/publications/Publications/Perioperative%20antibiotic%20prophylaxis%20-%20June%202013.pdf>
- ECDC (2019). Antimicrobial resistance in the EU/EEA (EARS-Net). Annual Epidemiological Report for 2019. <https://www.ecdc.europa.eu/sites/default/files/documents/surveillance-antimicrobial-resistance-Europe-2019.pdf>
- Engesaeter, L. B., Lie, S. A., Espehaug, B., Furnes, O., Vollset, S. E., & Havelin, L. I. (2003). Antibiotic prophylaxis in total hip arthroplasty: effects of antibiotic prophylaxis systemically and in bone cement on the revision rate of 22,170 primary hip replacements followed 0–14 years in the Norwegian Arthroplasty Register. *Acta Orthop Scand*, 74(6), 644–651. <https://doi.org/10.1080/00016470310018135>
- Harbarth, S., Samore, M. H., Lichtenberg, D., & Carmeli, Y. (2000). Prolonged antibiotic prophylaxis after cardiovascular surgery and its effect on surgical site infections and antimicrobial resistance. *Circulation*, 101(25), 2916–2921. <https://doi.org/10.1161/01.cir.101.25.2916>
- McDonald, M., Grabsch, E., Marshall, C., & Forbes, A. (1998). Single- versus multiple-dose antimicrobial prophylaxis for major surgery: a systematic review. *Aust N Z J Surg*, 68(6), 388–396. <https://doi.org/10.1111/j.1445-2197.1998.tb04785.x>
- McIntosh, J., & Earnshaw, J. J. (2009). Antibiotic Prophylaxis for the Prevention of Infection after Major Limb Amputation. *European Journal of Vascular and Endovascular Surgery*, 37(6), 696–703. <https://doi.org/doi:10.1016/j.ejvs.2009.01.013>
- Nichols, R. L., Condon, R. E., & Barie, P. S. (2005). Antibiotic Prophylaxis in Surgery – 2005 and Beyond. *Surgical Infections*, 6(3), 349–361. <https://doi.org/10.1089/sur.2005.6.349>
- Weiser, T., Haynes, A., & Molina, G. (2016). Bulletin of the World Health Organization. Size and distribution of the global volume of surgery in 2012. <http://dx.doi.org/10.2471/BLT.15.159293>

IMPACT OF A COSMETIC PRODUCT CONTAINING DRACOCEPHALUM RUYSCHIANA EXTRACT ON BIOPHYSICAL PARAMETERS OF THE SKIN

Agnese Ričika¹, Aleksejs Zavorins², Anna Ramata-Stunda³

¹Rīga Stradins University, Faculty of Medicine, Dzirciema street 16, Rīga,
richika.agnese@gmail.com

²Rīga Stradins University, Department of Dermatology and Venereology, Baznīcas street 18, Rīga,
aleksejs.zavorins@gmail.com

³SIA Alternative Plants, Podraga street 2, Rīga, anna.ramata-stunda@lu.lv

Abstract

Impact of a cosmetic product containing *Dracocephalum ruyschiana* extract on biophysical parameters of the skin

Key Words: dermatology, hydration, *Dracocephalum ruyschiana*

Introduction. Skin changes with age, it produces less collagen, elastin and hyaluronic acid, loses elasticity, becomes drier and these changes can affect the quality of life. *Dracocephalum ruyschiana* callus culture extract has demonstrated in studies (in vitro) that it promotes the proliferation of keratinocytes and dermal fibroblasts, stimulates collagen synthesis and inhibits its degradation, protects the skin from ultraviolet radiation induced oxidative stress, inhibits endothelial cell proliferation and neoangiogenesis.

Materials and methods. Participants (n = 42) were asked to apply two test products on a clean facial skin twice a day. The test products were marked – one for the left side of the face and the other one for the right side of the face. Only one of both cosmetic products contained *Dracocephalum ruyschiana* extract, participants did not know which one of the both products contains a plant extract. Instrumental assessment of hydration, viscoelasticity (R2, R5, R7), pigmentation and erythema parameters were made using Corneometer CM 825, Cutometer dual MPA580 and Mexameter MX18 (Courage + Khazaka GmbH, Germany). Parameters were evaluated three times: before using cosmetic products (day 0) and after 4 and 8 weeks of regular everyday use of the test products. Six measurements were made during each visit: three on the participant's right cheek and three on the left cheek to determine skin hydration, viscoelasticity, pigmentation and erythema parameters. The assessment also included standardized photography during each visit using Reveal Imager. At the end of the study, participants answered written questions about the cosmetic products and its effectiveness. Independent and paired sample T-test was used for analyzing collected data. P value < 0,05 was considered statistically significant.

Results. Statistically significant increase in the skin hydration level was observed on the left side of the facial skin in the start of the study (day 0) (46,52, SD = 9,61) compared to the hydration level after 8 weeks (55,75, SD = 10,99), p = 0,000107. Statistically significant increase in the skin melanin level was observed on the both sides of the participants facial skin – on the left side in the start of the study (day 0) (137,61, SD = 25,50) compared to the melanin level after 8 weeks (153,10, SD = 34,67), p = 0,001335 and on the right side of the facial skin in the start of the study (day 0) (137,76, SD = 23,96) compared to the melanin level after 8 weeks (156,64, SD = 34,05), p = 0,000643. The increase in the skin melanin level was explained by the summer season when the measurements were made.

Conclusions: Everyday use of cosmetic product containing *Dracocephalum ruyschiana* extract leads to improvement in hydration level of the skin.

Kopsavilkums

Kosmētiskā līdzekļa, kas satur *Dracocephalum ruyschiana* ekstraktu, ietekme uz ādas biofizikāliem parametriem

Atslēgvārdi: dermatoloģija, hidratācija, *Dracocephalum ruyschiana*

Ievads. Āda mainās līdz ar vecumu, tā sintezē mazāk kolagēna, elastīna un hialuronskābes, zaudē elastību, kļūst sausāka un šīs izmaiņas var ietekmēt dzīves kvalitāti. *Dracocephalum ruyschiana* kallusu kultūras ekstrakts pētījumos (in vitro) ir pierādījis, ka tas veicina keratinocītu un dermālo fibroblastu proliferāciju, stimulē kolagēna produkciju un kavē tā noārdīšanos, pasargā ādu no ultravioletā starojuma inducēta oksidatīvā stresa, kavē endoteliocītu proliferāciju un neoangiogēzi.

Materiāli un metodes. Dalībniekiem (n = 42) tika lūgts divas reizes dienā uz tīras sejas ādas uzklāt divus testa produktus. Testa produkti tika marķēti – viens sejas kreisajai pusei, otrs – labajai sejas pusei. Tikai viens no abiem kosmētikas līdzekļiem saturēja *Dracocephalum ruyschiana* ekstraktu, un dalībnieki nezināja, kurš no abiem produktiem satur auga ekstraktu. Instrumentālais hidratācijas, viskoelastitātes (R2, R5, R7), pigmentācijas un eritēmas parametru novērtējums tika veikts, izmantojot Corneometer CM 825, Cutometer dual MPA580 un Mexameter MX18 (Courage + Khazaka GmbH, Vācija). Parametri tika vērtēti trīs reizes: pirms kosmētikas līdzekļu lietošanas (0. diena) un pēc 4 un 8 nedēļu regulāras testa produktu lietošanas katru dienu. Katras vizītes laikā tika veikti seši mērījumi: trīs uz dalībnieka

labā vaiga un trīs uz kreisā vaiga, lai noteiktu ādas hidratācijas pakāpi, viskoelasticitātes, pigmentācijas un eritēmas parametrus. Novērtējumā tika iekļauta arī standartizēta fotogrāfēšana katra apmeklējuma laikā, izmantojot Reveal Imager. Pētījuma beigās dalībnieki atbildēja uz rakstiskiem jautājumiem par kosmētikas līdzekļu efektivitāti. Datu analīzei tika izmantoti neatkarīgo un atkarīgo izlašu T-testi. P vērtība $< 0,05$ tika uzskatīta par statistiski ticamu.

Rezultāti. Statistiski nozīmīgs hidratācijas līmeņa pieaugums tika novērots sejas ādas kreisajā pusē pētījuma sākumā (0. diena) (46,52, SD = 9,61), salīdzinot ar hidratācijas līmeni pēc 8 nedēļām (55,75, SD = 10,99), $p = 0,000107$. Statistiski nozīmīgs ādas melanīna līmeņa pieaugums dalībniekiem tika novērots abās sejas pusēs – kreisajā pusē pētījuma sākumā (0. diena) (137,61, SD = 25,50), salīdzinot ar melanīna līmeni pēc 8 nedēļām (153,10, SD = 34,67), $p = 0,001335$ un sejas ādas labajā pusē pētījuma sākumā (0. diena) (137,76, SD = 23,96), salīdzinot ar melanīna līmeni pēc 8 nedēļām (156,64, SD = 34,05), $p = 0,000643$. Ādas melanīna līmeņa pieaugums tika skaidrots ar vasaras sezonu, kurā tika veikti mērījumi.

Secinājumi: Dracocephalum ruyschiana ekstraktu saturoša kosmētikas līdzekļa lietošana ikdienā uzlabo ādas hidratācijas pakāpi.

Introduction

The normal aging process of the skin leads to atrophy, decreased elasticity, and impaired metabolic and reparative responses. The epidermis becomes thinner, and the dermoepidermal junction flattens, resulting in increased fragility of the skin (Taffet, 2021). Skin is also affected by photoaging, also called extrinsic aging, that is premature skin aging resulting from prolonged and repeated exposure to solar radiation. The changes of photodamage are responsible for most of the age-associated features of skin appearance and include fine and coarse wrinkles, dyspigmentation, and loss of elasticity. Facial photoaging and skin aging signs impact quality of life and self-esteem. Photodamage can be partially prevented and reversed with proper sun protection and prescription medications, cosmeceuticals and cosmetic procedures (Chien, Kang et al. 2022).

The term “cosmeceuticals” refers to a nonprescription topical products, including antioxidants, vitamins, retinoids, hydroxyacids, and plant extracts, that may have some activity in the treatment of photoaging. Cosmeceuticals are popular ingredients of a wide range of cosmetic products. However, there is limited evidence from clinical studies to suggest that they are beneficial or that one particular preparation is better than another (Chien, Kang et al. 2022).

Dracocephalum ruyschiana, commonly known as dragonhead, is a clump-forming herbaceous perennial of the mint family and it is native to montane grasslands from central Europe to Siberia. Plants from genus Dracocephalum are used in traditional medicine and are valuable sources of biologically active polyphenolic compounds for cosmetic, food and medical industry. However, availability and consistency of plant material remains challenging (Kaktiņa, Silamiķele, Ramata-Stunda et al. 2019; Razgonova, Okhlopkona, Golokhvas, 2022).

Dracocephalum ruyschiana callus culture extract has demonstrated in studies (in vitro) that it is capable to boost proliferation of dermal fibroblasts and keratinocytes, stimulates collagen synthesis and inhibits its degradation, protects the skin from ultraviolet radiation induced oxidative stress, inhibits endothelial cell proliferation and neoangiogenesis. Results indicate the potential application of Dracocephalum ruyschiana cell biomass extracts in production of skin protecting, regenerating and anti-angiogenic products (Kaktiņa, Silamiķele, Ramata-Stunda et al., 2019).

An extract of plant has showed in vitro study that it inhibits mushroom and cellular tyrosinase activity showing that it can be used as whitening agent but has not proved significant effect on melanin concentration and gene expression in melanoma cells (Kaktiņa, 2016).

Therefore, the goal of this study is to evaluate the effects of a cosmetic product containing *Dracocephalum ruyschiana* callus culture extract on the skin hydration, viscoelasticity parameters, erythema and pigmentation.

Materials and Methods

The research was approved by Riga Stradins University Ethics Committee and the study was conducted in accordance with the Declaration of Helsinki. A safety assessment has been performed for the cosmetic product.

Before start of the study participants received all relevant information about the course of the study, possible side effects, the expected benefits and the possibility to voluntarily terminate participation in the study at any time without any consequences. Participant also signed an informed consent form.

In the study participated 42 adults (35 years and older). Exclusion criteria were:

- Individual intolerance or allergy to substances in a cosmetic product;
- Local infection or other manifestations of the inflammatory process on the facial skin, such as reactivation of the herpes simplex virus, impetigo, psoriasis, rosacea;
- Fractional or full field laser ablation of the facial skin, radiofrequency procedure, deep or medium deep chemical peeling, correction of acne scars with fillers during the last 6 months;
- Superficial chemical peeling, microneedling, mesotherapy or biorevitalization in the last 4 weeks;
- Phototype III–VI of skin or tan resulting from sun exposure or other ultraviolet radiation in the last 4 weeks;
- Pregnancy or lactation.

Participants were included in the study by a certified dermatologist based on the inclusion and exclusion criteria.

Participants (n = 42) were asked to apply two test products on a clean facial skin twice a day. The test products were marked – one for the left side of the face and the other one for the right side of the face. Only one of both cosmetic products contained *Dracocephalum ruyschiana* extract, participants did not know which one of both products contains a plant extract.

Instrumental assessment of hydration, viscoelasticity (R2, R5, R7), pigmentation and erythema parameters were made using 3 probes: Corneometer CM 825, Cutometer dual MPA580 and Mexameter MX18 (Courage + Khazaka GmbH, Germany).

Parameters were evaluated three times: before using cosmetic products (day 0) and after 4 and 8 weeks of regular everyday use of the test products. Six measurements were made during each visit: three on the participant's right cheek and three on the left cheek to determine skin hydration, viscoelasticity, pigmentation and erythema parameters. The assessment also included standardized photography during each visit using Reveal Imager. At the end of the study, participants answered written questions about the cosmetic products and its effectiveness.

Independent and paired sample T-test was used for analyzing collected data. P value < 0,05 was considered statistically significant.

Results

Statistically significant increase in the skin hydration level was observed on the left side of the facial skin in the start of the study (day 0) (46,52, SD = 9,61) compared to the hydration level after 8 weeks (55,75, SD = 10,99), $p = 0,000107$. Statistically significant increase in the skin melanin level was observed on the both sides of the participants facial skin – on the left side in the start of the study (day 0) (137,61, SD = 25,50) compared to the melanin level after 8 weeks (153,10, SD = 34,67), $p = 0,001335$ and on the right side of the facial skin in the start of the study (day 0) (137,76, SD = 23,96) compared to the melanin level after 8 weeks (156,64, SD = 34,05), $p = 0,000643$.

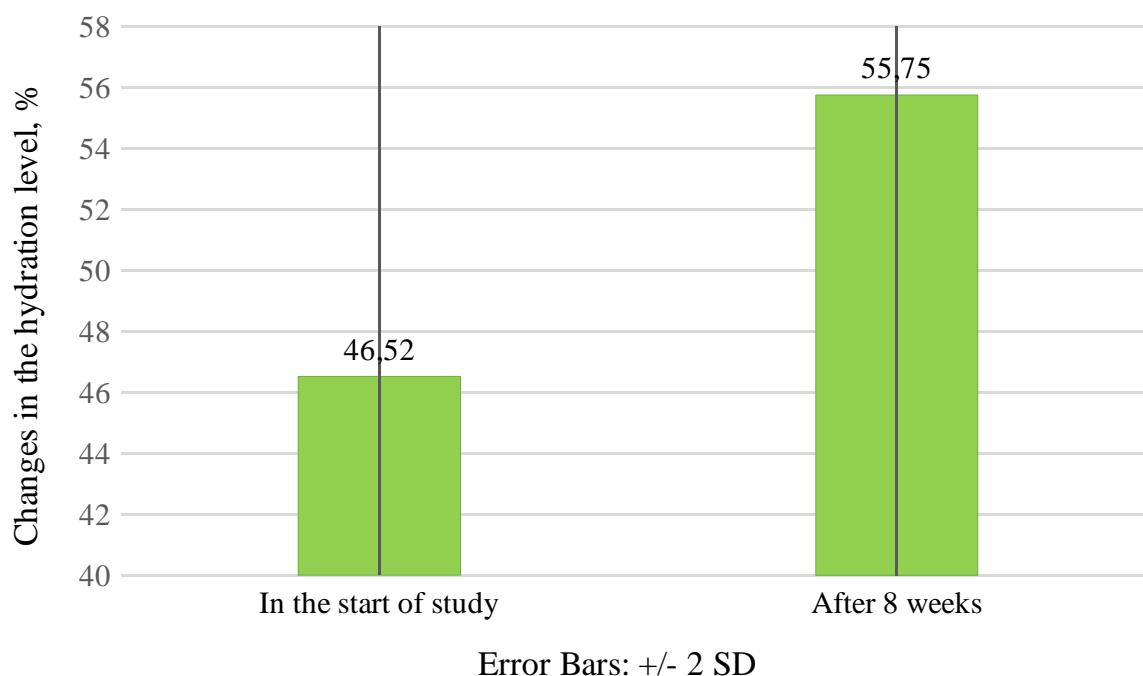


Figure 1. **Percentage changes of the hydration level on the left side of the facial skin in the start of study and after 8 weeks**

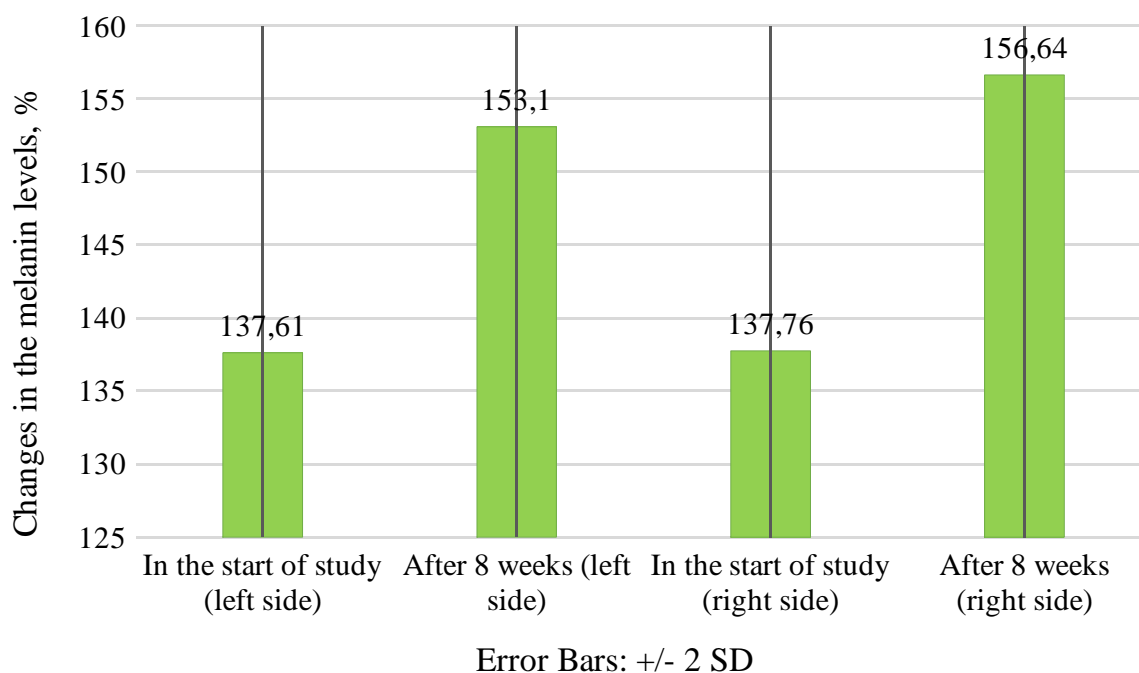


Figure 2. **Percentage changes of the melanin level on the left and the right side of the facial skin in the start of study and after 8 weeks**

Discussion

In vitro studies of plant extract indicate the potential application of *Dracocephalum ruyschiana* cell biomass extracts in production of skin protecting, regenerating and anti-angiogenic products (Kaktiņa, Silamiķele, Ramata-Stunda et al., 2019).

Instrumental assessment of hydration, viscoelasticity (R2, R5, R7), pigmentation and erythema were measured during the study in the first visit (day 0), after 4 weeks and 8 weeks using Corneometer CM 825, Cutometer dual MPA580 and Mexameter MX18 (Courage + Khazaka GmbH, Germany). Statistically significant improvement was observed in skin hydration level on the left side of the facial skin – the side where participants applied cosmetic product that contained *Dracocephalum ruyschiana* extract.

Other studies use similar methods to determine plant effects on the skin. One study used cream formulation containing 10% of *Aloe barbadensis* leaf extract to determine its effects on skin hydration and barrier function by the measurement of transepidermal water loss (TEWL), derma firmness, and elasticity. To detect biophysical parameters this study also used Corneometer and Cutometer. Study showed that *Aloe barbadensis* cream improves skin barrier function, increases moisture level, and enhances skin elasticity more than a placebo cream (Laneri S, Di Lorenzo RM et al. 2020).

Statistically significant increase in the skin melanin level was observed on both sides of the participant’s facial skin. The results were explained by the summer season when the measurements were made. In order to obtain more precise data repeating research also in winter season when there

is less ultraviolet exposure would be advised. Erythema values could also be affected by summer season and intense sunlight which can cause sunburn, especially in participants with skin phototype I and II (by Fitzpatrick scale). Participants also would only benefit from it, as complaints of dry skin are common during the cold months of the year.

Another research also used Mexameter to determine melanin levels of patients' facial skin with melasma. Patients used emulsion formulations containing plant extracts that include catechins/polyphenols. Research showed that formulations containing plant extracts could be an effective alternative treatment of melasma (Barkat Ali Khan, Naveed Akhtar et al. 2013).

It was not possible to guarantee that measurements were taken from exactly the same skin spots. This could particularly, affect results if participant has combined skin type. Three measurements on each side of the face were made during each visit for each parameter in every participant. To calculate a mean parameter and improve the result reproducibility, it could be suggested to take even more measurements.

Extending research could be useful in order to gain results and knowledge about the effects in long term of skin cosmetic products containing *Dracocephalum ruyschiana* extract.

The results could also be impacted by the participants willingness to follow the strict regimen, regular use of products on cleansed skin and application of each product on the appropriate side of the face, regular application of sunscreen with sun protection factor, avoidance of using other cosmetic products. Asking participants to fill out a card on a daily basis that documents the use of cosmetic products, could at least partly help us control the way the participants were using their products.

Conclusions

Everyday use of cosmetic product containing *Dracocephalum ruyschiana* extract leads to improvement in hydration level of the skin. Further research are suggested to evaluate the hydration, viscoelasticity (R2, R5, R7), pigmentation and erythema parameters in long term and also in winter season.

References

- Barkat Ali Khan, Naveed Akhtar et al. 2013. *Whitening efficacy of plant extracts including Hippophae rhamnoides and Cassia fistula extracts on the skin of Asian patients with melasma*. [viewed 08.12.2022]. Accessed: <https://pubmed.ncbi.nlm.nih.gov/24278079/>
- Chien Anna L., MD. Kang Sewon, MD et al. 2022. *Photoaging*. [viewed 12.04.2022]. Accessed: [https://www-uptodatecom.db.rsu.lv/contents/photoaging?search= skin%20aging&source=search_result&selectedTitle=2~39&usage_type=default&display_rank=2](https://www-uptodatecom.db.rsu.lv/contents/photoaging?search=skin%20aging&source=search_result&selectedTitle=2~39&usage_type=default&display_rank=2)
- Kaktiņa. E. 2016. *No Dracocephalum ruyschiana L. Iegūtu bioloģiski aktīvo vielu ādu balinošo īpašību novērtējums in vitro*. [viewed 12.04.2021]. Accessed: <https://dspace.lu.lv/dspace/handle/7/32195>
- Kaktiņa E., Silamiķele B., Ramata-Stunda A. et al. 2019.[viewed 15.04.2021]. *Evaluation of skin protecting, regenerating and anti-angiogenic potential of extract derived from callus culture of*

Dracocephalum ruyschiana. Accessed: <https://alternativeplants.eu/research/alternative-plants-presents-in-vitro-efficacy-data-of-dracocephalum-ruyschiana-stem-cell-culture-derived-extracts-in-icbb-2019/>

Laneri S., Di Lorenzo R.M. et al. 2020. *Aloe barbadensis*. A plant of nutricosmetic interest. [viewed 08.12.2022]. Accessed: <https://journals.sagepub.com/doi/pdf/10.1177/1934578X20932744>

Razgonova M., Okhlopkona Z., Golokhvast K. 2022. *Research of Dracocephalum palmatum S. and Dracocephalum ruyschiana L. originating from Yakutia and identification of metabolites by tandem mass spectrometry*. [viewed 05.04.2022]. Accessed: https://www.researchgate.net/publication/357948435_Research_of_Dracocephalum_palmatum_S_and_Dracocephalum_ruyschiana_L_originating_from_Yakutia_and_identification_of_metabolites_by_tandem_mass_spectrometry

Taffet George E. MD. 2021. *Normal aging*. [viewed: 12.02.2022] Accessed: https://www.uptodate-com.db.rsu.lv/contents/normal-aging?search=skin%20aging&source=search_result&selectedTitle=1~39&usage_type=default&display_rank=1

TENSION AND ACTIVITY IN NECK EXTENSOR MUSCLES DEPENDING ON THE HEAD POSITION WORKING ON COMPUTER

**Diāna Pabērza¹, Monta Dancīte¹, Undīne Skujiņa², Anna Marija Skudra²,
Jelena Reste³**

¹Rīga Stradiņš University, Faculty of Medicine, Dzirciema street 16, Riga, Latvia, LV-1007, paberzadiana@gmail.com, monta.dancite@gmail.com

²Rīga Stradiņš University, Faculty of Rehabilitation, Dzirciema street 16, Riga, Latvia, LV-1007, undine.skujina@gmail.com, annamarijaskudra@gmail.com

³Rīga Stradiņš University, Institute of Occupational Safety and Environmental Health, Dzirciema street 16, Riga, Latvia, LV-1007, jelena.reste@rsu.lv

Abstract

Tension and activity in neck extensor muscles depending on the head position working on computer

Key Words: Muscle, neck extensors, tension, computer monitor

Introduction. In recent years, the need to use a computer in daily life has been increasing rapidly, especially since the start of the COVID-19 infection pandemic in 2019. To continue studies and work, people were forced to use the internet and, consequently, computers daily. As time spent in front of computer monitors increases, so does the incidence of musculoskeletal health problems – neck muscle pain being only one of them. Too much tension in neck muscles can also cause head and neck pain, dizziness, and fatigue. The wrong positioning of the screen might be related to these complaints in employees and computer users.

Aim. The study aims to determine how the position of the head relative to the computer monitor affects the tension of the neck extensor muscles.

Materials and Methods. A quantitative cross-sectional study of neck extensor muscle tension was performed in healthy participants regularly working on computer (n = 19, of them 6 males and 13 females, mean age 35 years). Measurements of the neck extensor muscle (*m.semispinalis capitis* and *m.splenius capitis*) tension, decrement, stiffness, and relaxation were obtained bilaterally by myotonometer MyotonPro 5.0.0 in the sitting position. The change of head position occurred in the sagittal plane and was obtained by measuring the craniovertebral angle with a goniometer. Data were analysed by program IBM SPSS Statistics version 23 using Spearman's test with $p < 0.05$ considered statistically significant.

Results. Results showed statistically significant differences: for *m.semispinalis capitis* there was a positive correlation between angle and oscillation frequency $r = 0.286$; $p < 0.001$, angle and stiffness $r = 0.268$; $p < 0.001$, but a negative correlation between angle and relaxation $r = -0.344$, $p < 0.001$.

There was no significant correlation between angle and decrement. The highest oscillation frequency value was at the angle of +30 degrees (19.79 ± 2.76 Hz), the lowest at neutral position (17.9 ± 2.66 Hz). The highest decrement was at neutral position (1.35 ± 0.17), the lowest – at +30 degrees – (1.31 ± 0.16).

For *m.splenius capitis* there was a positive correlation between angle and oscillation frequency ($r = 0.298$; $p < 0.001$), angle and stiffness ($r = 0.271$; $p < 0.001$), but a negative correlation between angle and relaxation ($r = -0.375$, $p < 0.001$). The highest oscillation frequency value was at the angle of +30 degrees (17.83 ± 1.94 Hz), the lowest – at neutral position (16.39 ± 1.73 Hz). The highest decrement was at the neutral position (1.21 ± 0.23), the lowest – at +30 degrees (1.15 ± 0.17).

Conclusion. The maximal neck extensor muscle tension was at +30° angle, whereas the minimal – at neutral head angle, which corresponds with neck extensor muscle physiology and biomechanics. Thus, neutral head position would be recommended to reduce neck muscle overload while looking at the screen.

Kopsavilkums

Saspringums un aktivitāte kakla atliecējmuskuļos atkarībā no galvas pozīcijas darbā ar datoru

Atslēgvārdi: Muskuli, kakla atliecējmuskuļi, saspringums, datora monitors

Ievads. Pēdējos gados datora izmantošana ikdienā ir strauji pieaugusi, īpaši kopš Covid-19 pandēmijas sākuma 2019. gadā. Lai attālināti turpinātu mācības un darbu, cilvēki ir spiesti pastiprināti izmantot internetu un līdz ar to arī datorus ikdienā. Palielinoties pie datora monitora pavadītajam laikam, pieaug risks biežāk saskarties ar muskuloskeletālās sistēmas veselības problēmām, kā vienu no biežākajām minot kakla muskuļu sāpes. Šīs problēmas varēt būt tieši saistītas ar nepareizu monitora novietojumu un kraniovertebrālo leņķi darbā ar datoru. Patogēnētiski pārāk liels kakla muskuļu sasprindzinājums var izraisīt arī galvas un kakla sāpes, reiboni un nogurumu. Nepareizs ekrāna novietojums var būt saistīts ar šīm respondentu sūdzībām.

Mērķis. Noskaidrot kakla atliecējmuskuļu sasprindzinājumu un aktivitāti atkarībā no galvas pozīcijas maiņas darbā ar datoru.

Materiāli un metodes. Kvantitatīvs šķērsriezuma pētījums kakla atliecējmuskuļu saspringuma mērīšanai veseliem respondentiem, kas ilgstoši strādā ar datoru ($n = 19$, 6 vīrieši, 13 sievietes, vidējais vecums 35 gadi). Kakla atliecējmuskuļu (*m.semispinalis capitis* un *m.splenius capitis*) stīvuma, svārstību frekvences, relaksācijas laika un elastības mērījumi tika iegūti ar miotonometru MyotonPro 5.0.0 mērot sēdus stāvoklī. Galvas pozīcijas maiņa notika sagitālajā plaknē, mērot kraniovertebrālo leņķi ar goniometru. Dati tika analizēti ar IBM SPSS Statistics versiju 23, izmantojot Spīrmena testu ar $p < 0,05$, kas tika uzskatīts par statistiski nozīmīgu.

Rezultāti. Statistiski nozīmīgi dati tika iegūti, nosakot pozitīvu korelāciju starp kraniovertebrālo leņķi un *m.semispinalis* stīvumu $r = 0,268$; $p < 0,001$, kā arī leņķi un muskuļa svārstību frekvenci $r = 0,286$; $p < 0,001$, bet negatīva korelācija starp leņķi un relaksācijas laiku $r = -0,344$, $p < 0,001$. Leņķa un elastības attiecība nenorādīja uz statistiski nozīmīgu korelāciju. Augstākā svārstību frekvence novērojama pie +30 grādu leņķa ($19,79 \pm 2,76$ Hz), zemākā vērtība neitrālā pozīcijā ($17,9 \pm 2,66$ Hz). Augstākais samazinājuma koeficients novērojams neitrālā pozīcijā ($1,35 \pm 0,17$), zemākais +30 grādos ($-1,31 \pm 0,16$).

Statistiski nozīmīgi dati tika iegūti, nosakot pozitīvu korelāciju starp kraniovertebrālo leņķi un *m.splenius capitis* stīvumu ($r = 0,271$; $p < 0,001$), kā arī leņķi un muskuļa svārstību frekvenci ($r = 0,298$; $p < 0,001$), bet negatīva korelācija starp leņķi un relaksācijas laiku ($r = -0,375$, $p < 0,001$). Augstākā svārstību frekvence novērojama pie +30 grādu leņķa ($17,83 \pm 1,94$ Hz), zemākā vērtība neitrālā pozīcijā ($16,39 \pm 1,73$ Hz). Augstākais samazinājuma koeficients novērojams neitrālā pozīcijā ($1,21 \pm 0,23$), zemākais +30 grādos ($1,15 \pm 0,17$).

Secinājumi. Maksimālo saspringumu kakla atliecējmuskuļi sasniedza palielinot leņķi līdz +30 grādiem savukārt zemākais saspringums bija novērojams leņķim esot maksimāli pietuvinātam neitrālajai galvas pozīcijai, kas atbilst informācijai par normālu kakla muskuļu fizioloģiju un biomehāniku.

Introduction

The Covid-19 pandemic has led to a sharp increase in the use of digital technologies due to national distance restrictions and the introduction of teleworking. To continue their studies and work, people were forced to use the Internet and, consequently, their computers daily. The use of an application such as Zoom has increased 10 times compared to the time before the pandemic (Rahul et al., 2020).

Oleg Baranov, a leading researcher at the Institute for European Policy Studies of the Latvian Academy of Sciences, and colleagues have published an article on the impact of telework, stating that in 2019 average of 14.4% of the total number of employees worked on computer and that is 1.3 times more than in 2010 (Barānovs et al., 2021). According to the data of the Central Statistical Bureau, in the 2nd quarter of 2020, remote workers accounted for almost 20% of the total number of employees in Latvia. The result also shows that 17% of the US population worked on a computer at least 5 days a week before the pandemic, but this percentage rose to 44% during the pandemic. Similar data can be found in many countries.

Musculoskeletal complaints in the neck and upper extremities in connection with computer work are common in modern society. Several previous reviews have indicated a possible causal relationship between computer work and musculoskeletal complaints in the neck (Waersted et al., 2012).

Computer workstation ergonomics guidelines such as the American National Standards Institute (ANSI)/HFES 100-2007 Human Factors Engineering of Computer Workstations provide information to plan and design workspaces and equipment and to guide equipment choice and implementation. It provides information related to workstation heights, arrangement, equipment features, and suggested work postures. Computer monitor position is an important consideration for

neutral cervical spine position when at the computer workstation. It is recommended that monitors be in line with the user's head, neck, and torso to keep the neck close to or in neutral when viewing the screen. The height of the monitor should be such that the employee does not look up at the monitor but looks straight ahead at the monitor (Emerson and Finch, 2021).

A cross-sectional study in China also confirms the incorrect positioning of the monitor as a risk factor for neck muscle pain. In the results, 86.3% of 417 respondents observed neck muscle pain associated with inaccurate computer monitor placement (Ye et al., 2017).

The musculature of the cervical spine includes flexors, extensors, lateral flexors, and rotators. Major flexors include the sternocleidomastoid, scalenes, and prevertebral muscles. Extensors include the posterior paravertebral muscles (splenius capitis, semispinalis capitis) and trapezius. Lateral flexors include the sternocleidomastoid, scalenes, and interspinous (between the transverse processes) muscles, and the rotators include the sternocleidomastoid and the interspinous muscles. The paraspinal muscles can be strained and become spastic. Occasionally, so-called trigger points – hyperirritable myonodules and taut muscle fiber bands – may develop (Singh et al., 2020).

More data are available on neck flexion muscle measurements and no other studies of this type with measurements of neck extensor activity were found, so the data obtained in the study would be unique, especially in Latvia.

The study aims to determine how the position of the head relative to the computer monitor affects the tension of the neck extensor muscles.

Materials and Methods

A quantitative, cross-sectional experimental study simulating head position looking at the monitor was performed in 19 healthy volunteers (6 males and 13 females, mean age 35 years (from 19 to 60 years old)). Measurements of muscle tension, decrement, stiffness, and relaxation in the neck long extensors (semispinalis capitis and splenius capitis muscles) were taken by myotonometer MyotonPro 5.0.0. in a sitting position in 4 different head positions. The parameters studied were:

- Oscillation frequency (in Hertz) – the intrinsic tension of the muscle in its passive state;
- Dynamic stiffness (in Newtons per meter) – resistance to deformation;
- Logarithmic decrement – a parameter that reflects muscle elasticity, that is, a muscle's ability to reduce tension after muscle work;
- Mechanical stress relaxation time (in milliseconds) – the time it takes for the muscle to restore its shape after deformation.

Firstly, participants were tested for a range of motion (RoM) in neck and physiological neck extensor muscle strength to determine their suitability for the study by performing the Spurling and Lhermitte's sign test (Singh et al., 2020).

Active RoM was tested first. Normal RoM includes the extension of 70° (chin pointed straight up to the ceiling), flexion of 60° (chin on chest, or within 3 cm of the chest), lateral flexion of approximately 45° (ear to shoulder), and rotation of approximately 80° (looking right and left).

Spurling test assesses for nerve root irritation. To perform the Spurling test, the head was extended, side-bent, and partially rotated towards the testing side. An axial load was then gently applied to the top of the head. Muscle strength was tested by applying resistance to the head with hand after the testing position was taken. The test was positive if radiating pain, generally into the posterior shoulder or arm on the ipsilateral side, was experienced.

Lhermitte's sign was used to test for cervical radiculopathy. Forward flexion of the neck that causes paraesthesia down the spine or extremities suggests cervical radiculopathy, spondylosis, myelopathy, or multiple sclerosis. Respondents with positive any of these tests were not further investigated.

The change of head position occurred in the sagittal plane while sitting straight on a chair and was obtained by measuring the craniovertebral angle with a goniometer performing the measurements bilaterally. First, an imaginary horizontal line that goes through the C7 spinous process was drawn, which is the back of the vertebra at the bottom of the neck. Then a second line was drawn from the C7 spinous process up to the tragus, which is the cartilaginous part in front of the earhole. Conjunction of both lines at the C7 vertebra forms the craniovertebral angle (CVA) and was taken as a reference point. Following that, measurements were taken as the respondent moved their head forward for 10 degrees, then 20 and 30 degrees, taking forward head posture (FHP) also known as nerd neck.

Data were analysed by IBM SPSS Statistics version 23 using Spearman's test with $p < 0.05$ considered statistically significant. Participation in the study was voluntary and anonymity was ensured in the data processing. The research protocol was developed in accordance with the general protocol of the Research Ethics Commission of Rīga Stradiņš University, and it was approved on 14.12.2021.

Results

Results showed statistically significant differences in muscle biomechanical parameters according to craniovertebral angle while holding head in different positions.

For **semispinalis capitis muscle** there was a weak positive correlation between angle and oscillation frequency ($r = 0.286$; $p < 0.001$), as well as between angle and stiffness ($r = -0.268$; $p < 0.001$). Negative correlation was found between angle and relaxation time ($r = -0.344$, $p < 0.001$). There was no significant correlation between angle and decrement. The highest oscillation frequency value was at the angle of +30 degrees (19.79 ± 2.76 Hz), the lowest – at neutral position (17.90 ± 2.66 Hz) (Figure 1). It means that forward head posture for +30 degrees

directly affects muscle tension which increases with increasing angle. The highest stiffness value was at the angle of +30 degrees (382.86 ± 105.67 N/m), the lowest at neutral position (333.86 ± 80.04 N/m). This indicates that the resistance of the muscle is greater as the CVA increases.

The highest decrement was in neutral position (1.35 ± 0.17), the lowest – at +30 degrees (1.31 ± 0.16). The lower is result of decrement, the longer time muscle takes to relax, which is related to the elasticity of muscle.

For **splenius capitis muscle** there was a positive correlation between angle and oscillation frequency (Figure 1) ($r = 0.298$; $p < 0.001$), angle and stiffness (Figure 2) ($r = 0.271$; $p < 0.001$), but a negative correlation between angle and relaxation time ($r = -0.375$, $p < 0.001$). The highest oscillation frequency value was at the angle of +30 degrees (17.83 ± 1.94 Hz), but the lowest – in neutral position (16.39 ± 1.73 Hz). The highest decrement was in the neutral position (1.21 ± 0.23), the lowest – at +30 degrees (1.15 ± 0.17).

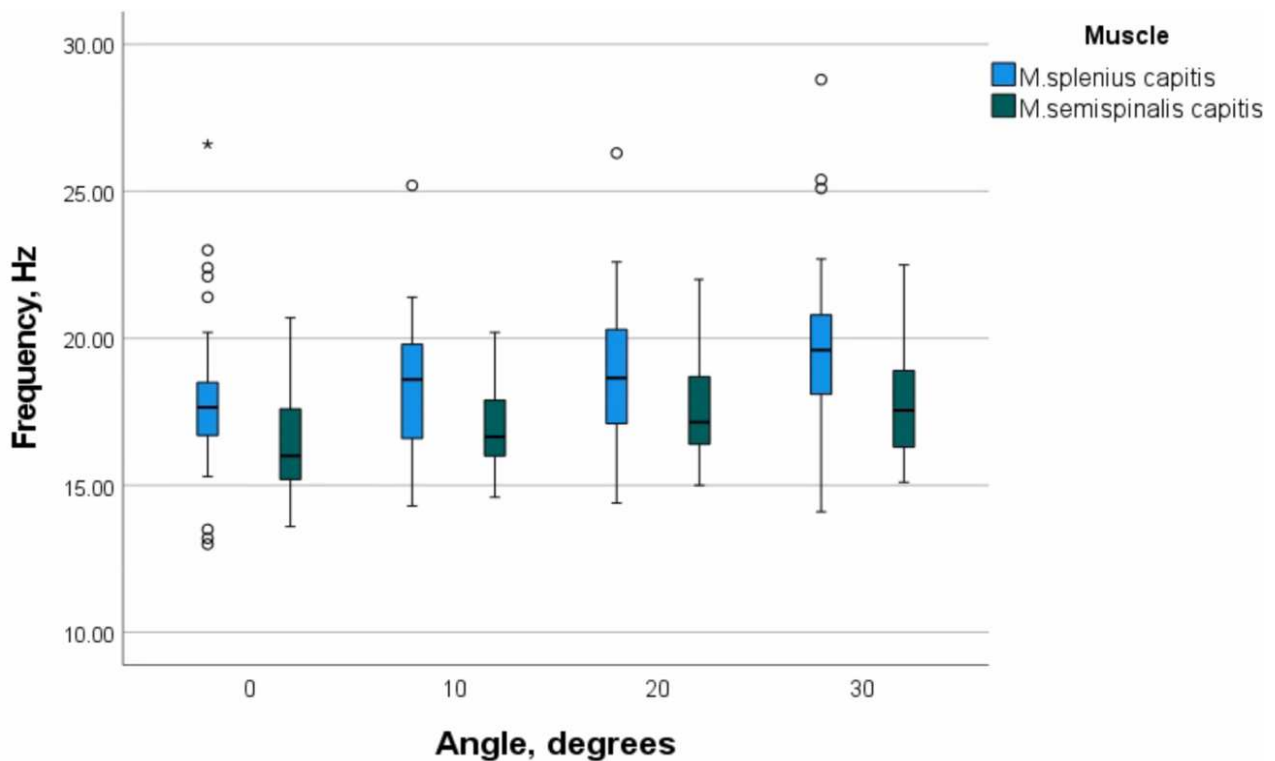


Figure 1. **Splenius capitis and semispinalis capitis muscle oscillation frequency (Hz) at different forward head posture angles**

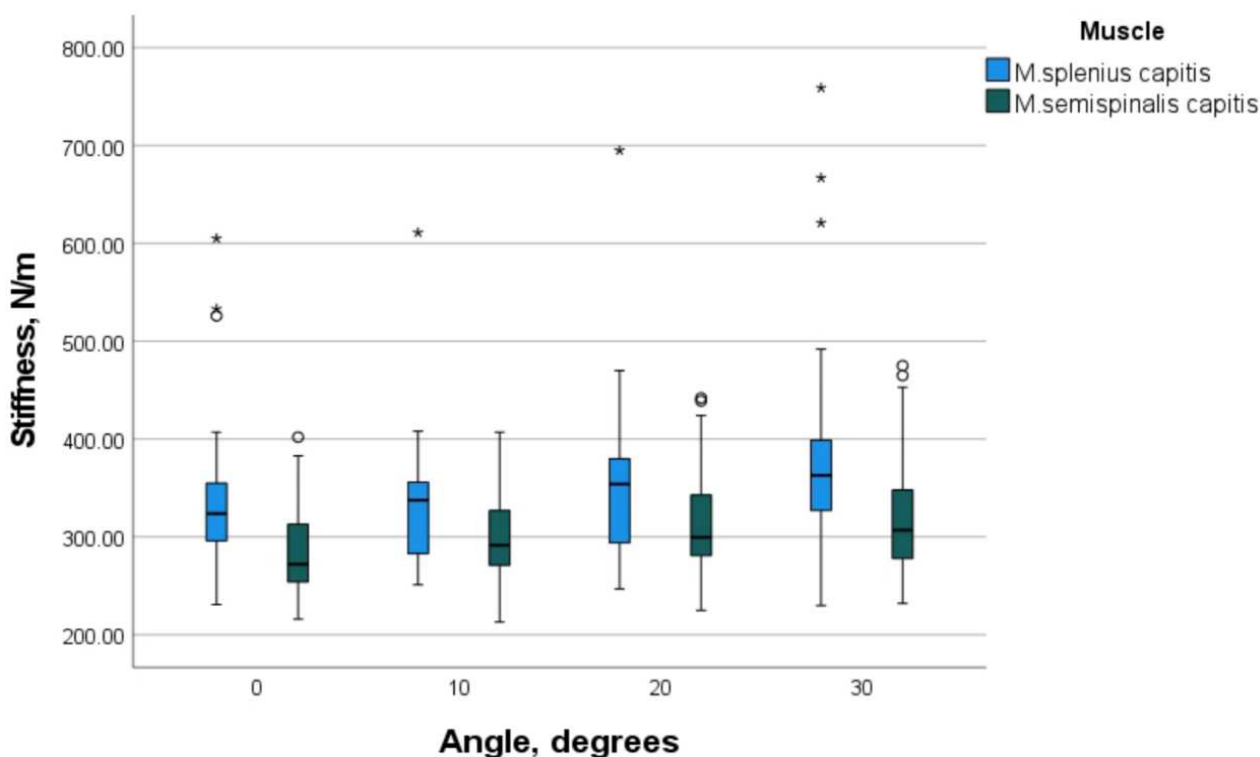


Figure 2. Splenius capitis and semispinalis capitis muscle stiffness (N/m) at different forward head posture angles

Discussion

The purpose of this study was to find out whether the forward position of the head in relation to the computer monitor has an effect on the strain of the neck extensor muscles. Research using the same methodology as the present study is sparse. In Mahmoud et al. article looking at FHP, it was found that adults with neck pain show an increase in FHP in comparison to adults with no symptoms, and there was a significant correlation between neck pain in both adults and older adults. Even though the results in this research depicted a compelling contrast between adults with and without pain and an important connection between FHP and neck pain in adults. Mahmoud et al. concluded that it remains unknown whether FHP could be the causing factor or a consequence of idiopathic neck pain in adults, and that there is a need for high-quality longitudinal studies to investigate how temporary and casual this occurrence is (Mahmoud et al., 2019). As it was found in the present study that as the CVA increases, the muscle stiffness and logarithmic decrement, which describes muscle's ability to relax after contraction, also rises, these could be few of the causes of the neck pain.

In comparison, Alowa and Elsayed's study compared the electromyographic activity of the regional spinal muscle in patients with FPH and those with a normal CVA. They concluded that female individuals with FHP had more cervical muscle activation than healthy controls. As a result, people with FHP needed more muscle work to keep their spine stable when holding a weight. Authors suggested that if such muscle effort is repeated, the cervical spine's structure might be

exposed to increased mechanical demands (Alowa and Walaa, 2021). Statements of both studies support present study's obtained results by the increase of oscillation frequency, which is an indication of increased muscle tone, and decrease of relaxation time.

Furthermore, Lee et al. studied whether FHP has an effect on muscle activity (upper and middle trapezius, splenii and sternocleidomastoid (SMC)) according to the head posture. During neck protraction, the EMG activity of the splenii and SCM differed significantly between the control and FHP groups. Consequently, during neck retraction, the EMG activity of the middle trapezius muscle differed significantly between the groups. These findings imply that FHP affects EMG activity by reducing the length of the splenii and SCM muscles, as well as increasing the length and weakening of the middle trapezius muscle. Finally, FHP inhibits EMG activity in the middle trapezius, splenii, and SCM muscles. Lee et al. concluded that these findings show that the lowered activities are caused by FHP-induced changes in muscle length, which are linked to a reduced ability to generate force (Lee et al., 2015). This study supports the finding in the present study as well by stating that prolonged FHP can be the cause for biomechanical changes in the long run.

However, Choi et al. performed a study with an aim to identify changes in the activity and fatigue of the neck supporting agonists (splenius capitis and upper trapezius muscles) under three most frequently adopted postures while using a smartphone. Authors concluded that a slight bending of the neck while using a smartphone, is better than bending it too far or keeping it straight, to reach lesser fatigue of the cervical extensor muscles (Choi et al., 2016), which partially supports findings of the present study.

Conclusion

Study concluded that maximal muscle tension was at +30° angle (i.e., significant forward head posture), whereas the minimal – at neutral head angle, keeping head straight, which corresponds to neck extensor muscle physiology and biomechanics. Thus, a neutral head position would be recommended to reduce neck muscle overload while looking at the screen to avoid neck pain and forward head posture.

References

- Alowa Z., Elsayed W. (2020). The impact of forward head posture on the electromyographic activity of the spinal muscles. *Journal of Taibah University Medical Sciences*, 16(2), 224–230. <https://doi.org/10.1016/j.jtumed.2020.10.021> [22.05.2022.].
- Barānovs O., Salmiņš J., Skribāne I. *Attālinātā darba ietekme uz produktivitāti un strukturālajām izmaiņām*. Latvijas Universitātes Akadēmiskais apgāds. 12.2021. <https://doi.org/10.22364/ltpēpii.09> Retrieved from: https://www.apgads.lu.lv/fileadmin/user_upload/lu_portal/apgads/izdevumi/2021/Lat_tautsaim_peckrize/09.pdf [18.05.2022.].
- Choi J. H., Jung M. H., Yoo K. T. (2016). An analysis of the activity and muscle fatigue of the muscles around the neck under the three most frequent postures while using a smartphone. *Journal of physical therapy science*, 28(5), 1660–1664. <https://doi.org/10.1589/jpts.28.1660> [22.05.2022.].

- Emerson and Finch. (2021). The Injured Worker: Onsite Evaluation and Services. *Rehabilitation of the Hand and Upper Extremity. Seventh edition*, 119, 1704–1728. Elsevier. ClinicalKey. Retrieved from <https://www-clinicalkey-com.db.rsu.lv/#!/content/book/3-s2.0-B978032350913800119X?scrollTo=%23hl0001822> [26.05.2022.].
- Lee K. J., Han H. Y., Cheon S. H., Park S. H., and Yong M. S. (2015). The effect of forward head posture on muscle activity during neck protraction and retraction. *Journal of physical therapy science*, 27(3), 977–979. <https://doi.org/10.1589/jpts.27.977> [22.05.2022.].
- Mahmoud N. F., Hassan K. A., Abdelmajeed S. F., Moustafa I. M., Silva A. G. (2019). The Relationship Between Forward Head Posture and Neck Pain: a Systematic Review and Meta-Analysis. *Current reviews in musculoskeletal medicine*, 12(4), 562–577. <https://doi.org/10.1007/s12178-019-09594-y> [20.05.2022.].
- Rahul D., Pandey N., Pal A. (2020) Impact of digital surge during Covid-19 pandemic: A viewpoint on research and practice. *International journal of information management*. 2020; 55: 102171. doi: 10.1016/j.ijinfomgt.2020.102171 [16.05.2022.].
- Singh S., Ho G. K., Howard T. M. Neck Pain. In: South-Paul J.E., Matheny S.C., Lewis E.L. (2020) eds. *CURRENT Diagnosis & Treatment: Family Medicine, 5e*. McGraw Hill; 2020. Retrieved from <https://accessmedicine-mhmedical-com.db.rsu.lv/content.aspx?bookid=2934§ionid=247400156> [18.05.2022.].
- Waersted M., Hanvold T.N., Veiersted K.B. (2010) Computer work and musculoskeletal disorders of the neck and upper extremity: a systematic review. *BMC Musculoskelet Disord*. 2010; 11: 79. doi: 10.1186/1471-2474-11-79 [17.05.2022.].
- Ye S., Jing Q., Wei C., Lu J. (2017) Risk factors of non-specific neck pain and low back pain in computer-using office workers in China: a cross-sectional study. *BMJ Open*. 2017 Apr 11; 7(4): e014914. doi: 10.1136/bmjopen-2016-014914. PMID: 28404613; PMCID: PMC5594207 [19.05.2022.].

REDUCTION OF THE MUSCLE IMBALANCE FOR SOCCER PLAYERS BETWEEN FOUR-HEADED THIGH MUSCLE AND TWO-JOINT EXTENSOR WITH BIODEXSYSTEM ISOKINETIC DYNAMOMETRY AND POST-ISOMETRIC RELAXATION

Undīne Čeire¹, Aivars Kaupužs², Līga Antoneviča³

¹Rīga Stradiņš University, Dzirciema street 16, Rīga, undine.ceire@inbox.lv

²Rēzekne Academy of Technologies, Atbrīvošanas alley 115, Rēzekne, aivars.kaupužs@inbox.lv

³Daugavpils University, Parādes street 1, Daugavpils, liga.antonevica@du.lv

Abstract

Reduction of the muscle imbalance for soccer players between four-headed thigh muscle and two-joint extensor with biodexsystem isokinetic dynamometry and post-isometric relaxation

Key Words: muscle imbalance, soccer players, risk of traumatism, post-isometric relaxation, BiodexSystem isokinetic dynamometry

Introduction. In sports, such as football, handball and basketball, the cause of muscle injuries in athletes is often associated with sudden acceleration, stopping, rapid change of direction, jumps, landings. One of the risk factors for injury is a lack of strength and flexibility, fatigue, or an imbalance of strength between agonist muscles and antagonist muscles.

The aim of this study was to explore the muscle functional state and effectiveness of the therapeutic gymnastic in reducing muscle imbalance between four-headed thigh muscle and two-joint extensor with BiodexSystem isokinetic dynamometry and post-isometric relaxation methods for soccer players.

Material and methods. The research was performed at the Laboratory of Rehabilitation Technology of the Rezekne Academy of Technologies in 2019. Footballers of the indoor football club Rezekne participated in the research. The research was conducted in three phases: functional evaluation of muscles, therapeutic gymnastic and re-evaluation of muscle function. 24 soccer players (16–22-year-old male) took part in the first phase of the study, but 12 in the second and third. The following methods were used: straight-leg raise tests, Ely's tests, dynamometry (*BiodexSystem* muscle test + eccentric contraction exercise), physiotherapy methods (therapeutic exercises, stretching technique (PIR)) and statistical data processing.

Results. Muscle functional evaluation was performed in 24 athletes, of whom 12 athletes participated in the study, who were divided into two groups (six + six participants). Athletes were selected with greater muscle imbalance and shortening of the length of the hamstring muscle group. In the second phase physiotherapy program was developed: therapeutic exercise with a *BiodexSystem* dynamometer (BSD) and therapeutic exercise with post-isometric relaxation (PIR) for a group of hamstring muscles. Six athletes attended 12 classes with a *BiodexSystem* dynamometer, and six athletes were treated with a PIR hamstring muscle group that included 12 classes. After therapeutic exercise, the results in the BSD group (average) improved by $17 \pm 1,40$ with a confidence factor ($p < 0.0001$) and the results in the PIR group improved significantly by $6,0 \pm 0,60$ with a confidence factor ($p = 0.013$), which is statistically significant.

Conclusions. Muscle imbalances result from muscle imbalances and asymmetric effects of agonists / antagonists, who affect postural control and are a risk factor for trauma.

The tests and methods selected for the functional examination and evaluation of footballers' muscles reflected significant changes in the muscle strength ratio of agonists and antagonists after the course of therapeutic exercise.

Kopsavilkums

Augšstilba četrgalvainā muskuļa un gūžas divlocītavu ekstensoru disbalansa mazināšana futbolistiem ar biodexsystem izokinētisko dinamometriju un postizometrisko relaksāciju

Atslēgvārdi: muskuļu disbalanss, futbolisti, traumatisma risks, postizometriskā relaksācija, BiodexSystem dinamometrija.

Ievads. Sportā, piemēram, futbolā, handbolā un basketbolā, muskuļu traumatisma cēlonis sportistiem bieži saistīts ar pēkšņu paātrinājumu, apstāšanos, strauju virzienu maiņu, lēcieniem vai piezemēšanos. Viens no traumu riska faktoriem ir spēka un elastības trūkums, nogurums vai spēka nelīdzsvarotība starp agonistu un antagonistu muskuļiem.

Mērķis Noskaidrot augšstilba četrgalvainā muskuļa un gūžas divlocītavu ekstensoru funkcionālo stāvokli un terapeitiskās vingrošanas efektivitāti muskuļu disbalansa mazināšanā futbolistiem ar *BiodexSystem* izokinētiskās dinamometrijas un postizometriskās relaksācijas metodēm.

Materiāli un metodes. Pētījums veikts Rēzeknes Tehnoloģiju akadēmijas Rehabilitācijas tehnoloģiju laboratorijā 2019. gadā. Pētījumā tika iesaistīti Rēzeknes minifutbola kluba spēlētāji. Pētījums tika veikts trīs posmos: muskuļu funkcionālais novērtējums, ārstnieciskā vingrošana un muskuļu funkcijas atkārtota novērtēšana. Pirmajā pētījuma posmā piedalījās 24 futbolisti (vīrieši vecumā no 16 līdz 22 gadiem), bet otrajā un trešajā – pa 12. Tika izmantotas šādas metodes: taisnās kājas pacelšanas tests, Eli tests, dinamometrija (*BiodexSystem*), stiepšanās tehnika (PIR)) un statistikas datu apstrāde.

Rezultāti. Pirmajā pētījuma posmā tika nolemts iekļaut sportistus. Muskuļu funkcionālais novērtējums tika veikts 24 sportistiem, no kuriem pētījumā piedalījās 12 sportisti, kas tika sadalīti divās grupās (seši + seši dalībnieki). Tika atlasīti sportisti ar lielu muskuļu nelīdzsvarotību un saīsinātu paceses muskuļu grupas garumu. Otrajā posmā tika izstrādāta vingrojumu terapijas programma: vingrojumu terapija uz *BiodexSystem* dinamometra (BSD muskuļu tests + ekscentriskās kontrakcijas vingrojumi) un terapeitiskā vingrošana ar postizometrisko relaksāciju (PIR) augšstilba aizmugurējās daļas muskuļu grupā. Ar lielāko muskuļu disbalansu seši sportisti apmeklēja 12 sesijas ar *BiodexSystem* dinamometru, bet seši sportisti tika ārstēti ar PIR paceses muskuļu grupu, kas ietvēra 12 sesijas. Pirms vingrojumu terapijas sportistiem BSD grupā bija lielāka paceses muskuļu garuma kontrakcija nekā PIR grupā. Pēc vingrošanas terapijas rezultāti BSD grupā (vidēji) uzlabojās par $17 \pm 1,40$ ar ticamības varbūtību ($p < 0,0001$), un rezultāti PIR grupā būtiski uzlabojās par $6,0 \pm 0,60$ ar ticamības varbūtību. ($p = 0,013$), kas ir statistiski nozīmīgi. abām kājām.

Secinājumi. Muskuļu nelīdzsvarotība rodas muskuļu nelīdzsvarotības un asimetriskas agonista/antagonista iedarbības rezultātā, kas ietekmē stājas kontroli un ir traumu riska faktors. Izvēlētie testi un metodes futbolistu muskuļu funkcionālajai izmeklēšanai un novērtēšanai atspoguļoja būtiskas izmaiņas agonistu un antagonistu muskuļu spēka attiecībās pēc fizikālās terapijas kursa.

Introduction

One of the risk factors for injury in footballer is a lack of strength and flexibility, fatigue, or an imbalance of strength between agonist muscles and antagonist muscles (Adkitte, 2016). The use of *BiodexSystem* equipment to reduce muscle imbalance. In 2009, the fourth model of the *BiodexSystem* dynamometer was developed, which is currently recognized as one of the best measuring instruments and rehabilitation devices in the world. This is supported by over 800 scientific articles based on the use of *BiodexSystem* equipment to reduce muscle imbalances (Tankevicius et al., 2013). A study by Portuguese researchers Teixeira, Carvalho, Moreira & Santos (2012) using the *BiodexSystem* dynamometer in 25 football players with an imbalance in the quadriceps femoris and hamstring muscle groups showed that the faster the knee flexion/extension occurs (from 60 to 300 degrees in the second), the greater the imbalance between agonists and antagonists (Teixeira et al., 2012).

The aim of the research

To explore the muscle functional state and effectiveness of the therapeutic gymnastic in reducing muscle imbalance between four-headed thigh muscle and two-joint extensor with *BiodexSystem* isokinetic dynamometry and post-isometric relaxation methods for soccer players.

Material and methods

The research was performed at the Laboratory of Rehabilitation Technology of the Rezekne Academy of Technologies in 2019. Footballers of the indoor football club Rezekne participated in the research. The research was conducted in three phases: functional evaluation of muscles, therapeutic gymnastic and re-evaluation of muscle function. 12 soccer players (16–22-year-old male). The following methods were used: straight-leg raise test (*hamstring* muscle group length), Ely's tests (*m.quadriceps femoris* (*m.rectus femoris*) length), dynamometry (*BiodexSystem* (BSD) including two methods: *hamstring/m.quadriceps femoris* functional tests – peak torque, total work, agonist to antagonist ratio) un BSD provides for therapeutic exercise (eccentric contraction for the *hamstring* muscle group – 3 times a week for 40 min)), physiotherapy methods (stretching technique (PIR – active and passive with the help of another player – 3 times a week for 15 min),

therapeutic exercise (diaphragmatic breathing) and statistical data processing. Isokinetic dynamometry including eccentric contraction and stimulation, adaptation of nerves. Postisometric relaxation including static drawing and muscle relaxation. The objective of the physiotherapy programme was to improve muscle function and to reduce muscle imbalance between four-headed muscle and hip two-joint extensor muscle groups, applying PIR method (*hamstring* stretching) to one group and the eccentric contraction (*hamstring* muscle group) to the other group. After 12 exercise sessions, both groups were given initial applied tests: straight-leg raise test (*hamstring* muscle group length), Ely's tests (*m.quadriceps femoris* (*m.rectus femoris*) length), BSD: *hamstring/m.quadriceps femoris* functional tests – peak torque, total work, agonist to antagonist ratio) and the results were compared, which method (stretching or work in eccentric contraction) decrease the imbalance between *m.quadriceps femoris* and *hamstring* muscle group.

Results

After therapeutic exercise, the results in the BSD group (average) improved by $17 \pm 1,40$ with a confidence factor ($p < 0.0001$) and the results in the PIR group improved significantly by $6,0 \pm 0,60$ with a confidence factor ($p = 0.013$), which is statistically significant. In the right leg, there was a positive, moderately strong correlation ($r = 0.68$) between speed increase and agonist/antagonist muscle ratio outcomes that was statistically significant between the two legs ($p = 0.037$), while in the left leg it was that there is a negative, weak correlation ($r = 0.22$). It can be concluded that with an increase in speed, the proportion of muscle imbalance increases, which confirms the correlation of speed with the ratio of muscle strength. The ratio of the force parameter between the hamstring muscle group and the quadriceps femoris is $60^0/\text{sec}$. should be 60%–69%; $180^0/\text{sec}$. – 70%–79%; $300^0/\text{sec}$ – 80%–95% (Hawkins, 2001). It can be concluded that before exercise therapy in the PIR group on the right leg $60^0/\text{sec}$ – 58.3%, $180^0/\text{sec}$ – 56.7%, $300^0/\text{sec}$. – 61.4%, and in the left leg $60^0/\text{sec}$ – 56.5%, $180^0/\text{sec}$ – 50.7%, $300^0/\text{sec}$. – 55.2%, none of the indicators corresponds to the ratio of muscle strength parameters with a normal distribution of muscles, which symbolizes muscle imbalance, more pronounced $180^0/\text{sec}$. Figure 1 shows how the increase in speed affects the ratio of muscle agonists and antagonists after exercise therapy in the PIR group. Agonist to Antagonist Ratio: Muscle group ratio (AGON/ANTAG) is calculated by dividing the maximum moment of force using the BiodexSystem formula (Lubkina et al., 2013; Struzik, 2019):

- $\text{AGON} / \text{ANTAG} = (\text{Peak Torque Hamstring (Nm)}) / (\text{Peak Torque Quadriceps (Nm)}) \times 100\%$.

The relationship between the hamstring muscle group and the strength indicators of the quadriceps femoris muscle in the normal position of the knee joint (Struzik, 2019):

- $60^0/\text{sec}$: (60%–69%);
- $180^0/\text{sec}$: (70%–79%);
- $300^0/\text{sec}$: (80%–95%).

The quadriceps femoris should be 25–35% stronger than the hamstring muscle group. The potential risk of injury will increase if one of the muscle groups is significantly stronger (Lubkina et al., 2013; Struzik, 2019). In the third phase, after a course of therapeutic exercise, muscle functional re-evaluation was performed with a BiodexSystem dynamometer (maximum torque; total and maximum work performed; ratio of agonist and antagonist muscle groups) and hamstring muscle group length test – straight-leg raise test and length test for m.quadriceps femoris – Ely’s test. It was found that for both methods the muscle imbalance between the m.quadriceps femoris and hamstring muscle group was reduced (300⁰/sec.), both BSD group and PIR group showed a statistically significant difference, the result was statistically significantly improved for both legs. A correlation was observed between increasing speed and increasing muscle imbalance. The higher the speed an athlete develops, the greater the muscle imbalance, which means that it is important to train while also developing higher speed, reducing the risk of injury during the game.

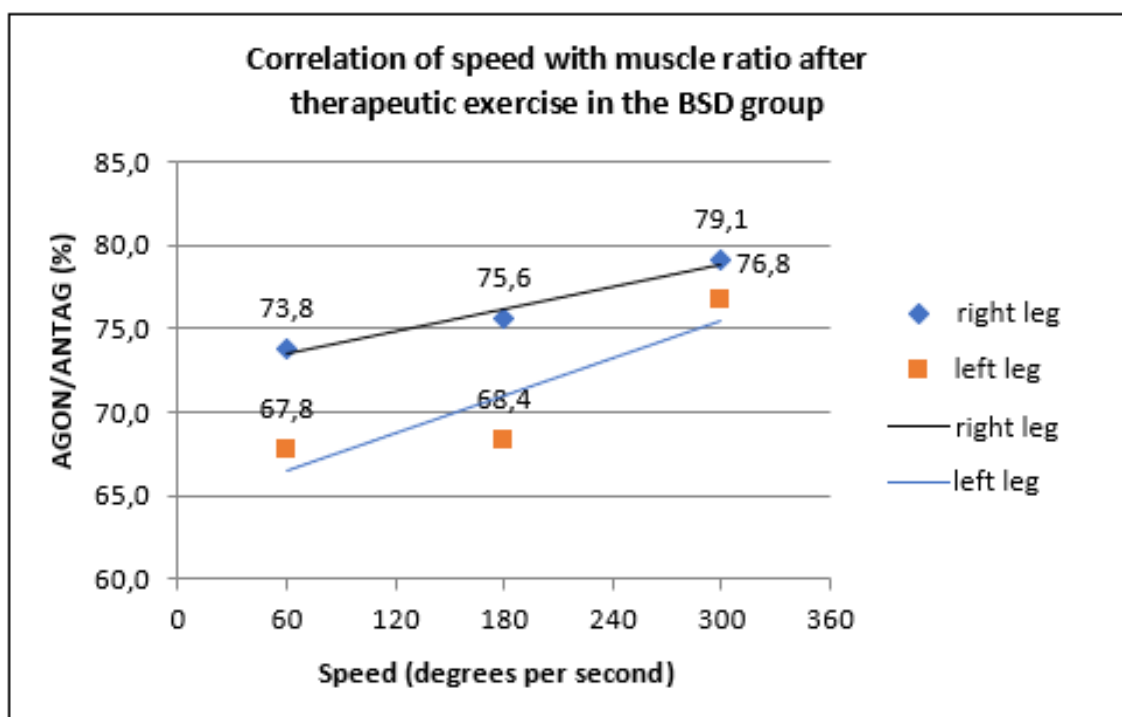


Fig. 1. Correlation between speed and AGON/ANTAG by PT in the PIR group

In the right leg ($r = 0.89$), left leg ($r = 0.86$) there was a positive strong correlation between speed increase and agonist/antagonist muscle ratio, which was statistically significant between the two legs ($p = 0.029$). It can be concluded that with an increase in speed, the proportion of muscle imbalance increases, which confirms the correlation of speed with the ratio of muscle strength. Before physiotherapy exercises in the BSD group on the right leg 60⁰/sec – 51.6% (normal 60–69%); 180⁰/sec – 56.8% (norm 70–79%), 300⁰/sec. – 65.8% (norm 80–95%), and on the left leg 60⁰/sec – 44.9% (norm 60–69%); 180⁰/sec – 48.7% (norm 70–79%), 300⁰/sec. – 60.9% (norm 80–

95%). None of the indicators correspond to the ratio muscle strength indicators with a normal distribution of muscles, which symbolizes muscle imbalance. Insufficient muscle strength increases the risk of injury from contact games. Figure 2 shows how an increase in speed affects the ratio of agonist to antagonist muscles after exercise therapy in the BSD group.

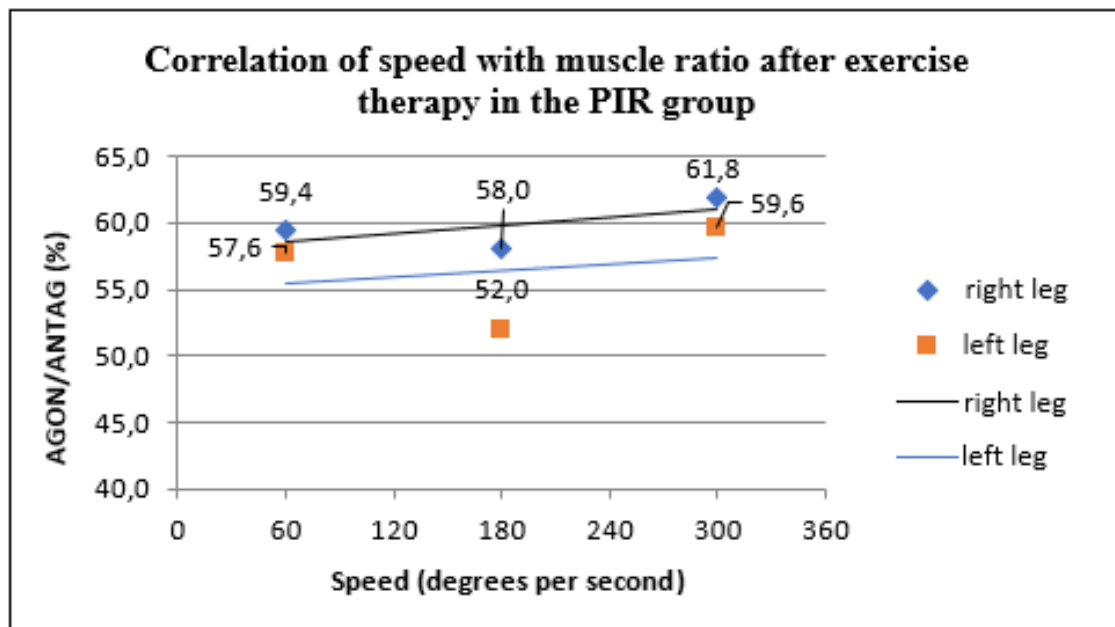


Fig 2. Correlation between speed and AGON/ANTAG before PT in the BSD group

There was a positive, close correlation in the right foot ($r = 0.88$); in the left leg ($r = 0.71$) between the increase in velocity and the results of the agonist / antagonist muscle ratio, which is statistically significant between the two legs ($p = 0.049$). It can be concluded that with increasing speed, the proportion of muscle imbalance increases, which confirms that speed correlates with the ratio of muscle strength. After therapeutic exercise in the BSD group on the right leg $60^0 / \text{sec} - 73.8\%$ (norm 60–69%, improved by 22.2%); $180^0 / \text{sec} - 75.6\%$ (norm 70–79%, improved by 18.8%), $300^0 / \text{sec} - 79.1\%$ (norm 80–95%, improved by 13.3%), while on the left leg $60^0 / \text{sec} - 67.8\%$ (norm 60–69%, improved by 22.9%); $180^0 / \text{sec} - 68.4\%$ (norm 70–79%, improved by 19.7%), $300^0 / \text{sec} - 76.8\%$ (norm 80–95%, improved by 15.9%). The ratio of muscle strength parameters has improved, which reduced muscle imbalance, several indicators correspond to the ratio of muscle strength parameters in the normal muscle distribution (Koulouris, 2005).

The ratio of agonists and antagonists of the BSD group to muscle groups ($300^0 / \text{sec}.$) for the right leg before the course of exercise therapy was $60.9 \pm 10.5\%$, after the course of exercise therapy the average index improved to $76.8 \pm 11.1\%$. An improvement of $15.9 \pm 0.6\%$ was calculated with a confidence level ($p = 0.037$), which means that for the left leg the change is different and statistically significant. Based on the data obtained, it can be concluded that in both

methods, the muscle imbalance between *m.quadriceps femoris* and the hamstring muscle group decreased (300⁰/sec), both the BSD group and the PIR group showed a statistically significant difference, the result was statistically significantly improved for both legs.

It was found that the agonist/antagonist muscle strength ratio in the right leg improved by 0.9% with the PIR method and by 18.1% with the BSD method. In the left leg, the agonist/antagonist muscle strength ratio improved by 2.3% with the PIR method and by 19.5% with the BSD method. It was concluded that the percentage distribution of the agonist/antagonist muscle strength ratio in the BSD group is relatively higher than in the PIR group, but it was concluded that both methods show improvement and reduction in flexor/extensor muscle imbalance in the *hamstring* muscle group and *m.quadriceps.femoris* (see Figure 3) (Brughelli, 2010; Struzik, 2019).

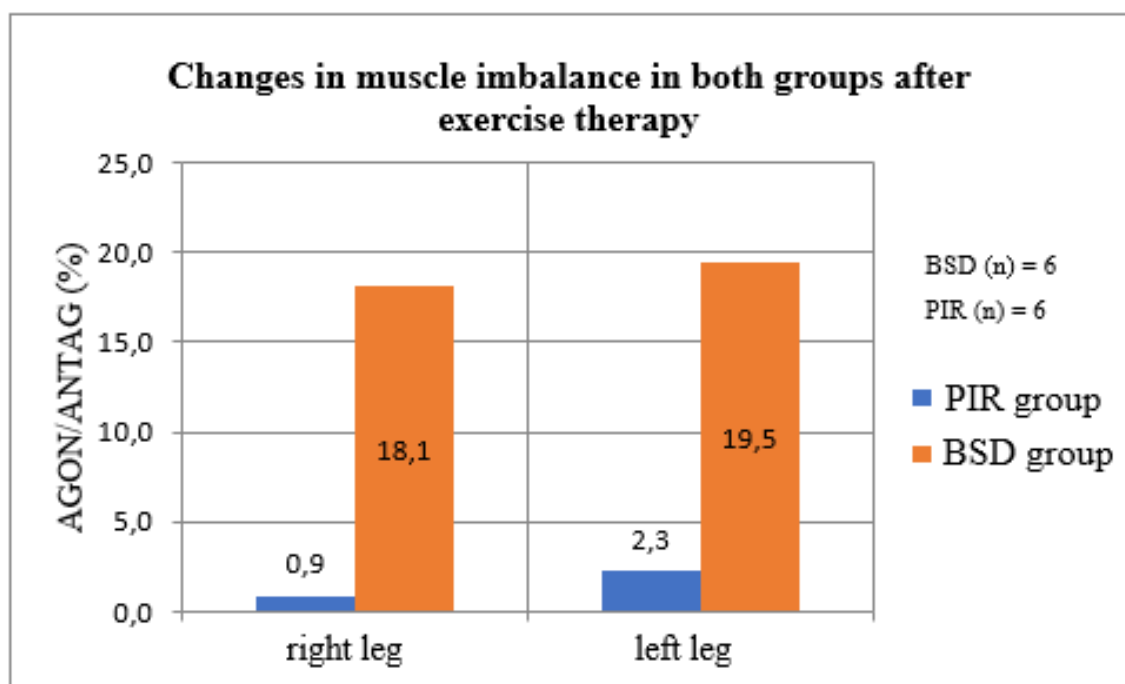


Fig. 3. Changes in muscle imbalance in both groups after PT

Discussion

Gioftsidou, Beneka, Malliou (2006), Teixeira et al. (2012) and McCall (2016) on the BiodexSystem isokinetic dynamometer using the muscle training program – knee flexion/extension 60⁰/sec.–180⁰/sec, revealed significant differences between the ratio of muscle agonists/antagonists. Maximal muscle strength improved, total work done improved, muscle imbalance decreased in soccer players, and Struzik (2019) in his study concluded that the isokinetic exercise regimen (development of isokinetic angles) (90⁰/sec.–120⁰/sec.) (Struzik, 2019; Gioftdidou et al., 2006; Teixeira et al., 2012; McCall, 2016). Based on the results of this study and the articles of the beforementioned authors, it can be concluded that the isokinetic regimen of eccentric exercise

develops and improves greater muscle strength, and the faster the contraction occurs, the less muscle is developed over a period of time. As a result, the imbalance between agonists and antagonists increases. A study by Lord, Aitkens, McCrory & Bernauer (2002) examined the effectiveness of an isometric and isokinetic contraction training program. The results show that the effect of angular velocity on maximum torque is correlated in both flexor and extensor contraction modes, while maximum torque improved with increasing isokinetic angular velocity. It was concluded that in the isokinetic mode, improvements are observed both in the flexors and extensors, and in the isometric mode, they are more pronounced in the extensors (Lord et al., 2002). Small et al. (2009) investigated the risk factor for hip muscle injury with eccentric contraction exercises. It was concluded that there was a 65% reduction in the likelihood of injury (Small et al., 2009).

Conclusion

The tests and methods selected for the functional examination and evaluation of footballers' muscles reflected significant changes in the muscle strength ratio of agonists and antagonists after the course of therapeutic exercise. Improvement in isokinetic contraction exercise regimen has been shown to be statistically significant, resulting in increased muscle strength and improved agonist-antagonist muscle ratio. The postisometric relaxation therapeutic exercise complex accepted effectiveness of the method in reducing muscle imbalance, but the results and progress were less pronounced than in eccentric contraction strength training.

Acknowledgement

Thanks to the athletes (football players) for participating in the study and also to their trainer. Rezekne Academy of Technology (Rehabilitation Laboratory) for support and advice. Associate Professor Irena Kaminska for precise guidance in the study.

References

- Adkitte R., Rane G.S., Yeole U., Nandi B., Gawai P. (2016). Effect of muscle energy technique on flexibility of hamstring muscle in Indian national football players. *Saudi Journal of Sports Medicine*, 16, 28–31. doi: 10.4103/1319-6308.173467.
- Brughelli M., Cronin J., Nosaka K. (2010). Muscle architecture and optimum angle of the knee flexors and extensors: a comparison between cyclists and Australian Rules football players. *The Journal of Strength & Conditioning Research*, 24, 717–721. doi: 10.1519/JSC.0b013e318197009a.
- Gioftsidou A., Beneka A., Malliou P. (2006). Soccer player's muscular imbalances: restaration with an isokinetic strength training program. *Journal of the perceptual and motor skills*, 103, 151–159. doi: 10.2466/PMS.103.5.151-159.
- Hawkins R.D., Hulse M.A., Wilkinson C., Hodson A., Gibson M. (2001). The association football medical research program: an audit of injuries in professional football. *Journal of Sports and Medicine*, 35, 43–47. doi: 10.1136/bjism.35.1.43.
- Koulouris G., Connell D. (2005). Hamstring muscle complex: an imaging review, *Radiological Society of North America. RadioGraphics*, 25, 571–586. doi: 10.1148/rg.253045711.

- Lubkina V., Kaupuzhs A., Uscha S., Rizhakova L., Chukmatsis A. (2013). Technology for testing the neuromuscular system, methods for its implementation. Latvia: Rezekne Higher Educational Institution.
- Lord J.P., Aitkens S.G., McCrory M.A., Bernauer E.M. (2002). Isometric and isokinetic measurement of hamstring and quadriceps strength. *Archives of physical medicine and rehabilitation*, 73, 324–330. doi: 10.1016/0003-9993(92)90004-g.
- Small K., McNaughton L., Greig M., Lovell R. (2009). Effect of timing of eccentric hamstring strengthening exercises during soccer training: implications for muscle fatigability. *Journal of Strength and Conditioning Research*, 23, 1077–1083. doi: 10.1519/JSC.0b013e318194df5c.
- Small K., McNaughton L., Greig M., Lovell R. (2010). The effects of multidirectional soccer-specific fatigue on markers of hamstring injury risk. *Journal of Science and medicine in Sport*, 13, 120–125. doi: 10.1016/j.jsams.2008.08.005.
- Struzik A., Pietraszewski B. (2019). Relationships between Hamstrings-to-Quadriceps Ratio and Variables Describing Countermovement and Drop Jumps. *Journal applied bionics and biomechanics*, 2, 4481–4505. doi.org/10.1155/2019/4505481.
- Tankevicius G., Lankaite D., Krisciunas A. (2013). Test-Retest Reliability of Biodex System 4 Pro for Isometric Ankle Eversion and Inversion Measurement. *Journal of Sport Rehabilitation*, 22, 212–215. doi: 10.1123/jsr.22.3.212.
- Teixeira J., Carvalho P., Moreira C., Santos R. (2012). Isokinetic Assessment of Muscle Imbalances and Bilateral Differences between Knee Extensores and Flexores' Strength in Basketball, Football, Handball and Volleyball Athletes. *International Journal of Sports Science*, 4, 1–6. doi: 10.5923/j.sports.20140401.01.
- McCall P. (2016). Functional Anatomy Series: The Hamstrings. Available at: <https://www.acefitness.org/education-and-resources/professional/prosource/june2016/5925/functional-anatomy-series-the-hamstrings/>

BIOLOĢIJA / BIOLOGY

EVALUATION OF YIELD FOR HEMP VARIETIES

Veneranda Stramkale, Larisa Černova, Inga Morozova, Aldis Stramkalis

Institute of Agricultural Resources and Economics, Crop Research Department at Vilani, Zinatnes street 2, Priekuli, Priekulu parish, Cesu district, Latvia, LV-4126, veneranda.stramkale@arei.lv

Abstract

Evaluation of yield for hemp varieties

Key Words: *hemp, variety, fiber, plant height, yield*

Introduction. Hemp is multifunctional, sustainable crop that provides raw material to a large number of traditional and innovative industrial applications. Have two types of hemp like seeds and fiber hems. Hemp varieties are distributed and adapted different environmental conditions.

Material and Methods. Varieties/line from diverse European and Latvian origin ('Adzelvieši', 'Pūriņi', 'KA-2-2011', 'Finola', 'Henola', 'USO 31', 'Futura 75', 'Austa') were sown in randomized field experiments in Latvia. Plant height dynamic, stem, fiber, shives yield and fiber contents were assessed across two growing seasons (2020–2021).

Results. Results show that hemp, seeds and fiber varieties/line, performed well giving high stem and fiber productivity by year and variety. Stem yield of seed hemp varieties/line ranged from 6.1 to 11.4 t ha⁻¹, fiber yield ranged from 3.2 to 5.2 t ha⁻¹ while shives yield ranged from 2.8 to 5.7 t ha⁻¹ while fiber contents from 23.4 to 36.3%. Stem yield of fiber hemp varieties ranged from 18.1 to 27.4 t ha⁻¹, fiber yield ranged from 8.8 to 12.3 t ha⁻¹, shives yield ranged from 8.5 to 13.6 t ha⁻¹ while fiber contents from 33.4 to 42.9%.

Conclusions. Agrometeorological conditions for hemp growth and yield were favourable in 2020. The dry conditions in Jun and extremely dry in July had a negative effect on the hemp plant height dynamic in 2021. In Latvian local climatic conditions the seed hemp line 'KA-2-2011' and fiber hemp variety 'Futura 75' exhibited the most valuable and perspective genotypes for highest stem yield, shives yield and fiber yield. The trial indicated that a higher fiber content from seeds hemp varieties had 'Henola' and from fiber varieties 'Austa'.

Kopsavilkums

Kaņepju šķirņu ražas izvērtējums

Atslēgvārdi: *kaņepe, šķirne, šķiedra, auga garums, raža*

Ievads. Kaņepes ir daudzfunkcionāls, ilgtspējīgs kultūraugs, ko izmanto kā tradicionālu un inovatīvu izejvielu dažādu industriālu produktu ražošanā. Ir divu tipu augi, kā sēklas un šķiedras kaņepes. Kaņepu šķirnes ir izplatītas un pielāgotas audzēšanai dažādos klimatiskos apstākļos.

Materiāli un metodes. Pētījumā izvērtētas dažādas Eiropas un Latvijas izcelsmes šķirnes/līnija ('Adzelvieši', 'Pūriņi', 'KA-2-2011', 'Finola', 'Henola', 'USO 31', 'Futura 75', 'Austa'). Izmēģinājums ierīkots randomizētos lauka apstākļos Latvijā. Pētījums tika ierīkots divus gadus (2020–2021) un novērtēta auga garuma dinamika, salmiņu, šķiedras, spaļu raža un šķiedras saturs.

Rezultāti. Rezultāti pierāda, ka sēklu un šķiedras kaņepēm bija augsta salmiņu un šķiedras produktivitāte atkarīga no ražas gada un šķirnes. Sēklu kaņepju šķirņu/līnijas salmiņu raža bija robežās no 6.1 līdz 11.4 tha⁻¹, šķiedras raža bija no 3.2 līdz 5.2 t ha⁻¹, spaļu raža bija robežās no 2.8 līdz 5.7 tha⁻¹ un šķiedras sastāvs no 23.4 līdz 36.3%. Šķiedru kaņepju šķirņu salmiņu raža bija robežās no 18.1 līdz 27.4 tha⁻¹, šķiedras raža bija no 8.8 līdz 12.3 tha⁻¹, spaļu raža bija no 8.5 līdz 13.6 tha⁻¹ un šķiedras sastāvs no 33.4 līdz 42.9%.

Secinājumi. Agrometeoroloģiskie apstākļi kaņepju augšanai un ražai bija labvēlīgi 2020. gadā. 2021. gadā sausie apstākļi jūnijā un ārkārtīgi sausie apstākļi jūlijā negatīvi ietekmēja kaņepju augu augšanu garumā. Atzīmēti vērtīgākie un perspektīvākie genotipi no sēklu kaņepēm līnija 'KA-2-2011' un šķiedras kaņepēm šķirne 'Futura 75' ar augstāku salmiņu, spaļu un šķiedras ražu Latvijas vietējos klimatiskajos apstākļos. Izmēģinājums konstatē, ka augstāks šķiedras saturs no kaņepju sēklu šķirnēm ir 'Henola' un no šķiedru šķirnēm 'Austa'.

Introduction

Industrial hemp (*Cannabis sativa* L.) is a high-yielding, environmentally friendly fiber crop (Ranalli et al., 2004), having great potential as a sustainable source of textile fiber, and is a multipurpose crop that, worldwide in the last decades, has been the object of a multitude of research projects and industrial enterprises (Amaducci et al., 2015; Clarke, 2016; Placet et al., 2017; Müssiga et al., 2018; Vandepitte et al., 2020). Moreover, tasks set maximizing the use of Latvia's

renewable natural raw materials in the production of various industrial, food and feed products in the Latvian Bioeconomy Strategy for 2030 require.¹ The current excessive demand for the analogous, long flax fiber (linen), which is primarily cultivated and processed in Western Europe, combined with increased customer awareness on the environmental impacts of cotton and synthetic fibers (Foundation, 2017), and an increasing public interest in locally produced goods, foster the prospects of hemp as a local source of textile fiber within the growing European bio-based economy (Vandepitte et al., 2020). The economic value of hemp can be maximized if all plant biomass (stems, inflorescences and seeds) is exploited; delaying harvest until the generative phase is completed (Calzolari et al., 2017).

Unlike cotton, world's most popular natural textile fiber, hemp cultivation requires little water and pesticides, and can positively contribute to crop rotation (Poisa et al., 2010; Vandepitte et al., 2020). Under natural conditions, Industrial hemp can be grown in a wide range of environments (Tang et al., 2016; Musio et al., 2018). Biomass and fiber yield are known to vary widely between hemp varieties, agronomic practices and environmental conditions (Strazds et al., 2012; Tang et al., 2016; Tang et al., 2017; Müssiga et al., 2018). Due to the climate and industrial hemp's growth cycle, Latvia is suitable place for growing industrial hemp. However, the best genotypes to cultivate in Latvia have yet to be determined. Therefore, in order to grow industrial hemp in Latvia as a valuable crop, it is important to find out the suitable industrial hemp varieties. The aim of this study was to evaluate different industrial hemp varieties suitability for fiber production under the agrometeorological conditions in Latvia.

Material and methods

Field trials. The field trial was carried out in Institute of Agricultural Resources and Economics, Priekuli Research Centre, Crop Research Department at Vilani in the middle of Latgale (56°34'10"N, 26°58'01"E) Latvia from 2020 to 2021. Experimental material for the study consisted of 8 hemp genotypes: seed hemp varieties/ line 'Adzelvieši', 'Pūriņi', 'KA-2-2011', 'Finola', 'Henola' and fiber hemp varieties 'USO 31', 'Futura 75', 'Austa'. The all seed hemp have varieties/line dioecious and fiber hemp varieties monoecious plants. Hemp was grown in a Humic Gleyic Podzol (WRB, 2014). The main agrochemical parameters of the arable soil layer were as follows: organic matter contents – 7.41, 6.60%, soil acidity (pH_{KCl}) – 6.61, 7.30, available P₂O₅ – 151, 199 mg kg⁻¹ and available K₂O – 112, 183 mg kg⁻¹ soil in years 2020 and 2021, respectively.

The field trials were laid out in a randomized block design of four replicates. Hemp was planted in 25m² plots. Seeds were sown during the first and second decade of May using an experimental sowing machine (SN-16) with an inter-row distance of 12.5 cm and seeding rate – 60 kg ha⁻¹. Complex fertilizer Yara Mila NPK(S) 18-11-13(7) 300 kg ha⁻¹ was applied after the first

¹ https://www.llu.lv/sites/default/files/2018-07/Bioeconomy_Strategy_Latvia_LV.pdf [10.02.2022]

cultivation of soil, 35 days after sowing, were fertilized with 60 kg ha⁻¹ of nitrogen, as recommended in a previous study (Tang et al., 2017).

Four sub-plot of 1 m² were selected, for each variety/line, at emergence to carry out analysis relative to plant height dynamic (of each genotype for 10 plants from four replicates and four times during the vegetation period), stem yield and to collect the stems needed for lab-decortication measurements. Harvesting was carried out using a grain harvester Sampo SR 2035 and reaper KD-210 (duplex type).

Meteorological conditions. Agro-meteorological conditions characteristics were used by Rezekne hydrometeorological station. In the study, hydrothermal coefficient (HTC) of each month was calculated during the growing season (Fig. 1). The calculations were performed using the formula (Selyaninov, 1928):

$$HTC = \Sigma x / \Sigma t \times 10,$$

where Σx is the total precipitation for the period (mm), Σt – the total temperature for the period, in which the average temperature exceeds 10°C.

Ranges of values of this index were classified according to Selyaninov coefficient modified by Skowera et al. (2014) as: extremely dry – $HTC \leq 0.4$, very dry – $0.4 < HTC \leq 0.7$, dry – $0.7 < HTC \leq 1.0$, relatively dry – $1.0 < HTC \leq 1.3$, optimal – $1.3 < HTC \leq 1.6$, relatively humid – $1.6 < HTC \leq 2.0$, humid – $2.0 < HTC \leq 2.5$, very humid – $2.5 < HTC \leq 3$ and extremely humid – $HTC > 3.0$.

Statistical analysis. Software Excel (Microsoft, USA) was used for data statistical analysis. The difference between the yields properties were determined using analysis of variance (ANOVA). Significant differences among the measured characteristics of hemp were compared by Fisher’s protected least significant difference (LSD) tests ($p \leq 0.05$).

Results

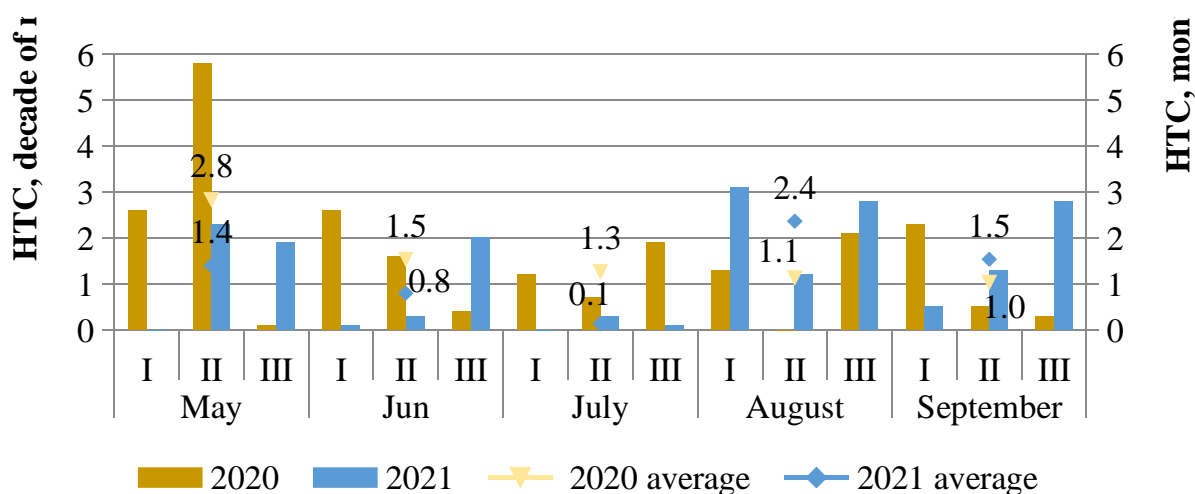


Figure 1. **Hydrothermal coefficient (HTC) of each decade of month and month average during 2020–2021 growing seasons of hemp**

The hydrothermal conditions (Fig. 1) during 2020–2021 growing seasons of hemp were differed. In 2020, HTC was 1.6 optimal; in 2021 it was 1.2 relatively dry. In 2021 were recorded dry conditions in Jun and extremely dry condition in July and very humid condition in August.

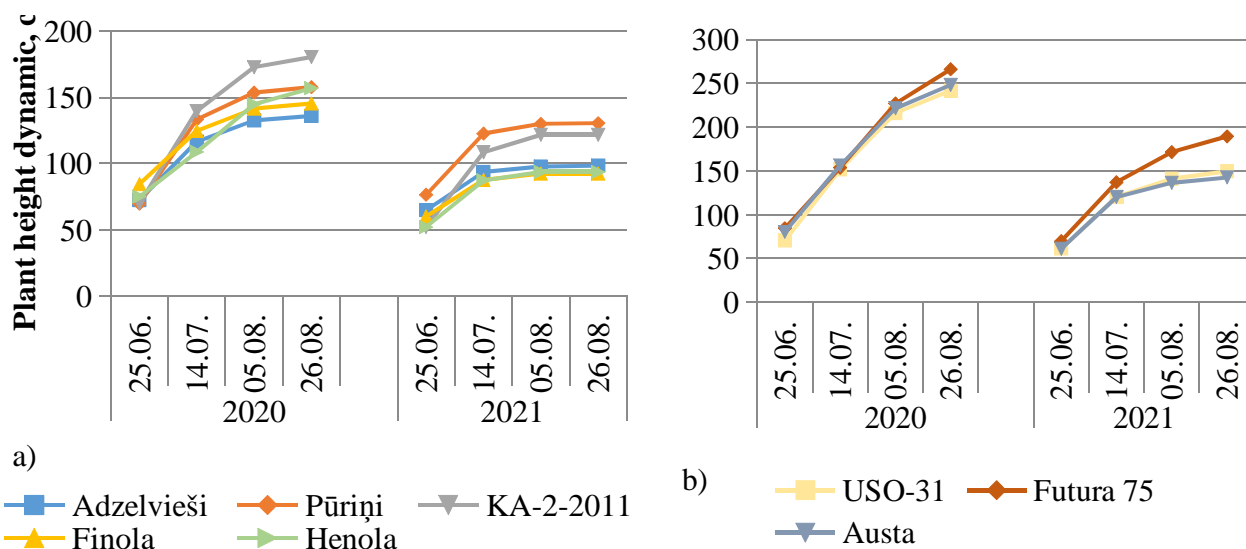


Figure 2. **Plant height dynamic of seed (a) and fiber (b) hemp varieties/line during 2020–2021 growing seasons**

One of the most important characteristic in determining hemp yield is plant height (Fig. 2). The plant height of hemp varieties of the fastest growth was observed for all varieties at the beginning of the vegetation period (end of June – beginning of July). The extremely dry conditions in July 2021 affected negative plant growth and at the very humid conditions in August the plants do not compensate for growth height. Lower growth rates were observed at the end of August for all hemp genotypes in the both years. The highest plant height from seed hemp varieties in the year with optimal conditions in 2020 was showed variety ‘Adzelvieši’ and at dry conditions in 2021 variety ‘Pūriņi’ and from fiber hemp varieties ‘Futura 75’ in both years. The highest plant height was observed in 2020 from 135.9 cm for the variety ‘Adzelvieši’ to 266.0 cm for the variety ‘Futura 75’.

The significant ($p \leq 0.05$) highest yield components were observed for seeds varieties/line in 2020 (Table 1). The line was harvested with significant ($p \leq 0.05$) higher stem, fiber and shives yield for ‘KA-2-2011’ in both years. Stem yield of seed hemp varieties/line ranged from 6.1 to 11.4 t ha⁻¹, fiber yield ranged from 3.2 to 5.2 t ha⁻¹ while shives yield ranged from 2.8 to 5.7 t ha⁻¹ for ‘Finola’ and ‘KA-2-2011’ respectively. The fiber content was influenced by variety and a significant ($p \leq 0.05$) highest was recorded in ‘Henola’ at 36.3% and the lowest in ‘Adzelvieši’ at 24.6%.

Table 1. The yield of seed hemp varieties/line of during 2020–2021 growing seasons

Factor	Stem yield, t ha ⁻¹	Fiber yield, t ha ⁻¹	Shives yield, t ha ⁻¹	Fiber content, %
Variety/line (factor A)				
<i>p-value</i>	<0.001	<0.001	<0.001	<0.001
<i>LSD_{0.05}</i>	0.15	0.20	0.18	0.43
‘Adzelvieši’	7.2 ^d	3.5 ^c	3.4 ^d	24.6 ^d
‘Pūriņi’	9.2 ^b	4.0 ^b	4.6 ^b	23.4 ^e
‘KA-2-2011’	11.4 ^a	5.2 ^a	5.7 ^a	25.6 ^c
‘Finola’	6.1 ^f	3.2 ^d	2.8 ^f	26.9 ^b
‘Henola’	8.0 ^c	4.1 ^b	3.6 ^c	36.3 ^a
Year (factor B)				
<i>p-value</i>	<0.001	0.208	<0.001	<0.001
<i>LSD_{0.05}</i>	0.10	0.13	0.12	0.27
2020	8.7 ^a	4.0	4.5 ^a	28.6 ^a
2021	8.1 ^b	3.9	3.5 ^b	26.0 ^b

abcdf – means followed by the same letters in each column are not statistically significant.

The highest yield components were recorded for fiber hemp varieties (Table 2). The significant ($p \leq 0.05$) highest yield components were observed for fiber hemp varieties in 2020, similar to seed hemp varieties/line. Stem yield of fiber hemp varieties ranged from 18.1 to 27.4 t ha⁻¹, fiber yield ranged from 8.8 to 12.3 t ha⁻¹ while shives yield ranged from 8.5 to 13.6 t ha⁻¹. The variety was harvested with significant ($p \leq 0.05$) higher stem, fiber and shives yield for ‘Futura 75’ (27.4, 12.3 and 13.6 t ha⁻¹ respectively) in both years. The significant ($p \leq 0.05$) highest fiber content was recorded in ‘Austa’ at 42.9% and the lowest in ‘USO-31’ at 33.4%.

Table 2. The yield of fiber hemp varieties during 2020–2021 growing seasons

Factor	Stem yield, t ha ⁻¹	Fiber yield, t ha ⁻¹	Shives yield, t ha ⁻¹	Fiber content, %
Variety (factor A)				
<i>p-value</i>	<0.001	<0.001	<0.001	<0.001
<i>LSD_{0.05}</i>	0.19	0.28	0.26	0.40
‘USO-31’	18.2 ^b	8.8 ^c	8.5 ^b	33.4 ^b
‘Futura 75’	27.4 ^a	12.3 ^a	13.6 ^a	34.7 ^b
‘Austa’	17.1 ^c	9.4 ^b	6.9 ^c	42.9 ^a
Year (factor B)				
<i>p-value</i>	<0.001	<0.001	<0.001	<0.001
<i>LSD_{0.05}</i>	0.15	0.23	0.21	0.33
2020	23.2 ^a	10.9 ^a	11.6 ^a	41.3 ^a
2021	18.6 ^b	9.4 ^b	7.6 ^b	32.7 ^b

abc – means followed by the same letters in each column are not statistically significant.

Discussion

The study noted that the moisture supply of hemp in the first half of the vegetation period is significant in plant growth height. A study by Struik et al. (2000) reveals that the hemp is very sensitive to shortage or excess water during the early stages of growth. According to Strazds et al. (2012) precipitation in June and July has a decisive effect on productivity, for hemp requiring 250

to 300 mm during vegetation. Analysing the genetic response at different meteorological conditions the trials indicated the highest height of seeds hemp line 'KA-2-2011' at optimal conditions however variety 'Pūriņi' at dry conditions.

Analysing the results stem, fiber, shives yield and plant height were dependent on year (factor B) and variety/line (factor A). Campbell et al. (2019) and Baldini et al. (2020) similarly found that meteorological conditions are one of the main factors influencing hemp yield. In general, increased precipitation led to higher yields, but genotypes did not respond in a uniform manner. In the study, varieties with higher yield data also showed higher yields independent of the year. Regarding hemp varieties/line were identified genotypes are more suitable for local conditions from seed hems line 'KA-2-2011' and fiber hems variety 'Futura 75'.

The data about fiber content was supported that the trait is largely controlled by genetic factors (factor A), but there was a significant effect of environmental factors (factor B). The varieties that are significant highest fiber contents independent higher yield like stem, fiber or shives were identified.

The seed hemp varieties/line was observed that suitable for extraction of stem and fiber yield. In the study, compared average years the yield of stem for seed hemp varieties was 7% lower, but for fiber hemp varieties was 20% lower in 2021. Regarding fiber contents, seed hemp varieties were 10% lower, but fiber hemp varieties was 21% lower in 2021. In the case of hemp types identified that stem yield and fiber contents have the highest difference of fiber hemp under environmental conditions.

Conclusions

1. Agrometeorological conditions for hemp growth and yield were favourable in 2020.
2. The dry conditions in Jun and extremely dry in July had a negative effect on the hemp plant height dynamic in 2021. The trials indicated the highest height of seeds hemp line 'KA-2-2011' in 2020 and variety 'Pūriņi' in 2021, between fibre hemp varieties 'Futura 75'.
3. In Latvian local climatic condition the seed hemp line 'KA-2-2011' and fiber hemp variety 'Futura 75' exhibited most valuable and perspective genotypes for highest stem yield (11.4 and 27.4 t ha⁻¹), shives yield (5.7 and 13.6 t ha⁻¹) and fiber yield (5.2 and 12.3 t ha⁻¹), respectively.
4. The trial indicated that a higher fiber content from seeds hems variety 'Henola' (36.3%) and from fiber hems variety 'Austa' (42.9%).

Acknowledgements

Project "Innovative solutions for the treatment and processing of industrial hemp" (No. 18-00-A01612-000026) supported by the European agricultural fund for rural development (EAFRD).

References

- Amaduccia S., Scordiab D., Liuc F.H., Zhangd Q., Guod H., Testab G., Cosentinob S.L. 2015. Key cultivation techniques for hemp in Europe and China. In: *Industrial Crops and Products*. Vol. 68, pp. 2–16.
- Calzolari D., Magagnini G., Lucini L., Grassi G., Appendino G., Amaducci S. 2017. High added-value compounds from Cannabis threshing residues. In: *Industrial Crops and Products*. Vol. 198, pp. 558–563.
- Campbell B.J., Berrada A.F., Hudalla C., Amaducci S., McKa J.K. 2019. Genotype × Environment Interactions of Industrial Hemp Cultivars Highlight Diverse Responses to Environmental Factors. In: *Agrosystems Geosciences & Environment*. Vol. 2, Article 180057.
- Clarke R.C., Merlin M.D. 2016. Cannabis domestication, breeding history, present-day genetic diversity, and future prospects. In: *Critical Reviews in Plant Sciences*. Vol. 35 (5–6), pp. 293–327
- Baldini, M., Ferfuia, C., Zuliani, F., Danuso, F. 2020. Suitability assessment of different hemp (*Cannabis sativa* L.) varieties to the cultivation environment. In: *Industrial Crops and Products*. Vol. 143, Article 111860.
- Foundation E.M. 2017. *A New Textiles Economy: Redesigning Fashion's Future*. [skatīts 10.02. 2022]. Pieejams (Accessed): https://www.circularonline.co.uk/wp-content/uploads/2017/11/A-New-Textiles-Economy_Full-Report.pdf
- Musio S., Müssig J., Amaducci S. 2018. Optimizing Hemp Fiber Production for High Performance Composite Applications. In: *Frontiers in Plant Science*. Vol. 9, Article 1702.
- Müssiga J., Amaduccib S. 2018. Scanner based image analysis to characterise the influence of agronomic factors on hemp (*Cannabis sativa* L.) fibre width. In: *Industrial Crops and Products*. Vol. 113, pp. 28–37.
- Placet V., Day A., Beaugrand J. 2017. The influence of unintended field retting on the physicochemical and mechanical properties of industrial hemp bast fibres. In: *J. Mater. Sci*. Vol. 52, pp. 5759–5777.
- Poisa, L., Adamovics, A. 2010. Hemp (*Cannabis sativa* L.) as an Environmentally Friendly Energyplant. *Sci. J. Riga Tech. Univ. Environ. Clim. Technol.* Vol. 5, pp. 80–85.
- Ranalli P., Venturi G. 2004. Hemp as a raw material for industrial applications. In: *Euphytica* Vol. 140, pp. 1–6.
- Selyaninov G.T. 1928. About climate agricultural estimation. In: *Proceedings of Agricultural Meteorology*. Vol. 20, pp. 165–177.
- Skowera B., Jędrszczyk E., Kopcińska J., Ambroszczyk A.M., Kołton A. 2014. The effects of hydrothermal conditions during vegetation period on fruit quality of processing tomatoes. In: *Polish Journal of Environmental Studies*. Vol. 23 (1), pp. 195–202.
- Strazds, G., Stramkale, V., Laizans, T. 2012. Ieteikumi rupniecisko kanepju audzetajiem un parstradatajiem. Praktiska rokasgramata. Rīga: Izdevejs SIA “Biznesa augstskola Turība”.
- Struik P.C., Amaduccia S.M., Bullard J., Stutterheim N.C., Venturi G., Cromack H.T.H. 2000. Agronomy of fibre hemp (*Cannabis sativa* L.) in Europe. In: *Industrial Crops and Products*. Vol. 11 (2–3), pp. 107–118.
- Tang K., Struik P.C., Yin X., Calzolari D., Musio S., Thouminot C., Bjelková M., Stramkale V., Magagnini G., Amaducci S. 2017. A comprehensive study of planting density and nitrogen fertilization effect on dual-purpose hemp (*Cannabis sativa* L.) cultivation. In: *Industrial Crops and Products*. Vol. 107, pp. 427–438.
- Tang K., Struik P.C., Yin X., Thouminot C., Bjelková M., StramkaleV., Amaducci S. 2016. Comparing hemp (*Cannabis sativa* L.) cultivars for dual-purpose production under contrasting environments. In: *Industrial Crops and Products*. Vol. 87, pp. 33–44.
- Vandepitte K., Vasileb S., Vermeireb S., Vanderhoevenb M., der Borgha W.V., Latréa J., Raeveb A.D., Trocha V. 2020. Hemp (*Cannabis sativa* L.) for high-value textile applications: The effective long fiber yield and quality of different hemp varieties, processed using industrial flax equipment. In: *Industrial Crops and Products*. Vol. 158, Article 112969.
- WRB. 2014. World reference database for soil resources. In: World soil resources report No. 106. FAO, pp. 187–189.

SHORT-TERM IMPACT OF FERTILIZATION ON WOOD VOLUME INCREMENT DEPENDING ON DOMINANT TREE SPECIES AND FOREST SITE TYPE

Guna Petaja, Viktorija Vendiņa, Sindija Žīgure

LSFRI 'Silava', Rigas street 111, Salaspils, Latvia, LV-2169, guna.petaja@silava.lv

Abstract

Short-term impact of fertilization on wood volume increment depending on dominant tree species and forest site type

Key Words: forest fertilization, ammonium nitrate, wood ash, volume increment

Fertilization is a useful silvicultural practice to improve tree growth and to increase timber output. Forests on mineral soils are mostly fertilized with nitrogen-containing fertilizers, whereas peatland forests require potassium and phosphorus fertilizers. This study evaluated the impact of fertilization on forest stands representing different site types and dominant tree species. Fertilization experiments were carried out in 42 forest stands all over Latvia. Wood ash was spread in Norway spruce stands with organic and mineral soils. Ammonium nitrate was spread in mature Scots pine, Norway spruce and Silver birch stands, as well as in middle-aged and young stands considering repeated fertilization after thinning. Both ammonium nitrate and wood ash were applied as a complex fertilizer in Scots pine, Norway spruce and Silver birch stands with drained organic and mineral soils and moist mineral soils. In all the experiments, except for the stands, where growth had been significantly affected by natural disturbances, the applied fertilizer provided a considerable additional increase of the volume increment comparing with the control areas already during the first 2–3 years, however the differences were not statistically significant. The most stable additional increment regardless of forest site type and distance between trees was found in pine stands.

Kopsavilkums

Meža mēslošanas īstermiņa ietekme uz krājas papildpieaugumu, atkarībā no valdošās koku sugas un meža tipa

Atslēgvārdi: meža mēslošana, amonija nitrāts, koksnes pelni, krājas pieaugums

Mēslošana ir noderīga mežsaimnieciska darbība, lai uzlabotu koku augšanu un palielinātu iegūstamo kokmateriālu daudzumu. Mežos ar minerālaugsnēm pārsvarā izmanto slāpekli saturošu mēslojumu, savukārt kūdreņu mežiem nepieciešams kālija un fosfora mēslojums. Šajā pētījumā novērtēta mēslošanas ietekme mežaudzēs, kas pārstāv dažādus meža tipus un valdošās koku sugas. Mēslošanas izmēģinājumi veikti 42 mežaudzēs visā Latvijā. Koksnes pelni izkaisīti parastās egles audzēs ar organiskām un minerālaugsnēm. Amonija nitrāts kaisīts pieaugušās parastās priedes, parastās egles un āra bērza audzēs, kā arī vidēja vecuma un jaunaudzēs, paredzot atkārtotu ienesi pēc kopšanas circes. Amonija nitrāts izmantots kopā ar koksnes pelniem kā kompleksais mēslojums parastās priedes, parastās egles un āra bērza audzēs ar nosusinātām organiskajām un minerālaugsnēm un mitrām minerālaugsnēm. Visos izmēģinājumos, izņemot audzes, kur augšanu būtiski ietekmējuši dabiskie traucējumi, jau pirmajos 2–3 gados izlietotais mēslojums nodrošināja ievērojamu krājas papildpieaugumu salīdzinājumā ar kontroles platībām, taču atšķirības nebija statistiski būtiskas. Vislielākais papildpieaugums konstatēts priedes audzēs neatkarīgi no meža tipa un attāluma starp kokiem.

Introduction

The demand for woody biomass-derived energy is increasing, since it is a sustainable alternative for fossil fuels and has a potential to mitigate climate change. Forest fertilization can be a valuable tool in optimizing the efficiency of a forest and enhancing the yield of timber. Recently, forest fertilization has been regaining popularity in the Nordic countries as a result of the demand for sustainable energy production.

Extensive forest fertilization methods have been used in the Nordic countries since the 1970s, applying nitrogen fertilizer to forest stands 5–15 years before regeneration felling. The history and approaches of the use of wood ash in forests for soil liming and fertilization vary among countries. In Finland wood ash has been used as soil ameliorant in forests for more than 80 years, whereas in Sweden, efforts to recycle ash and use it in forests on peat and podzol soils began in the 1970s

(Högbom and Nohrstedt 2001; Pitman 2006; Huotari et al. 2015). The beginning of forest fertilization in Latvia could be considered the afforestation trials of dunes and heaths, which began in 1950. The largest studies on forest fertilization were conducted in the early 70s of the last century by Visvaldis Kāposts and Rūdis Sacenieks. The forest fertilization trials were set up at the Forest Research Station in Jaunkalsnava. From 1968, forest fertilization began to be applied on a larger scale in middle-aged and mature conifer stands, investigating different ways to optimize the fertilizer dose and nutrient ratio per stand under different forest growth conditions, in both upland and peatland forests (Капостс, Сацениекс 1977). Forest fertilization was officially discontinued in 1989 due to the expenses associated with aviation services (Špalte 1991). Recently in Latvia a large-scale study has been carried out to gather knowledge to potentially reintroduce the practice. This study focused not only on tree growth, but also on various environmental indicators, to gain a better understanding and to mitigate the potentially negative environmental impact (LVMI Silava 2021).

The nutrients that usually limit plant growth are nitrogen (N), phosphorus (P) and potassium (K). Nitrogen fertilizers, such as ammonium nitrate (NH_4NO_3), are mostly used in forests on mineral soils. The dose of N applied is 150 kg ha^{-1} and the following growth response of trees is $20\text{--}25 \text{ m}^3\text{ha}^{-1}$ (Pukkala 2017). Along with increasing rate of woody biomass combustion, increased production of the solid waste byproduct – ash – is expected. The major elements of wood ash include calcium (Ca), potassium (K), magnesium (Mg), phosphorus (P), manganese (Mn), and sodium (Na); however the physical and chemical characteristics depend on the type of wood and the combustion technology used. The recommended dose of P for peatland forests is $40\text{--}50 \text{ kg ha}^{-1}$ and that of K is $40\text{--}80 \text{ kg ha}^{-1}$, corresponding to $2000\text{--}5000 \text{ kg}$ dry weight of wood ash (Sikström, Almqvist, Jansson 2010). Often wood ash alone cannot improve tree growth in nitrogen-poor sites, but it can be applied in combination with NH_4NO_3 .

The aim of the study was to evaluate the impact of fertilization on tree growth in forest stands representing different site types and dominant tree species.

Materials and methods

Forest fertilization study sites were established in 2015–2017, except for the wood ash fertilization site, which was partially set up already in the autumn of 2014. Forest stands were mainly chosen on the basis of tree species and forest site type, where Scots pine, Silver birch or Norway spruce were either the dominant species or make up at least 70% of the total growing stock. Stands available for the final felling within 10–20 years were chosen.

The total area of the forest fertilization study was 231.6 ha, from which 85.7 ha were fertilized areas. In total, the effect of fertilization has been investigated in 64 forest stands, where the dominant tree species are Scots pine, Norway spruce and Silver birch. In this paper 42 study sites are analyzed (159.3 ha). Study sites are shown in Figure 1.

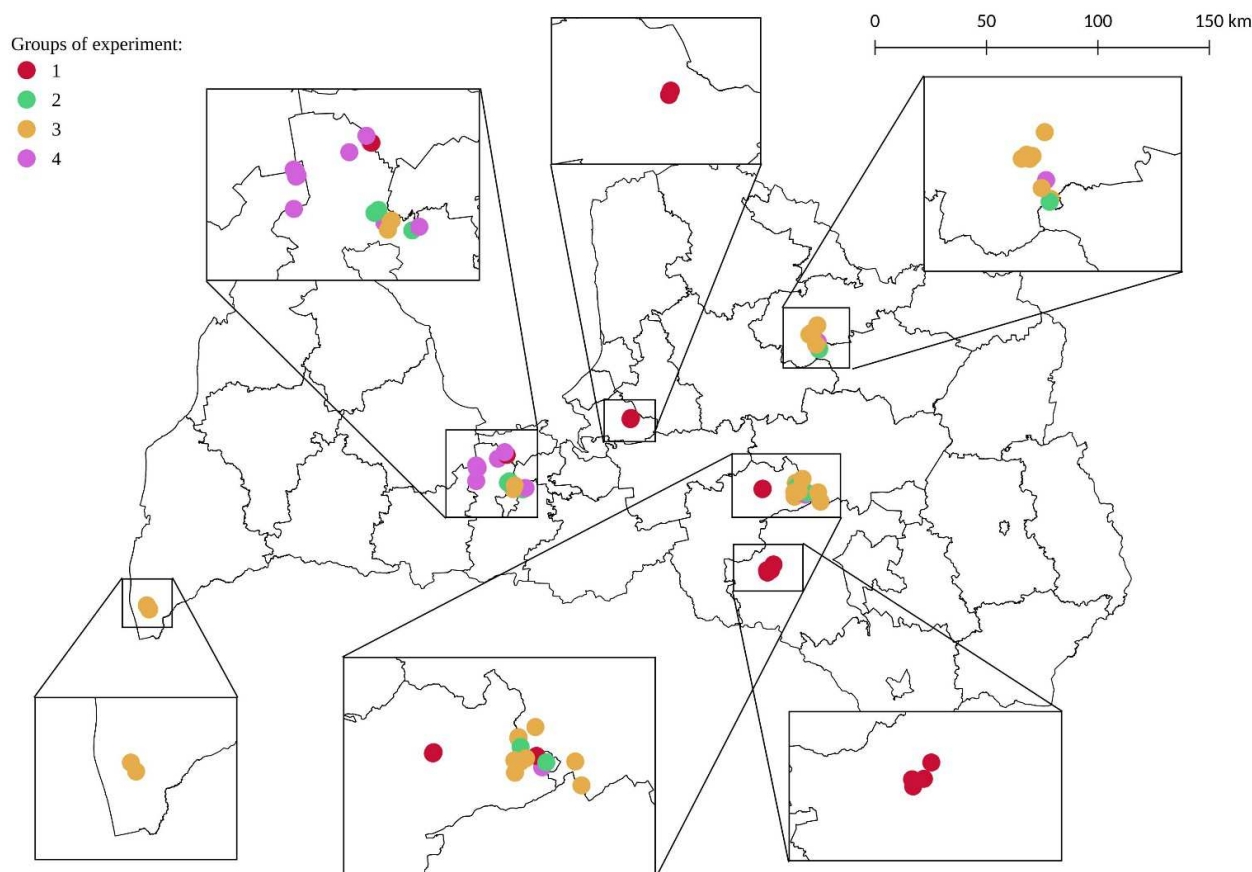


Figure 1. Forest fertilization study sites in Latvia

1 – Wood ash applied in Norway spruce stands in upland and drained peatland forests, 2 – Ammonium nitrate applied in pre-mature conifer and Silver birch stands, 3 – Ammonium nitrate applied in young and middle-aged conifer and Silver birch stands, considering repeated fertilization after thinning, 4 – Ammonium nitrate and wood ash applied in middle-aged conifer and Silver birch stands on drained organic and mineral soils.

In all the study sites control and fertilized plots were established. There were two types of sample plots – circular with an area of 500 m² and square with an area of 400 m². In study sites with circular plots, fertilizers were spread in strips using forest machinery. Square plots were established in areas, where fertilizers were spread manually. The distance between the sample plots should be at least 40 m and the distance from the edge of the stand – at least 20 m. About 3 m wide buffer strip was established around the plot, where the fertilizer was also spread. Prior to the use of fertilizers, reference data was collected in the control areas and areas planned to be fertilized. Forest stand characteristics were determined in according to the ICP Forests methodology for Level II plots (Dobbertin & Neumann, 2020), establishing circular monitoring plots for continuous tree growth measurements. The scheme of sample plots is shown in Figure 2. and, in a larger zoom, Figure 3.

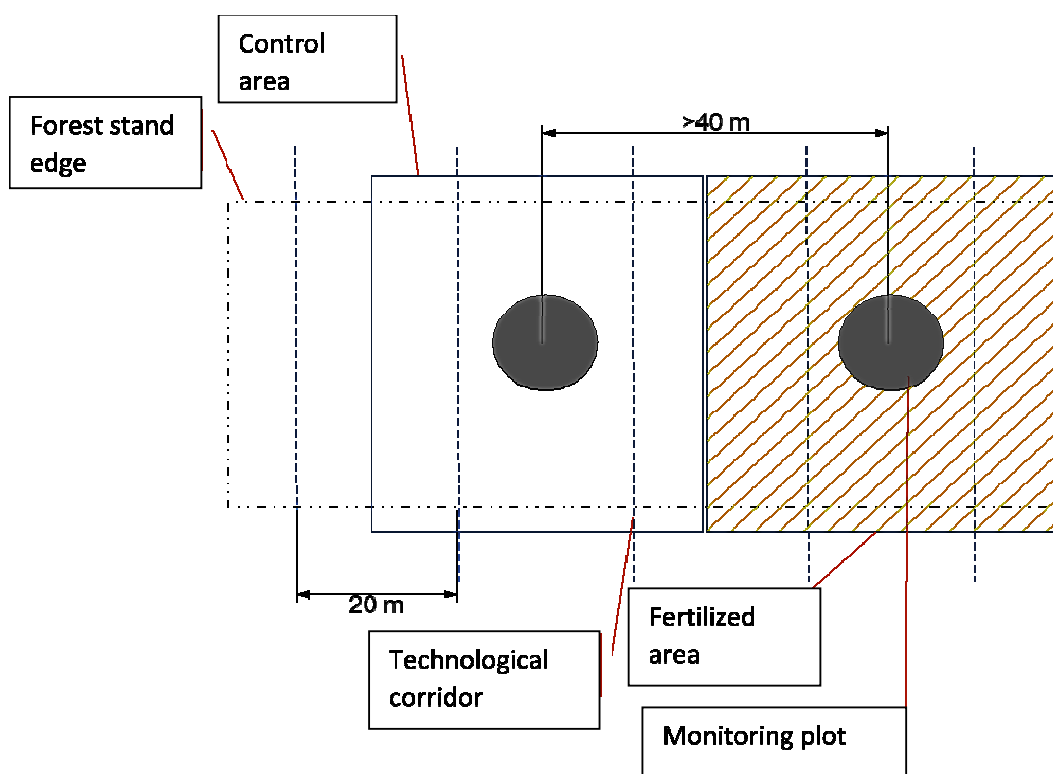


Figure 2. A scheme of control and fertilized sample plots

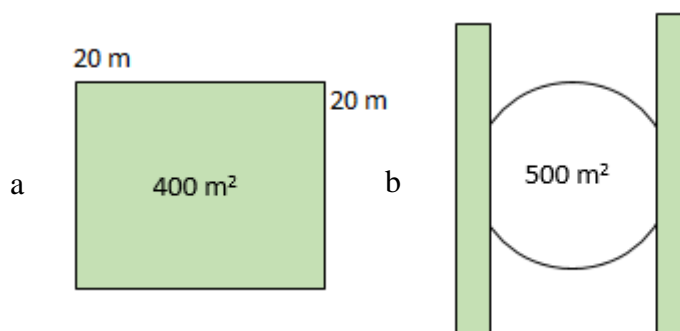


Figure 3. Sample plots of forest fertilization experiments: a) square, b) round

Wood ash was spread in spruce stands with organic and mineral soils. Ammonium nitrate (NH_4NO_3) was spread in mature pine, spruce and birch stands, as well as in middle-aged and young stands considering repeated fertilization after thinning. The research focused on the use of N fertilizer – NH_4NO_3 , without setting up additional experiments with a complex N and phosphorus (P) fertilizer, in order to evaluate the aspects of forest fertilization related to reducing the impact on the environment, which in previous studies in the Nordic countries are directly related to N fertilizers. The lack of this experiment is partially compensated by the experiment, which uses NH_4NO_3 and wood ash (contains K and P) together. Urea or carbamide (N content 46%) is also known as a N containing fertilizer; however it breaks down faster in hot weather and ammonia gas is released in the atmosphere.

Data were processed and analyzed with Microsoft Excel and RStudio.

Results and discussion

In most of the experiments the largest increase of volume increment in fertilized plots, comparing with the control plots, was measured in Scots pine stands (up to $0.6 \text{ m}^3 \text{ m}^{-2}$), but the smallest increase – in Silver birch stands. The increase of increment in Norway spruce stands vary between experiments. Figure 1 shows the difference of increase of annual volume increment between control and fertilized plots in stands of different dominant tree species.

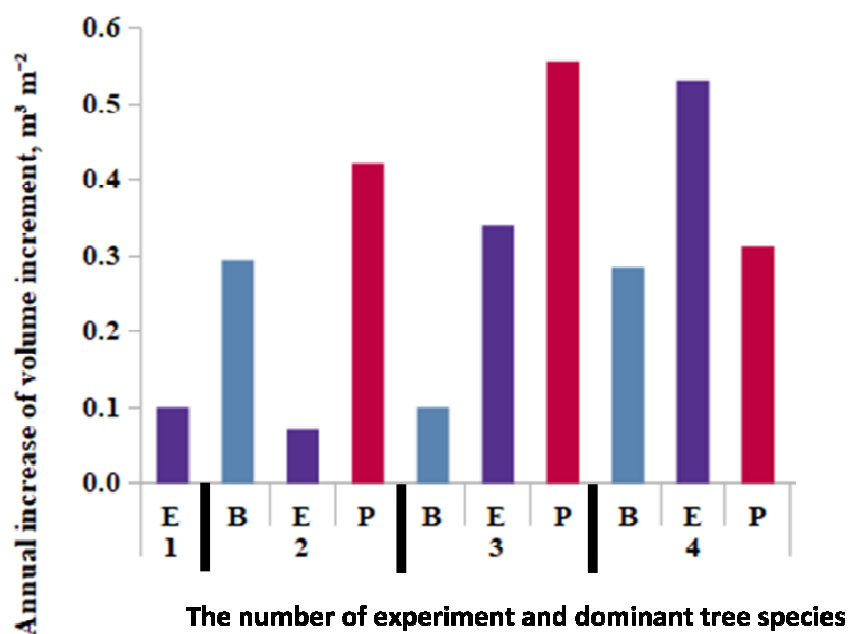


Figure 4. Increase of volume increment, depending on the experiment and dominant tree species

E – Norway spruce, B – Silver birch, P – Scots pine, 1 – Wood ash applied in Norway spruce stands in upland and drained peatland forests, 2 – NH_4NO_3 applied in pre-mature conifer and Silver birch stands, 3 – NH_4NO_3 applied in young and middle-aged conifer and Silver birch stands, considering repeated fertilization after thinning, 4 – NH_4NO_3 and wood ash applied in middle-aged conifer and Silver birch stands on drained organic and mineral soils.

When applying NH_4NO_3 in pre-mature conifer and Silver birch stands, the smallest increase of volume increment was measured for Norway spruce, whereas, when using NH_4NO_3 together with wood ash in drained forests, Norway spruce stands showed the largest increase. This may indicate that Norway spruce stands and other stands with a significant proportion of Norway spruce require a complex fertilizer, which includes other elements besides nitrogen such as phosphorus and potassium.

In Norway spruce stands in upland and drained peatland forests, the average annual volume increment in areas, where wood ash has been spread, is $9.7 \text{ m}^3 \text{ ha}^{-1}$ and difference between volume increment in control and fertilized areas 5 years after fertilization is $0.2 \text{ m}^3 \text{ ha}^{-1}$ or 30% annually. The largest difference between control and fertilized plots is in spruce stands with drained organic

soil ($1.4 \text{ m}^3 \text{ ha}^{-1}$ annually). In stands with drained mineral soil the difference was smaller almost by half ($0.8 \text{ m}^3 \text{ ha}^{-1}$ annually), whereas in a mesotrophic upland forest stands in fertilized areas the increase was smaller comparing with control areas. In Norway spruce stands there is a tendency in both control and fertilized areas for volume increment to increase along with increasing distance between trees (Figure 2). Significant differences between control and fertilized plots were not found.

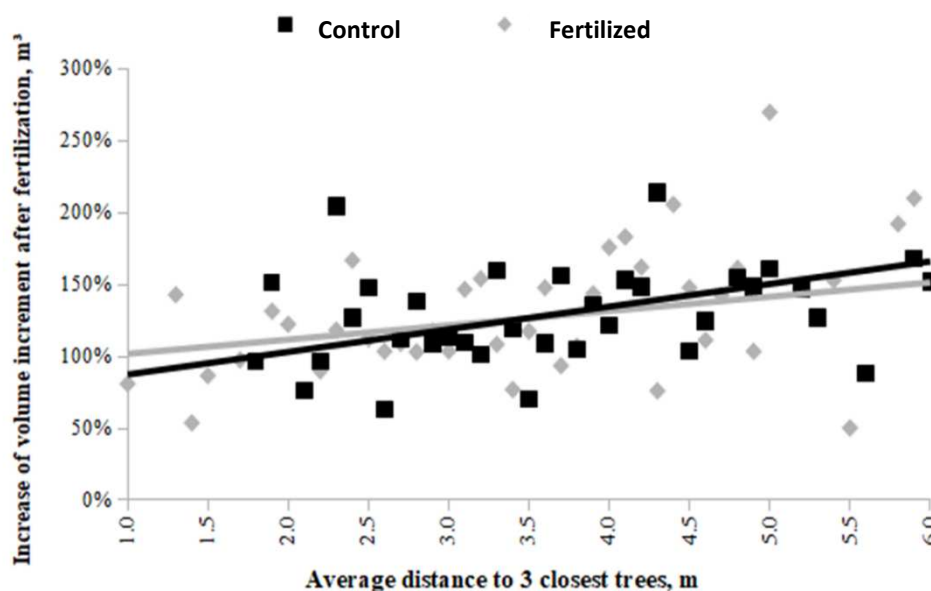


Figure 5. Increase of volume increment 5 years after fertilization in control and fertilized areas depending on the average distance to 3 closest trees in Norway spruce stands, where wood ash was spread

In pre-mature conifer and Silver birch stands, where NH_4NO_3 had been applied, the average annual increment in fertilized areas was $12.3 \text{ m}^3 \text{ ha}^{-1}$ (an increase by 18% comparing with measurements before fertilization). The difference of increment between control and fertilized plots after fertilization was $1.9 \text{ m}^3 \text{ ha}^{-1}$ annually. The largest difference between control and fertilized plots ($2.6 \text{ m}^3 \text{ ha}^{-1}$ annually) was measured in Scots pine stands. The difference is almost three times smaller in birch stands ($1.0 \text{ m}^3 \text{ ha}^{-1}$ annually). The difference is the smallest in spruce stands ($0.4 \text{ m}^3 \text{ ha}^{-1}$ annually).

In Silver birch stands, where NH_4NO_3 has been applied, the increase of volume increment in the control plots did not change significantly with increasing distance between trees. In the fertilized areas there is a significant increase in growth if the trees are further apart, whereas, if the distance between trees is less than 3.5 m, an increase in volume increment comparing with the 5-year period before fertilization is not observed (Figure 3).

In Norway spruce stands in plots, where the effect of NH_4NO_3 has been applied, the increase in volume increment in the control plots was smaller, when distance between trees increased. If the distance between the trees exceeds 3 m, the average volume increment increase in the control areas

is lower than 5 years before fertilization. The fertilized areas also show a decreasing trend with increasing distance between trees, but it is less pronounced and, regardless of the distance between trees, it increases more than prior to fertilization (Figure 4).

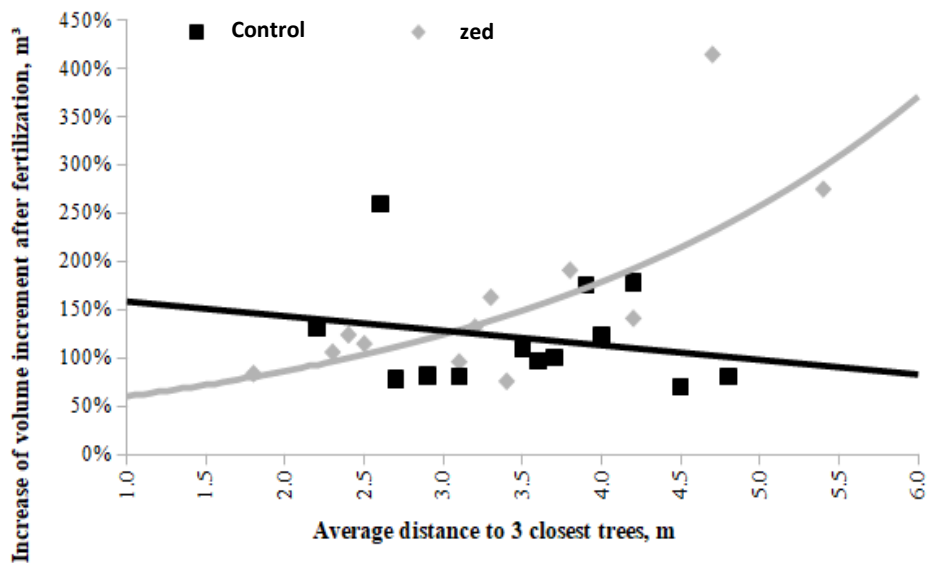


Figure 6. Increase of volume increment 5 years after fertilization in control and fertilized areas in Silver birch stands, where NH_4NO_3 has been applied, depending on the average distance to 3 closest trees

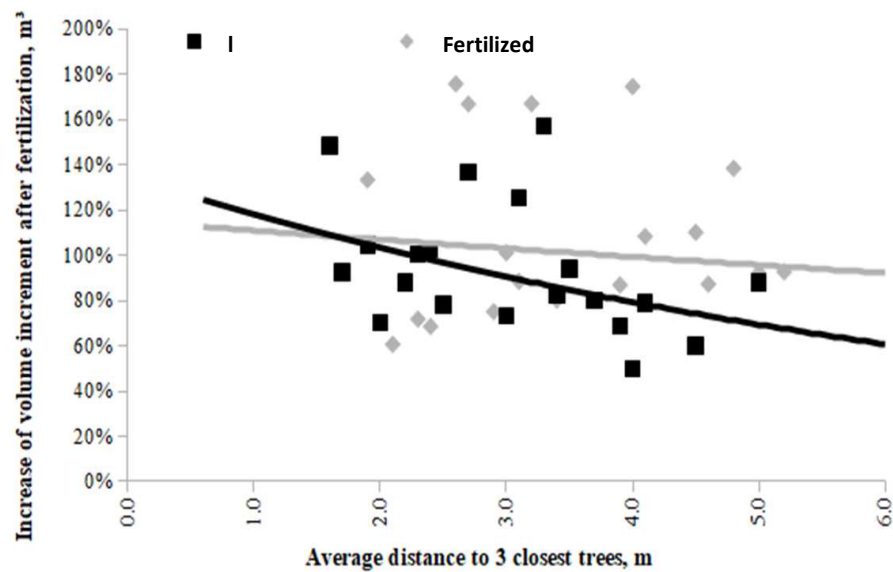


Figure 7. Increase of volume increment 5 years after fertilization in control and fertilized areas in Norway spruce stands, where NH_4NO_3 has been applied, depending on the average distance to 3 closest trees

In Scots pine stands the distance between the trees does not significantly affect tree growth in both control and fertilized areas. In fertilized areas volume increment is on average larger by 25% than in the 5-year period before fertilizer application. Also the increase in areas fertilized with NH_4NO_3 is higher than in control areas.

When using NH_4NO_3 in young and middle-aged stands, in fertilized areas the increase of volume increment is $10.7 \text{ m}^3 \text{ ha}^{-1}$ annually (by 24% larger than before fertilization), but the difference between control and fertilized areas after application of fertilizers is $1.1 \text{ m}^3 \text{ ha}^{-1}$ annually. The largest difference between volume increment values ($1.4 \text{ m}^3 \text{ ha}^{-1}$ annually) in control and fertilized areas is in pine stands, but the smallest – in birch stands ($0.2 \text{ m}^3 \text{ ha}^{-1}$ annually). When using NH_4NO_3 in young and middle-aged birch stands, only in the oligomesotrophic upland forest stands the difference between control and fertilized plots is statistically significant ($1.1 \text{ m}^3 \text{ ha}^{-1}$ annually). In stands of other site types it is only $0.1 \text{ m}^3 \text{ ha}^{-1}$ annually. In meso-eutrophic spruce stands the increase of increment in fertilized plots is almost 3 times larger comparing with a less fertile site type (2.1 un $0.6 \text{ m}^3 \text{ ha}^{-1}$ annually, respectively). In pine stands the increase of increment between control and fertilized plots in a slightly less fertile and more fertile upland site are similar – 1.2 and $1.5 \text{ m}^3 \text{ ha}^{-1}$ annually.

In young and middle-aged birch stands, in both control areas the increase of volume increment does not change significantly along with increasing distance between trees, but in fertilized areas the increase is higher, when trees are further apart from one another. In the control areas, regardless of the distance between the trees, the increase in recent years has been smaller than in the period before the application of fertilizer (Figure 5). In this case it might be related to the stress caused by thinning.

In Norway spruce stands of the same experiment, where NH_4NO_3 was applied, a similar, but more pronounced, trend is observed, and the increase in fertilized and control areas in the period following fertilizer application is higher than in the 5-year period before fertilization (Figure 6).

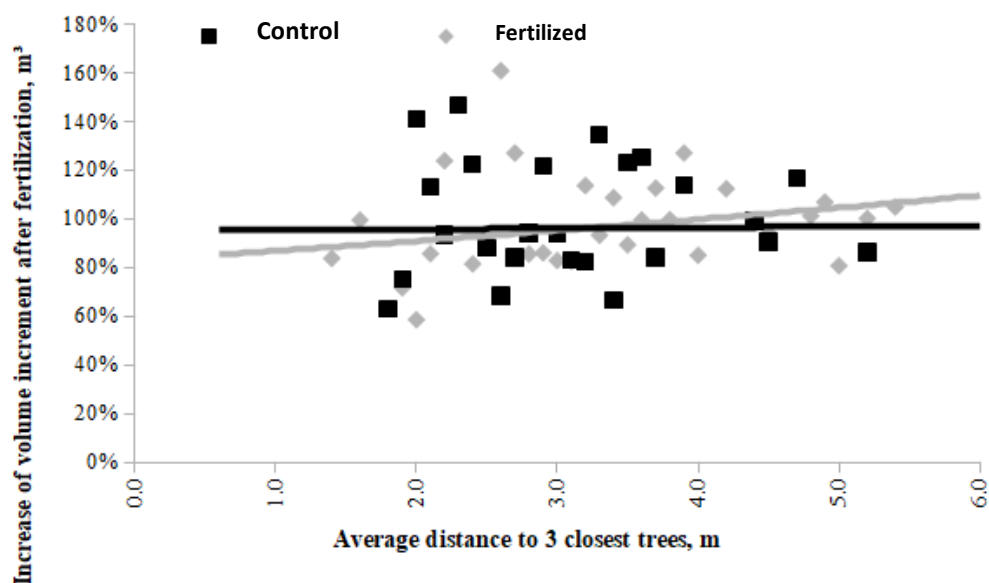


Figure 8. Increase of volume increment 5 years after fertilization in control and fertilized areas in young and middle-aged Silver birch stands, where NH_4NO_3 has been applied, depending on the average distance to 3 closest trees

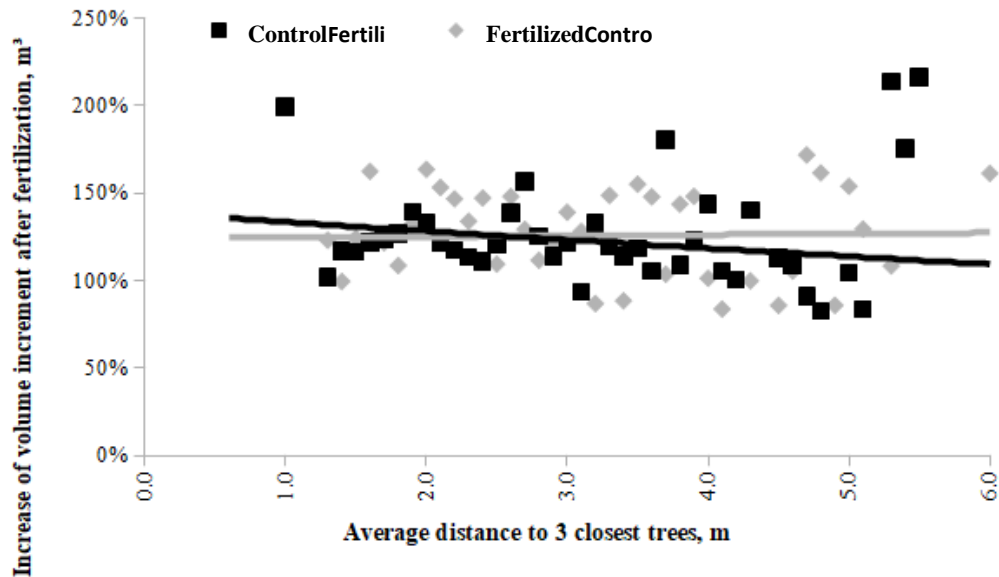


Figure 9. Increase of volume increment 5 years after fertilization in control and fertilized areas in young and middle-aged Norway spruce stands, where NH_4NO_3 has been applied, depending on the average distance to 3 closest trees

In Scots pine stands the increase of increment in control plots in the period following fertilizer application is higher than in the previous 5 years only in young stands where the average distance between trees does not exceed 2.5 m, but with increasing distance between trees, there is a decreasing trend. In the plots where fertilizer was applied, the volume increment increases with the distance between the trees. This tendency is observed in both young and middle-aged stands (Figure 7).

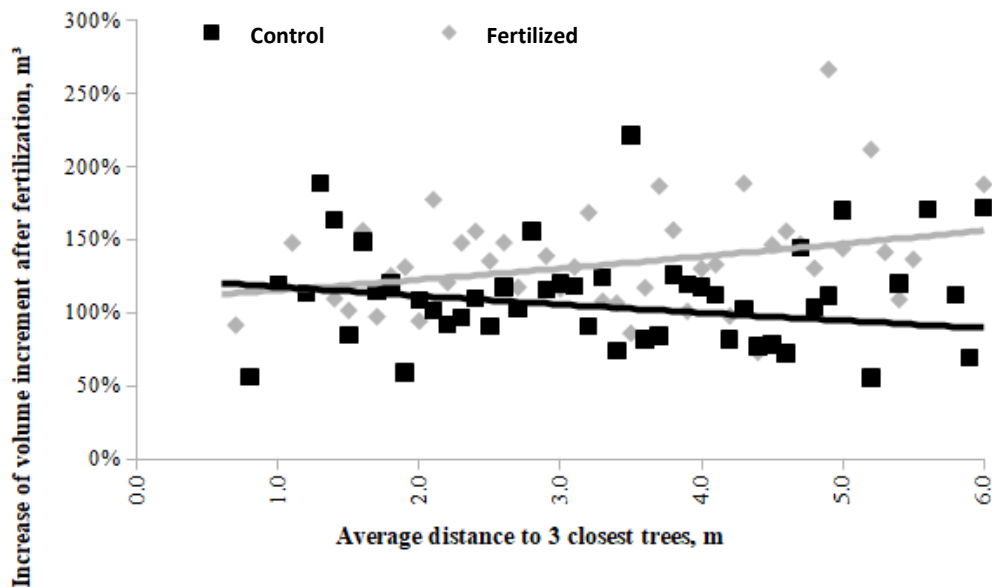


Figure 10. Increase of volume increment 5 years after fertilization in control and fertilized areas in young and middle-aged Scots pine stands, where NH_4NO_3 has been applied, depending on the average distance to 3 closest trees

When evaluating the effect of wood ash applied together with NH_4NO_3 in pre-mature stands, the average annual increment in fertilized areas is $10.9 \text{ m}^3 \text{ ha}^{-1}$ (larger by 14% 5 years after application of fertilizer); the difference between control and fertilized areas is $1.6 \text{ m}^3 \text{ ha}^{-1}$ annually. The largest difference ($1.8 \text{ m}^3 \text{ ha}^{-1}$ annually) between control and fertilized areas was observed in pine stands, but the smallest – in birch stands ($1.4 \text{ m}^3 \text{ ha}^{-1}$ annually). In birch stands the largest difference between control and fertilized plots was in stands with drained organic soils (1.9 un $2.1 \text{ m}^3 \text{ ha}^{-1}$ annually), whereas in forest stands with drained mineral soil it was 3 times smaller ($0,6 \text{ m}^3 \text{ ha}^{-1}$ annually). In spruce stands the difference between control and fertilized areas is positive only in the forest stand with drained organic soil ($2.0 \text{ m}^3 \text{ ha}^{-1}$ annually). In pine stands with both drained organic and mineral soil the annual difference is positive ($2.0 \text{ m}^3 \text{ ha}^{-1}$ and $1.7 \text{ m}^3 \text{ ha}^{-1}$, respectively).

In Silver birch stands the distance between the trees does not significantly affect volume increment. Fertilizers have a constant positive effect on volume increment (on average 10% compared to the 5-year period before fertilizer application). In Norway spruce stands, there is no significant increase of volume increment in fertilized areas comparing with the control. The increase may be due to other factors, such as improved growth conditions for trees of a lower storey, which explains the significant increase in stock growth in control areas for trees close to each other. In Scots pine stands the increase in control plots, regardless of the distance between trees, is smaller than in fertilized plots and in the period before fertilizer application. There is no significant effect of distance between trees on growth in the fertilized and control plots.

Previously extensive forest fertilization studies in Latvia have been conducted only from the 1970s till the late 1980s. These studies also measured the impact of fertilization on a slightly longer time scale. The estimates of increase in volume increment in the early studies are mostly higher than in our study.

In studies carried out in Latvia in the 1970s, the greatest effect was obtained by N fertilization ($80\text{--}120 \text{ kg ha}^{-1}$), which increased the radial increment by 130% compared to the control plots, and complex (NPK) fertilization ($80, 80$ and 120 kg ha^{-1} , respectively), which increased radial growth by 150%, comparing with the control. In oligomesotrophic upland pine stands, the greatest effect was obtained from N fertilizer ($80\text{--}100 \text{ kg ha}^{-1}$), which increased annual growth by 144% comparing with the control, and complex NPK fertilizer (respectively, $80\text{--}100, 80$ and 120 kg ha^{-1}) which increased the growth by 141% comparing with the control. The smallest effect was obtained by using P and K fertilizers in upland forests. Depending on the type of fertilizer, the additional growth of oligotrophic and oligomesotrophic upland pine stands, where N and NPK fertilizers were applied, was $3.2\text{--}4.0 \text{ m}^3 \text{ ha}^{-1}$ annually or $25\text{--}32 \text{ m}^3 \text{ ha}^{-1}$ during 8 years, but in oligomesotrophic pine stands – $1.4\text{--}3.0 \text{ m}^3 \text{ ha}^{-1}$ annually or $11\text{--}24 \text{ m}^3 \text{ ha}^{-1}$ in 8 years (Капустс, Сацениекс 1977). When

applying $N_{100}P_{60}K_{60}$ and $N_{85}P_{60}K_{80}$ fertilizers to oligotrophic forests with drained peat soil in Latvia, the effect was observed for 6–8 years. The additional volume increment of the fertilized pine stands was 0.9 m^3 annually. On the other hand, when fertilizing oligomesotrophic pine forests with drained peat soil ($N_{70}P_{60}$ and $N_{100}P_{60}K_{60}$), up to 2.6 m^3 was obtained annually within 6 years (Kāposts 1981).

Another study showed that in young pine stands the NPK fertilizer increased tree growth by 2.5–5 times. Fertilizing middle aged spruce stands with a N dose of 200 kg ha^{-1} , tree growth increased on average by 18% over the next 5 years. Using lower doses of fertilizer ($N_{90} \text{ kg ha}^{-1}$), most of the additional increment (27.3%) occurred in the first year after applying the fertilizer. The effect of fertilizer lasted for 6 years. By increasing the dose of fertilizer, the duration of its effect increased and the moment of peak effect of the fertilizer occurs later (Rone 1982).

Studies starting from the 1990s focused on residues – sewage sludge and wood ash on a smaller scale. At the beginning of the 1990s, along with adoption of environmental protection regulations of the European Union, the use of sewage sludge was introduced. Sewage sludge that has practical applications contains a significant amount of nitrogen (up to 10%), potassium (up to 1%), and phosphorus (up to 15% in the form of P_2O_5) (Fijalkowski et al. 2017). A number of studies in Latvia were carried out on the use of sewage sludge in forestry and the production of sewage sludge compost by mixing it with wood residues and other organic materials (Kāposts et al. 2000). In 1998, in cooperation with the municipal administration of the city of Valmiera, a study was conducted on the use of sewage sludge in reforestation. The study found that application of pure, freeze-dried sewage sludge with a dose of 3–5 kg per seedling area to nutrient-poor soils and burns, increases tree growth by 40%. The research concluded that sludge-wood chip compost is a more promising – easier to spread and safer fertilizer. Composting dilutes the concentration of heavy metals in the substrate and increases the supply of nutrients available to plants. Several studies in this field have been carried out in cooperation with SIA "Rīgas ūdens". In a study conducted in 1997, it was found that the limit values of heavy metals are not exceeded, if the dose of sludge does not exceed 30 tons ha^{-1} (LVMI Silava 1998). In 2003, several studies were started on the cultivation of tree plantations and the use of sewage sludge and manure in willow plantations. The largest biomass was obtained from *Salix purpurea* and *Salix viminalis* plantations, up to $39.2 \text{ m}^3 \text{ ha}^{-1}$ in the second year after the establishment of the plantation (LVMI Silava 2003 a,b). One of the most extensive studies on the use of sewage sludge in willow plantations was conducted in 2005. The study concluded that minimal tending is required in deciduous tree plantations in the second year after the application of sludge, because the seedlings have grown sufficiently large above-ground shoots, on which weed competition has a positive effect – the shoots have less branches. In the willow plantations, in the second year after cutting the shoots, the number of shoots per head increased, the plantation yield increased from $0.2\text{--}0.6 \text{ t DM ha}^{-1}$ to $4.6\text{--}5.5 \text{ t DM ha}^{-1}$.

According to research data conducted in Latvia in 2011–2012, in 30 40-year-old spruce stands damaged by spruce bark beetle with dry peat and mineral soils, potassium fertilization (61 kg of K in the form of K_2SO_4) increased annual growth in the following year after fertilization by 31%. A similar effect was produced by bringing ash (2.5 tons ha^{-1} dry matter) into the forest. In places where mineral fertilizer was applied (higher dose of K), the effect of tree recovery was more pronounced (Skranda, 2013).

Conclusions

1. Volume increment has increased in all the fertilization experiments; the effect of fertilization varies depending on dominant tree species, forest site type and stand age. The strongest effect was observed in pine stands regardless of experiment.
2. Wood ash application has resulted in a significant additional volume increment in spruce stands of drained forests on organic soils, but in upland forest stands and stands on drained mineral soils the effect is significant only when ammonium nitrate is added. Also the effect of ammonium nitrate alone is significant. More research needs to be carried out in spruce stands in other forest site types besides forests on drained organic soils.
3. Application of ammonium nitrate in oligotrophic upland forests has resulted in additional volume increment in birch and pine stands, but the effect in spruce stands is negligible.
4. In Silver birch stands the effect is similar for all fertilizers, but in contrary to conifer stands, the effect in young and middle-aged stands is significantly smaller. In case of Silver birch, it is recommended to use ammonium nitrate only in mature stands before regenerative felling.
5. In case of applying ammonium nitrate alone, the distance between trees has a positive effect on volume increment in fertilized areas. No effect or a less pronounced effect was observed in the control areas.

Acknowledgement

This study was funded through the project “Sustainable use of soil resources in the changing climate” (SUCC), EMP442. The contribution of Guna Petaja was funded by the European Regional Development Fund project “Development of greenhouse gas emission factors and decision support tools for management of peatlands after peat extraction” (1.1.1.1/19/A/064).

References

- Dobbertin M., Neumann M. 2020. Part V Tree growth Level II. No Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests (pp. 31). UNECE ICP Forests Programme Co-ordinating Centre.
- Fijalkowski K., Rorat A., Grobelak A., Kacprzak M.J. 2017. The presence of contaminations in sewage sludge – The current situation. *Journal of Environmental Management*. 203: 1126–1136.
- Högbom L., Nohrstedt H.-Ö., Nordlund S. 2001. Wood ash addition to an acid and highly N loaded Norway spruce site in SW Sweden, SkogForsk Report, vol. 2 (pp. 29–30).

- Huotari N., Tillman-Sutela E., Moilanen M., Laiho R. 2015. Recycling of ash – for the good of the environment? *Forest Ecology and Management*. 348, 226–240.
- Kāposts V. 1981. Mežaudžu barošānās režīms un to mēslošana: Apskats. Rīga: LatZTIZPI.
- Kāposts V., Kariņš Z., Lazdiņš A. 2000. Notekūdeņu dūņu izmantošanas mežsaimniecībā pieredze Latvijā. *Mežzinātne*, 10(43): 39–54.
- LVMI Silava 1998. Pilsētas notekūdeņu dūņu kvalitātes rādītāju noteikšana un dūņu izmantošanas normatīvu izstrādāšana mežsaimniecībā (pp. 17).
- LVMI Silava 2003a. Enerģētiskās koksnes plantāciju izveides tehnoloģijas izstrāde (pp. 12).
- LVMI Silava 2003b. Selekcionēto un dabisko kārķļu klonu izmēģinājuma stādījumu ierīkošana to izturības pret vides faktoriem pārbaudei (pp. 25).
- LVMI Silava 2021. Noslēguma pārskats par pētījumu programmas Koku augšanas apstākļu uzlabošanas pētījumu programma 2016.–2021. gadam rezultātiem (pp. 117).
- Pitman R. 2006. Wood ash use in forestry – a review of the environmental impacts. *Forestry* 79: 563–588.
- Pukkala T. 2017. Optimal nitrogen fertilization of boreal conifer forest. *Forest Ecosystems* 4, 3.
- Rone V. 1982. Разработать научные основы организации и технологические процессы создания еловых насаждений плантационного типа в условиях Латвийской ССР, отчет за 1978–1982 гг. Salaspils: Научнопроизводственное объединение "Силава". (1575-8-327).
- Sikström U., Almqvist C., Jansson G. 2010. Growth of *Pinus sylvestris* after application of wood ash or P and K fertilizer to a peatland in southern Sweden. *Silva Fennica*. 44(3): 411–425.
- Skranda I. 2013. Mēslojuma ietekme uz parastās egles *Picea abies* (L.) H. Karst. vitalitāti egļu bruņuts *Physokermes piceae* (Schrank) bojātajās audzēs. Bachelor's thesis, Latvia University of Life Sciences and Technologies.
- Špalte E. 1991. Meža mēslošanas problēmas un perspektīvas. *Jaunākais mežsaimniecībā*, 33, 47–53.
- Капостс В., Сацениекс Р. 1977. Применение минеральных удобрений в насаждениях хвойных парод Латвийской ССР. No Н. И. Будниченко, В. П. Вишнякова, & Н. В. Доркина (Red.), Применение минеральных удобрений в лесном хозяйстве (pp. 8–12). Всесоюзная опдена Ленина академия сельскохозяйственных наук имени В.И. Ленина Западноe отделение Эстонской научно-исследовательский институт лесного хозяйства и охраны природы Эстонская сельскохозяйственная академия.

