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PATİENT PRİVACY İN EXAMİNATİON AND İNTERVENTİON: A SYSTEMATİC REVİEW

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ABSTRACT

The aim of this study is to conduct a systematic review of the studies on ensuring body privacy during patient examination or intervention. In the systematic review, 1821 studies conducted between 2015 and 2023 within the scope of patient examination and intervention and by entering the keywords 'Patient privacy, Privacy, Private Life, Patient privacy' in the electronic databases of National Academic Network and Information Center, Higher Education Institution Theses, Pubmed, Google Scholar were scanned. A total of 6 studies that met the inclusion criteria were reached and compared in terms of their results. It was stated that the inpatients thought that their privacy was taken care of by the staff of the institution, the patients who participated in the research observed that the care shown to their privacy was better in private hospitals than in public hospitals, the average level of privacy knowledge of the patients was 73.9%, the average level of privacy evaluation was 81.6%, and the inpatients thought that their privacy was taken care of by the staff of the institution. It was found that the use of apron during the intervention to the patients increased the patient's sense of protection of privacy. In ensuring patient privacy; patient confidentiality all healthcare personnel who work in different institutions by showing the same attention to treating patients may contribute to the increase of level of privacy. It may be recommended to develop different aprons to protect their body privacy during the procedures applied to patients.

Keywords: *examination, privacy, patient privacy, personal life, intervention*.

Introduction

In 1980, the right to privacy, which was first addressed by Warren and Brandie, envisaged that each individual has the right to make decisions in sharing the feelings and thoughts of individuals who are provided with legal security in society with other people. (Woogara, 2001).

There is no universally accepted definition of privacy (Akyüz & Erdemir, 2013). The concept of privacy, which was first discussed by Altman, emphasised that it is the most basic human need and that the individual's control is important in ensuring privacy (Leino-Kilpi et al., 2001). The Turkish Language Association defines privacy as confidentiality (Turkish Language Association, 2019). The most fundamental aspect of privacy that is recognised is that it is a human need and a basic need (Akyüz & Erdemir 2013). It is emphasised that privacy is also an important concept in terms of the differences between people and people, within the same society or between cultures (İnan, 2008).

Privacy in health practices is a fundamental right that includes personal integrity and is included in both negative and positive rights. Controlling and sharing one's personal information, property and actions is a positive right, while preventing interference with one's own privacy is a negative right(Bekmezci & Özkan, 2015). It is important to define and provide the care that individuals need in health practices. Privacy in health practices can be considered in terms of physical, psychological, social and informational aspects (Akyüz & Erdemir, 2013; Ergül &Bayık, 2004; Coyle, 2002).

Physical privacy in health practices includes the room where patients stay during their hospital stay or an intervention to be made on the patient's body (Akyüz & Erdemir, 2013). It is a result of the individual's body privacy that no medical intervention is made without the patient's consent and that the interventions permitted by the patient are implemented by the health personnel by providing informed consent. Any forced medical practice falls within the scope of an interference with the individual's right to privacy. Refusal to accept requests for sterilisation, IUD application, voluntary abortion, etc., which are not medically inconvenient in practice, fall within the scope of violation of body privacy (Bekmezci & Özkan, 2015). Social privacy in health practices includes the control of the individual in the interaction process. In health care, this control usually passes to the health professional (Akyüz & Erdemir, 2013). Psychological

privacy in health practices can cause permanent problems that can leave deep scars on the individual if the violation is not recognised from the outside. For this reason, it is stated that the health professional should take care to protect the privacy of the individual during the application (Sarıbaş &Aktaş, 2023; Akyüz & Erdemir, 2013). Information privacy in health practices includes informing the patient. Thanks to the information privacy of the patients, it ensures both the confidentiality of medical records and the support of physical, social and psychological privacy by informing them about the decisions and practices taken. (Akyüz & Erdemir 2013).

Being respected as a human being, receiving the highest quality health care as much as possible, being informed, obtaining permission for planned medical interventions, respecting privacy and private life, ensuring continuity of care and treatment are among the most important patient rights. (Erbil, 2009). In terms of protecting the private lives of individuals, the right to privacy may also affect the right to sexual life and reproduction. The right to privacy includes the inaccessibility of information, bodily inviolability, self-development and expression (Bekmezci & Özkan, 2015).

Patient rights aim to support and socially empower patients. (Erbil, 2009). Any intervention to be made to the patient must be done by respecting the patient's privacy (Sarıbaş &Aktaş, 2023;Bekmezci & Özkan, 2015). Although gynaecological examination is perceived as a simple practice, it is an important examination and evaluation method in nursing and midwifery approach. All people experience anxiety when they encounter an unusual situation. In our country, the majority of women may experience anxiety and embarrassment during physical examination and intervention. (Sarıbaş & Akbaş, 2023; Altay & Kefeli, 2012). The attitude of the health personnel before, during and after the examination and the person's positive examination experience have an important effect on ensuring the continuity of the subsequent examination and increasing the quality of service provided. It is recommended that health professionals should be caring and respectful, show a smiling face, empathise and show an explanatory approach in preparing patients for the examination. (Sarpkaya & Vural 2014; Altay & Kefeli 2012; Taşkın, 2012; Mete, 1998). Diagnosis and treatment applications to be applied with the patient; examination covering the patient's body, anamnesis procedures that require him to express his private life and secrets must be carried out in a certain privacy environment.The health professional should have an assistant with him/her in this practice. If there is no medical problem, a relative can be present with the patient. If there are students in the health institution and they need to be present during the application, it is important to obtain consent from the patient (Sarıbaş &Aktaş, 2023; Arısoy 2009).

Materials and Methods

In this systematic review, 18581 studies published between 2015 and 2023 were examined. National Academic Network and Information Centre, Higher Education Institution Thesis, Pubmed, Google Scholar electronic databases were searched using the keywords ‘Patient privacy, Privacy, Private Life, Patient privacy’. The titles and abstracts of all relevant articles identified by electronic search were independently reviewed by the researcher. Meta-analysis, systematic review, randomised controlled trial, controlled experimental studies were included in the review. Although the number of articles examined in the study was 1821, 6 articles that met the limitations were included in the study.

As inclusion criteria, it was determined that the patients were planned within the scope of patient privacy, the publication language was Turkish or English, it was published between 2015 and 2023, and the full text could be accessed. In-vitro studies, case reports, and ongoing studies were excluded as research types. One retrospective controlled study, four descriptive studies, and one systematic review that met the criteria were included in the study.

Process Steps

With the keyword ‘Patient privacy, Privacy, Private Life’, National Academıc Network And Informatıon Centre and Higher Education Institution TEZ electronic databases were searched.

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A total of 1821 studies were reached.

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The studies were listed and evaluated according to the inclusion criteria.

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828 studies were excluded because they did not meet the condition that the publication date was between 2015 and 2019.

↓

394 studies were excluded because they did not meet the criteria of meta-analysis, systematic review, randomised controlled trial, controlled experimental study.

↓

110 studies were excluded because they were not within the scope of patient confidentiality.

↓

A total of 1332 studies that did not meet the criteria and could not be reached were excluded.

↓

A total of 6 studies included in the study were evaluated in terms of comparison, limitations and results.

Results

When the content of a total of 6 studies included in this study is examined in general;

- The level of knowledge of the patients participating in the study about patient privacy,
- The extent to which patients' privacy is respected in hospitals,
- The way patients perceive their right to privacy,
- Whether the care shown by healthcare professionals to patient privacy has an effect on the patient's perception of privacy
- How a new gown developed affects the patient's sense of privacy was analysed.

In line with this systematic review; it was determined that the patient privacy shown to the patient in private and public hospitals is different, the care shown to the privacy of the patients is better in private hospitals than in public hospitals, the privacy knowledge levels of the patients in private hospitals are higher than the patients in public hospitals, and when evaluated in terms of physical environment, it was determined that the physical spaces of private hospitals have more suitable physical conditions in terms of protecting the privacy of the patients. It was found that the average privacy knowledge level of the patients was 73.9%, the average privacy evaluation was 81.6%, and the inpatients thought that their privacy was taken care of by the staff of the institution. It was determined that adapting the response surface method to the concept of patient satisfaction will affect the variables affecting patient satisfaction and the targeted satisfaction values.

Table 1. Method, limitations of the reviewed studies.		
Name/year of the study Authors	Method	Limitations
Response Surface Approach to Patient Satisfaction Çiftçi E, Aktaş S 2015	-Cohort Retrospective	-It is known that the value of the variable of general satisfaction with hospital services takes a value between 0 and 100. Satisfaction coefficient takes its highest value as 100. However, when some independent variable values were substituted in the model, situations exceeding 100 were detected. Since it is known that satisfaction will be 100 per cent at most, general satisfaction is accepted as 100 in this case. This is a limitation of the study.
Evaluation of the care shown to the patient's privacy in the hospitals with the patient's point of view (The example of Antalya) Refik ERTEN 2017	-Descriptive study	- The results of the research are valid only for the population in which the research was conducted and cannot be generalised to the country. The fact that patients other than the patients who participated in the research in Antalya province could not be included in the research constitutes the limitations of the research. Due to the insufficient number of studies on this subject in the literature, the scarcity of the number of resources that can be used in the process of interpreting the findings is another limitation.
Evaluation of Inpatients' Opinions on Confidentiality of Personal and Disease Information Kutlu L, Baykal D, Urfa H, Keskin G, Güçlüel Y 2017	-Descriptive study	……
Evaluation of patient confidentiality Akar Y, Özyurt E, Erduran S, Uğurlu D, Aydın İ 2019	-Descriptive study	……
Effect of a Novel Patient Garment on Perceived Privacy during Colonoscopy: A Simple Approach to Minimize Embarrassment. Aamar A, Butt Z, Madhani K, Hussain I, Aslanian H 2019	-Descriptive study	Questionnaire responses were anonymous. The study included those who volunteered to participate in the research. We estimate that 10% of eligible participants declined participation; data for this group were not recorded. The questions were designed to determine the impact of the gown on privacy concerns before and during colonoscopy; however, we recognise that additional factors could potentially influence patient responses. A comparative study in a larger population with the inclusion of groups with low rates of colon cancer screening and no comparison between the old practice and the newly developed gown used during the procedure is warranted.
Understanding the Patient Privacy Perspective on Health İnformation Exchange: A systematic review. Shen N, Bernier T, Sequeira L, Strauss J, Silver MP, Carter-Langford A, Wiljer D 2019	-Systematic Review	-……

As a result of the studies, it was determined that patients were satisfied with the use of response surface method in determining patient satisfaction in health institutions (Çiftçi & Aktaş, 2015), patient privacy is provided more in private hospitals and physical conditions are more suitable for ensuring patient privacy (Erten, 2017), they are satisfied with the presence of their spouse during the examination and interventions (Kutlu et. al. al, 2017), healthcare staff did not pay attention to the body privacy of inpatients (Akar et. al, 2019), patient gowns developed for use during examination and intervention protect body privacy and increase satisfaction (Aamar et al, 2019), and perceived quality of care and privacy protection were found to be insufficient by patients (Shen et al, 2019).

Discussion

The phenomenon of privacy is a phenomenon that can change the emotional state of patients and increase the level of stress and anxiety. According to the study of Erbil et al. (2008), the negative approach of health service providers and their lack of attention to privacy, as well as the patient's previous negative experiences cause anxiety to increase and pain to be felt more (Erbil et al,. 2008).

Lemonidou et al. (2003) stated in their study that nursing staff need systematic and comprehensive training at all levels, especially in terms of the principles of autonomy, privacy and informed consent, which can be frequently violated.

Akar et al. (2019) questioned the attentiveness of not only nursing staff but also all employees to privacy and concluded that privacy is generally taken care of in the hospital.
In Dülgerin's study (2014), this training issue was addressed as ‘members of the health profession should be trained on this issue, and even by introducing Health Law courses in medical faculties, the necessity of protecting personal data and the consequences of not protecting personal data should be taught to future physicians in terms of both legal and professional ethics at the first stage’.

Conclusion and Recommendations

As a result of this study, it was determined that making patients wear patient gowns to protect body privacy during examinations and interventions to be performed on patients increased the feeling that body privacy was protected. In order to ensure the protection of patients' body privacy, health personnel providing services in public and private institutions should show the same attentive behavior to patients during treatment in order to increase the feeling that privacy is protected. It may be recommended to develop different gowns for examination and intervention practices to be performed on patients.

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Participation in the "Erasmus+": Perspectives on Attitudes, Motivational Drivers and Barriers to Engagement

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Abstract

This study examines students' engagement in the "Erasmus+" program in Georgia, their attitudes, motivations, obstacles to participation, and the program's effects on academic and career progress. Survey research was conducted with 215 students, and four focus groups were held with 50 students. The findings revealed, that participants' success in the "Erasmus+" program was associated with positive attitudes towards the program, students' motivations, effective preparation, and strong academic and language skills. A higher success rate was observed among female participants particularly within the age group of 23-29. These groups also expressed a desire to pursue further studies and apply for "Erasmus+". Participating in "Erasmus+" projects enhanced the social and academic skills of students, yet the direct impact on job prospects was uncertain. Non-participation primarily stems from barriers named by more than half of the surveyed students, such as a lack of information, inadequate support, and financial limitations. Previous experiences with mobility programs also influenced their preferences, as participants displayed a preference for further studies in EU countries, while non-applicants pursued educational opportunities in Georgia followed by EU countries.

Through by eliminating the aforementioned barriers, more young people would engage in the "Erasmus+" program, fostering their enhanced educational, professional, personal, and societal development.

Keywords: "Erasmus+", international mobility, student participation, attitudes, motives, barriers to participation.

Introduction

The ERASMUS (European et al. Scheme for the Mobility of University Students), established in 1987 by the European Commission, is one of the essential programs facilitating students' and staff mobility between European countries through co-financing. Students can study in a foreign country under bilateral agreements between host and home institutions (Patricio & Harden, 2010). The programme is divided into 6 sections; it covers 4 fields of education: Higher Education, Vocational Education, General Education, and Aduld Education, as well as Youth and Sports sectors. As the "Erasmus+" programme has been successful since its introduction in 2014, it has been extended with a second phase between 2021 and 2027 when it has been allocated with a total budget of around 26 billion EUR.

Georgia, as a "Third Country" in the "Erasmus+" Program, is actively engaged in international collaborations facilitated by "Erasmus+" including capacity-building projects, mobility programs, and cooperative initiatives across various disciplines. Georgia has been recognized for its success within the "Erasmus+" program, ranking 6th out of 141 participating countries based on international CMSs, and has benefited from numerous scholarships and collaborative projects involving Georgian Higher Educational Institutes (HEIs). Close to 10,400 scholarships have been allocated for students and staff ("Erasmus+" national office, 2022).

Studies indicate that internationally mobile students exhibit distinct traits compared to their non-mobile peers, including differences in abilities, chosen fields of study, familial backgrounds, and other personal characteristics (Zimmermann & Neyer, 2013). Additionally, participants in programs like "Erasmus+" demonstrated superior academic performance both in secondary (Kratz and Netz, 2016) and tertiary education (Di Pietro, 2015; Teichler, 2012). Moreover, hey frequently came from more affluent families or had parents who had gone to college (Kratz and Netz, 2016; Di Pietro, 2015). Empirical data suggests that women, younger students, and those in the Arts and Humanities fields are more inclined to engage in international study mobility (Kratz & Netz, 2016). To support inclusive participation nations are now implementing strategies like boosting resources for study abroad programs, enhancing students' understanding of its advantages, and fostering interaction among

local and international students, as well as between alumni and prospective participants (Perna et al., 2015).

Research on international student mobility emphasizes that "Erasmus+" participants tend to perform better academically and have higher career prospects. However, some research suggests that international study mobility may even delay access to initial employment opportunities (Wiers, Jenssen & Try, 2005; Rodriguez, 2013) as graduates develop international social and institutional ties that may discourage seeking employment in their home countries. It is noteworthy, however, that certain exceptions to this pattern have been observed. For instance, research has shown that Italian graduates who pursued studies abroad demonstrated high employment prospects three years after completing their studies (Di Pietro, 2015).

While existing literature widely explores the impact of international students' mobility on their personal and professional development, language proficiency, and intercultural competencies, limited attention has been given to students' perceptions of the "Erasmus+" program itself, particularly in the context of Georgia. Understanding the factors influencing student engagement in the program is fundamental for enhancing program effectiveness and inclusivity.

Using existing literature reviews and empirical research, this article aims to explore students' attitudes, motivations, and obstacles to participation in the "Erasmus+" program. By exploring these factors, the current research aims to provide insights into how institutions and policymakers can promote greater international experiences within the "Erasmus+" framework.

Problem statement

Participation in the "Erasmus+" program has multifaceted benefits for young people. To maximizee the potential advantages of the program and foster widespread engagement in the initiative; it is imperative to understand the underlying determinants shaping individuals' decisions regarding program participation including attitudes, motivations, and potential obstacles influencing youth engagement.

Accordingly, the following hypotheses were proposed:

H1. Student engagement in the "Erasmus+" program is influenced not only by internal factors such as attitudes and motivations but also by external determinants.

H2. Active involvement in "Erasmus+" projects is related with students' professional advancement.

Method

The study utilized a mixed-methods approach that combined quantitative survey research with qualitative focus group discussions. Following Creswell's emphasis on method triangulation, this design allowed for a comprehensive exploration of student experiences and perspectives by collecting both numerical data and rich, descriptive insights (Creswell, 2014).

The survey research involved 215 students and was designed to capture broad patterns, trends, and statistical relationships among various factors related to the study's objectives. This quantitative phase was structured using standardized questions, allowing for the effective analysis of frequency, trends, and potential correlations.

In addition, four focus group discussions with a total of 50 students were conducted, providing a deeper, more nuanced understanding of students' thoughts, feelings, and motivations. This qualitative component was crucial in capturing contextual details and personal narratives that could not be fully expressed through the survey alone. Creswell's approach highlights that focus groups are particularly useful for exploring complex topics where interaction among participants can stimulate richer data, as participants build on each other's responses.

Sample

The study applied a "convenient sampling" approach, where participating universities provided lists of their students. Questionnaires were administered to 820 students using Google Forms, and three reminders were sent to survey participants to increase the response rate. Of the 820 students, 215 completed the questionnaires (involving students, both participants and non-participants of "Erasmus+" projects); the response rate was 26%. The respondents were predominantly female (73% of the sample).

The study conducted two focus groups with participant students and two focus groups with non-participating students, totaling 50 participants (28 females and 22 males).

Instrument

The survey instrument was a questionnaire. It provided information about the project's objectives and sampling methodology and assured participants confidentiality. Implicit consent protocols were employed throughout the research process.

The survey instrument included structured questions covering various issues such as demographics, socioeconomic status, participation experiences, attitudes, motivations, future aspirations, and other relevant topics. The questionnaire included 52 questions, including Likert-type attitude scales and some open-ended questions.

A Focus Group guide was specifically developed for focus group sessions.

Data analysis

Quantitative data was analyzed using SPSS 26, using applicable statistical methods. Focus group data was analyzed using “Content Analysis”. The data analysis was performed considering different factors such as gender, age group, and prior experience with "Erasmus+" program whenever relevant.

Results

Background information

Three groups of students were identified in the research study: 61% were students who had never attended the "Erasmus+" program; 29% were students who had taken part in the "Erasmus+" program, and the lowest (10%) were students who were unsuccessful.

Demographic data for the participants is presented in Table 1. Female participants were predominant across all groups. The data revealed gender disparities in the participation in the "Erasmus+" program. In the group of successful applicants, women made up 62 % while men constitute a much smaller percentage, at 38% (χ^2 (2) =26.86; p<.05).

Table 1

Research Participants’ Characteristics

Participants characteristics	Never Applied %	Participant s tudents%	Applications were not successful %	Whole Group %
Gender *				
Females	73	62	91	83
Males	27	38	9	17
Age *				
18-22	57	33	62	51
23-29	23	57	29	34
30+ and more	20	10	10	16
Education *				
Bachelor of Arts (BA)	61	28	11	54
Master of Arts (MA)	33	54	13	35
Doctor of Philosophy (PhD)	71	29	0.0	11
Employment Status *				
Employed	53	76	90	63
Self-employed	3.0	3	19	3
Unemployed	44	21	10	34

Note. * differences by groups are statistically significant

Regarding age differences, the 23-29 age group demonstrated the highest participation rate among "Erasmus+" participants at 57%, whereas the 18-22 age group recorded 33%, and even lower figures were observed in the 30+ age group.

A majority of students who had never applied for "Erasmus+" projects, had attained a bachelor's degree as their highest level of education; In contrast, students who had participated in "Erasmus+" programs as well as those who were unsuccessful, were more likely to have obtained a master's degree.

Among the participants, the employment rate was higher among those whose applications were unsuccessful, followed by "Erasmus+" students.

Irrespective of the student cohort, 59 % of the surveyed students were employed domestically, while 4% were abroad and 3% were self-employed. Among the employed individuals, students who applied but were unsuccessful showed a higher prevalence compared to "Erasmus+" program participants. Statistical analysis revealed significant differences among the groups ($\chi 2$ (6)=16.862, p<.05) (see Table 2).

Table 2

Employment Status

	Student group	Employed in Georgia %	Employed abroad %	Self-employed %	Un-employed %
1	Students who had never submitted applications for "Erasmus+" programs.	53	0.0	3	44
	Students who had participated in "Erasmus+" programs.	69	7	3	21
	Students who had applied for "Erasmus+" programs but were unsuccessful in their applications.	71	19	0.0	10
	Whole group	59	4	3	34

$\chi 2$ (6)=33.296, p<.05

On the other hand, students who have never applied for the "Erasmus+" program were overrepresented among the unemployed students. These findings support Hypothesis 2, suggesting that participation in "Erasmus+" is associated with enhanced employment prospects. However, there is no evidence indicating a direct causality between employment status and studying abroad.

The analysis of salary distribution showed that students who did not apply for an Erasmus+ grant earned the lowest salary (up to 900 GEL), while participants in Erasmus+ projects earned 2001-2500 GEL or more. Students in the highest salary category (more than 2500 GEL) were mostly Erasmus participants. These results supported the hypothesis (H2) that participation in "Erasmus+" projects was positively related to career advancement.

The economic background of the surveyed participants was fairly homogeneous, as the category: – "Money is enough for food and clothes, but not enough for expensive durables like a refrigerator or washing machine" – was dominant among them (see Table 3).

Table 3

Economic Background by Group of Students

	Student group	1	2	3	4
1	Students who had never submitted applications for "Erasmus+" programs.	3	7	82	8
2	Students who had participated in "Erasmus+" programs.	4	8	84	4

3	Students who had applied for "Erasmus+" programs but were unsuccessful in their applications.	3	10	83	7
	Whole group	4	7	83	5

Note. 1- We can afford to buy anything we need
2 - We can afford to buy some expensive durables like a refrigerator or washing machine
3Money is enough for food and clothes, but not enough for expensive durables like a refrigerator or washing machine
4 Money is enough for food only, but not for clothes

Looking at the differences among these three groups, it becomes clear, that what separates them are their levels of education, employment, and income.

Source of information and participation in the "Erasmus+" program

The cohort with no "Erasmus+" experience primarily accessed data through the official websites of their Higher Education Institutions (HEIs), as well as from fellow students and peers. Conversely, participants enrolled in the "Erasmus+" predominantly relied on information sourced from institutional websites, "Erasmus+" application guidelines, and fellow students. Furthermore, individuals who were unsuccessful in securing grants primarily obtained information from institutional websites and administrative personnel within their universities.

We asked research participants to self-assess their level of English language proficiency on a 7-point scale, with 1 representing the lowest level and 7 representing the highest. The "Erasmus +" participants showed the highest proficiency level (*M*=6; *SD*=1.8) followed by those students whose applications were unsuccessful (*M*=4.5; *SD*=.9). Non-participating students had an average proficiency level (*M*=3.5; *SD*=.9).

Attitudes and motivations towards participation in the "Erasmus +"

The participants were asked to express their attitudes towards international mobility based on various factors. The analysis presented in Table 4 suggests that participants had the most positive attitudes, while non-participants demonstrated the lowest level of positivity. However, it is noteworthy that the overall attitude of even non-participants was higher than the average.

Table 4

Attitude towards "Erasmus+" by Group of Students

	International Mobility	**Cultural curiosity**	**Openness to new experiences**	**Average score**
1.Students who never applied for "Erasmus+"	3.9	3.8	3.5	3.8
2.Students who participated in Erasmus+ projects	7	5	7	6.3
3Students who applied for "Erasmus+" but their applications were not successful	5	5	4.5	4.8
Whole group				
Average	4.8	3.5	4.4	4.97

"Erasmus +" applicants and individuals whose applications were unsuccessful were primarily driven by similar factors, such as a desire to enhance their expertise and competences in their fields, improve their language proficiency, and improve their social skills. Participating students reported higher levels of motivation than students whose application was not successful (see Table 5).

Table 5

Motivation for Applying for an "Erasmus+" Project

	Selection criteria	Students who participated in Erasmus+ projects %	Students whose applications were not successful %
1.	Improving knowledge and competence in the field of study	6.6	5
2.	Learning/improving a foreign language	5.5	5
3.	Development of social skills (adaptability, communication, etc.)	5	4 3
4.	Improve employability in Georgia or abroad	6	5
5.	Gaining experience in different learning and teaching practices		3
		4.90	4.17

Comments from focus group participants:

„What especially helped me to be successful in „Erasmus +“ was a high academic performance, good command of English, and having information from previous participants (male, participant student).

"Erasmus+" is very good, but other countries, for example the United States, are no less interesting. The focus should be broader" (female, participant student).

The main reasons for not applying for the "Erasmus+" program are: a lack of information about the "Erasmus+" Program (60%); Insufficient support in the application process (11%) and financial difficulties (10%). It should be mentioned that "Erasmus+" Participants identified the following barriers to joining "Erasmus+": language (36%), lack of information from the home university (16%) and program compatibility (39%).

All of them can be considered barriers that confirm hypotheses (H1).

Comments from focus group participants:

"It is challenging to find information. Students who participated have more experience, that is why the same students participate several times; new students should be given some priority." (male, non-participant student)."

“This program gives young people excellent opportunities to improve their lives and knowledge. It should be open to many more students; they need good guidance " (male, participant student).

Each individual (100%) autonomously decided to participate in the „Erasmus +“ program and exclusively selected host countries within the European Union. The "Erasmus+" cohort, comprising 97% of students, selected EU member states, France, Germany, and Italy, alongside others. The selection criteria predominantly included geopolitical stability (70%), air travel accessibility (20%) and geographical proximity (10%).

In general, students assessed the "Erasmus+" program experience very positively, scoring higher than the average of 3.5 out of 5 in different areas, ranging from 3.6 to 4.6 (see Table 6). Particularly positive was the evaluation of the overall Erasmus+ experience followed by assistance received from the host institution, quality of teaching methods, and the expertise of academic staff at the host university.

Table 6

Evaluation of the Various Aspects of Participation in the "Erasmus+" Program

(where 1 means very negative and 7 very positive evaluation)

Evaluation criteria	Score points (1-7 scale)	SD
1. Erasmus+ experience	4.6	.5

2.	Home university's support for study abroad	4.1	.8
3.	Host university's support for study abroad	4.3	.9
4.	Social-cultural integration in the environment of the host university	4.2	1.1
5.	Quality of teaching methods	4.3	.7
6.	Quality of courses offered	4.1	.8
7.	Academic staff qualifications at the host university	4.3	.7
8.	Host university's support in finding housing	3.6	1.3
	Average	4.2	

All "Erasmus+" students reported improved skills in working with people from different cultural backgrounds (100%). Additionally, almost everyone agreed that they improved their English proficiency (97%) and are more interested in new challenges (97%). Furthermore, participants had a better understanding of their strengths and weaknesses (93%), were more confident in their abilities and roles, and gained a deeper understanding of Europe, the European Union, and European values (93%) (see Table 7).

Table 7

Self-evaluation of the Impact of the "Erasmus+" Program

	Item	Agree %	Neutral %	Not agree %
1.	I am more confident in my abilities and filed	93	7	
2.	I know better my strengths and weaknesses	93	7	
3.	I am more able to collaborate with people of other backgrounds and cultures	100.0		
4.	I am more interested in new challenges	97	3	
5.	I can better analyze information critically	89	17	
6.	I learned more about Europe, the European Union and the European values	93	7	
7.	I can better use digital technologies in learning or work	66	28	7
8.	I believe that the chances of getting a new or better job have increased	76	17	7
9.	I have a clear idea of my professional career aspirations and goals	86		14
10.	I improved my English	97	3	

Focus group participants also positively evaluated participation:

" I am very happy that I had such a chance in my life: The teaching method and quality of the university were just excellent. The same can be said about the professors" (female, participant student).

" The program gave me a lot, except knowledge of social contact was very exciting for me; I had no chance before to meet people from so many different backgrounds; I try to keep in contact with them. (male, participant student)" .

Almost all students who participated in the "Erasmus+" Program mentioned that their employment status improved (93%), though less than one third (28%) confirmed that their income increased.

Future plans

`The survey results revealed that more than half of the respondents (57 %) preferred to pursue further education in the EU. Following behind, 29 % of respondents preferred to pursue further education in Georgia. A smaller proportion of respondents, 9%, indicated a preference for other locations such as Turkey and Serbia. Additionally, only 5% of respondents reported that they do not have any plans for further education.

Students who had taken part in "Erasmus+" projects often express an interest in continuing their studies in European Union countries. In contrast, those who had not applied for "Erasmus+" opportunities are more likely to want to pursue their studies within Georgia. This suggests that previous experiences with mobility programs like "Erasmus+" influence students' aspirations and preferences regarding future academic endeavors.

A notably higher percentage of women expressed intentions to continue their studies compared to men. Specifically, 44 % of surveyed women indicated a desire to pursue further studies in Georgia. About 35% of surveyed women planned to continue their studies in the European Union, compared to 27% of men, while a minority of surveyed women (9%) and a more significant proportion of men (36%) did not plan to pursue further education ($\chi^2(3) = 8.894$; $p < .05$). In terms of age groups, a significant portion of the 18-22 age group expressed interest in continuing their studies (100%), compared to 71% in the 23-29 age group and 70% in the 30+ age group. This trend in Erasmus+" participation rates was evident, with 82% of participants in the 18-22 age group, 60% in the 23-29 age group, and 28% in the 30+ age group cohort ($\chi^2(2) = 16.725$; $p < .05$).

Considering the positive attitudes of respondents towards the "Erasmus+" project and the high level of satisfaction among the participating students, it is not surprising that approximately 78% of the respondents were eager to apply for "Erasmus+" projects. Notably, a significant portion of this group comprises students who have already participated (55%), followed by students who previously applied but were unsuccessful in the 'Erasmus+' program (35%). Interestingly, students who have never applied comprise 10%. This latter group is important in the study because their attitudes suggest that they could apply for "Erasmus+" projects if they do not encounter many barriers during the application process.

In terms of interest in the "Erasmus+" program, a significantly higher percentage of women, at 71 %, expressed their intentions to apply, compared to only 27 % of men (χ^2 (1)=8.352; $p<.05$). This discrepancy suggests a gender disparity in the tendency to participate in the "Erasmus+" program.

Correlation and Regresion anaysis

The correlation analysis identified several key findings about students' participation in Erasmus+ programs:

1. There is a strong and positive correlation ($r = 0.65$, $p < 0.01$) between students' attitudes towards "Erasmus+" and their participation.
2. A moderate negative correlation ($r = -0.45$, $p < 0.05$) indicates that students who experience fewer barriers, such as financial or logistical obstacles, were more likely to participate in Erasmus+. Reducing these barriers could encourage greater participation.
3. A positive correlation ($r = 0.40$, $p< 0.01$) shows that students involved in "Erasmus+" programs tend to report better career advancement. This highlights the program's potential benefits for students' long-term career outcomes.

Regression Analysis for Erasmus+ Participation

The regression analysis (Table 8) provides further insights into the factors that influence "Erasmus+" participation:

1. Positive attitudes are a significant predictor of participation, with a standardized coefficient ($\beta = 0.45$, $p < 0.01$).
2. The presence of barriers is a significant negative predictor ($\beta = -0.30$, $p < 0.05$), suggesting that as barriers increase, the likelihood of participation decreases. This underlines the importance of addressing and mitigating obstacles that prevent students from joining Erasmus+.
3. Students' motivations are also a significant predictor ($\beta = 0.35$, $p < 0.05$), with stronger motivational drivers correlating with higher participation. This finding suggests that fostering intrinsic motivations can encourage more students to take part in the program.

Table 8

Regression Analysis

Independent Variables	Unstandardized Coefficients (β)	Standard Error (SE)	Standardized Coefficients (β)	t-valu	Significance (p value)
Attitudes toward Erasmus+	0.45	0.10	0.45	4.50	< 0.01
Barriers to Participation	-0.30	0.08	-0.30	-3.75	< 0.05
Motivational Drivers	0.35	0.09	0.35	3.89	< 0.05

The regression model explains 49% of the variance in Erasmus+ participation ($R^2 = 0.49$, $p < 0.01$). The model is a strong fit, as evidenced by an F-value of 16.35, indicating that these factors collectively play a substantial role in predicting participation in "Erasmus+".

Discussion and Conclusion

This study has shown that attitudes toward the "Erasmus +" program and motivations play a critical role in participation in the "Erasmus+" program, together with different social factors. Female participants in "Erasmus+" programs, especially those aged 23-29, showed more excellent success rates. Other research also confirmed that positive attitudes towards international mobility, such as cultural curiosity and openness to new experiences, significantly influence students' decisions to join the program (Souto-Otero et al., 2013). A more significant proportion of female participants, expressed interest in further studies and indicated a desire to apply for the "Erasmus+" program. Regarding age variances, the 23-29 age group was more engaged in the "Erasmus+" program, while those aged 18-22 displayed enthusiasm for pursuing further studies in a general context and specifically within "Erasmus+". These findings underscore the importance of addressing gender and age-specific factors and barriers in promoting equal opportunities for participation in mobility programs such as "Erasmus+".

"Erasmus+" participants were driven to enhance academic knowledge, social skills, and language proficiency. Many participants reported improvements in their analytical capabilities, cultural sensitivity, and interpersonal skills. Notably, the students expressed appreciation for the values of the European Union. Other research also demonstrated that participants become more open to diverse perspectives through their cross-cultural experience (European Commission, 2018).

Research has shown that non-participation in "Erasmus+" was primarily related to barriers rather than negative attitudes or lack of motives. The primary factors contributing to non-participation encompass a perceived deficit in comprehensive understanding of the "Erasmus+" initiative, inadequacies throughout the application phase, and financial impediments. Though participants displayed the positive attitudes and highest motivation, as hypothesized (H1), students' participation was not solely dependent on these factors, but external barriers also played a significant role. Previous studies conducted in Georgia highlighted a range of barriers both adults and young people face in accessing education (Kitiasvili & Tasker, 2016; Kitiashvili et al., 2018). Cross's Model (1981, 1992) such as situational, dispositional, and institutional. Situational barriers, including financial constraints, time limitations, and transportation issues, are prevalent. Dispositional barriers, encompassing negative attitudes, beliefs, and low self-esteem, are within the individual's control to a greater extent. However, in the current research, there were no obstacles related to dispositional barriers, as the overall attitudes toward studying abroad were mostly positive.

Drawing from social psychology principles, attitudes significantly influence human behavior. The current study discovered that, despite having positive attitudes, many students were not participating in the program. According to the Theory of Planned Behavior (Ajzen, 2011) translating attitudes into behavior involves various factors. Key factors include intention, which encompasses motivation and readiness to act, and perceived behavioral control, which is the individual's subjective assessment of their ability to perform the behavior. Thus, it is crucial to overcome barriers to enhance perceived behavioral control and foster youth participation in the program.

While the direct link between studying abroad through the "Erasmus+" program and improved academic and employment outcomes may not be definitively established, the evidence suggests that such experiences can indeed contribute to students' personal and professional development. Furthermore, previous participation in the program influences students' preferences for future study destinations. Students who had participated in "Erasmus+" tend to express a desire to

continue their studies in European Union countries, while those who have never applied for "Erasmus+" opportunities were more motivated to pursue their studies within Georgia.

By addressing the aforementioned external barriers and encouraging positive attitudes especially towards participation among students who have never applied for "Erasmus+", it's possible to increase participation of students in "Erasmus+". There is a growing recognition of the importance of supporting more students' participation in study abroad programs. Governments and educational institutions worldwide are implementing various measures to support study abroad. These efforts aim to enhance educational outcomes, promote global citizenship, and prepare students for success in a fast-changing world.

It's important to recognize some limitations of the study like a small group of participants being involved and the chance that only people who really like the "Erasmus+" program participated. This might mean that the results cannot be applied to everyone in the country.

Though, this study represents a pioneering effort to investigate Georgian students' attitudes toward participation in "Erasmus+" initiatives, elucidate the factors influencing participation, and identify barriers. Future research should aim to include larger and more diverse cohorts, employ a wide range of methodological approaches, conduct international comparative analysis, and incorporate longitudinal studies.

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ADHERENCE TO INHALER THERAPY IN PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE AND CONTRIBUTING FACTORS

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Abstract

Chronic Obstructive Pulmonary Disease (COPD) is a leading cause of morbidity and mortality worldwide, with inhaler therapy being a cornerstone of its management. This review aims to evaluate adherence to inhaler therapy among COPD patients and identify factors influencing this adherence. A comprehensive literature search was conducted using databases such as PubMed, Scopus, and Web of Science, focusing on studies published between 2010 and 2023. The findings indicate that adherence rates to inhaler therapy range between 20% and 60%, primarily due to factors such as patient education, inhaler technique, and comorbid conditions. The review highlights the importance of effective patient education and simplified inhalation devices to improve adherence and, consequently, health outcomes in COPD patients.

Keywords: chronic obstructive pulmonary disease, inhaler therapy, treatment adherence, quality of life, barriers to adherence

Introduction

The definition of Chronic Obstructive Pulmonary Disease (COPD) was updated in 2023 by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) as ‘a heterogeneous condition characterized by chronic respiratory symptoms (dyspnea, cough, sputum) and persistent, often progressive airway obstruction, caused by airway (bronchitis/bronchiolitis) or alveolar (emphysema) abnormalities’ (GOLD 2021). Today, COPD has become the third leading cause of death worldwide, accounting for 5.5% of all deaths (WHO, 2003; WHO, 2024). In our country, respiratory diseases rank third among the most common causes of death, with 61.5% of these deaths attributed to COPD (hsgm.saglik). The World Health Organization (WHO) established the Global Alliance against Chronic Respiratory Diseases (GARD) to reduce the prevalence and incidence of chronic diseases, prevent their occurrence, and create an emergency action plan in response to the increasing prevalence of chronic diseases associated with extended life expectancy (WHO, 2008). In our country, the Turkish Thoracic Society (TTD) became a member of GARD in 2005 and between 2009-2013, developed the "National Program for the Prevention and Control of Chronic Airway Diseases – Action Plan" (Yıldız et al., 2013). Although COPD is a major public health issue worldwide, it is a chronic disease that remains relatively unknown to the general public. It is estimated that there are between 3-5 million COPD patients in our country, but only 300,000-500,000 of these patients have been diagnosed (saglik.gov). Yıldız et al. (2013), in a study conducted with 8,342 people living in urban and rural areas to assess asthma and COPD awareness within the Turkish population as part of the "Chronic Airway Diseases Prevention and Control Program," found that public awareness and knowledge levels regarding these diseases were low (Yıldız et al., 2013).

The objective of this review is to comprehensively assess the adherence to inhaler therapy in patients with Chronic Obstructive Pulmonary Disease (COPD) and to identify the various factors influencing this adherence. Given the significant global health burden posed by COPD, characterized by high morbidity and mortality rates, it is essential to evaluate the extent of treatment compliance and its implications for patient outcomes. By analyzing the existing literature from 2010 to 2023, this review aims to elucidate the barriers and facilitators of adherence to inhaler therapy, highlighting the critical role of patient education, awareness, and the usability of inhalation devices. Furthermore, the review seeks to provide insights that could inform clinical practices and interventions designed to enhance treatment adherence, ultimately improving the management and quality of life for COPD patients.

Previous studies have highlighted that medication adherence in chronic diseases is influenced by various factors, including the complexity of the treatment regimen, patient education, and social support (Vrijens et al., 2016). Furthermore, inadequate inhaler technique remains a significant barrier to effective COPD management, as improper use of inhalers can lead to suboptimal drug delivery and poor treatment outcomes (Bourbeau & Bartlett, 2008; Bosnic-Anticevich et al., 2017). This review will focus on the diverse factors influencing adherence to inhaler therapy, including the patient's understanding of their condition, the effectiveness of educational interventions, and the usability of different inhalation devices (Hamine et al., 2015; Jardim & Nascimento, 2019). Addressing these factors is critical for improving treatment adherence and enhancing the overall management of COPD patients.

Methodology

This study conducted a systematic literature review to identify factors influencing adherence to inhaler therapy among patients with Chronic Obstructive Pulmonary Disease (COPD). The research utilized the databases PubMed, Scopus, Web of Science, and Google Scholar, employing keywords such as “Chronic Obstructive Pulmonary Disease (COPD),” “inhaler therapy adherence,” and “factors affecting adherence.” The literature search was limited to studies published within the past 10 years in English and Turkish.

Inclusion Criteria

- *Patient Profile:* Studies focusing on individuals diagnosed with COPD.
- *Treatment Type:* Research focusing specifically on inhaler therapy.
- *Adherence Factors:* Studies that examine psychological, social, economic, and other factors influencing adherence to treatment were prioritized.
- *Publication Language:* Only articles published in English and Turkish were included.
- *Publication Date:* Studies published within the last 10 years were prioritized to ensure the most current information.
- *Study Type:* Both qualitative and quantitative studies, including literature reviews, surveys, clinical observations, and case series on adherence to inhaler therapy, were included.

Exclusion Criteria

- *Other Diseases:* Studies focusing on respiratory diseases other than COPD (e.g., asthma, pulmonary fibrosis) were excluded.
- *Alternative Treatments:* Studies on treatment methods other than inhaler therapy (e.g., oral medications, surgical interventions) were excluded.
- *Theoretical Studies:* Purely theoretical articles or literature evaluations were excluded.
- *Publication Language:* Articles published in languages other than English and Turkish were excluded.
- *Full-Text Access:* Studies without accessible full-text versions were excluded.

Literature Screening Process

In the initial phase of the literature review, a broad pool of literature was identified using predefined keywords. Articles were screened by title and abstract, followed by exclusion based on the inclusion and exclusion criteria. In the second phase, the full text of each eligible article was reviewed, and those meeting the criteria were analyzed.

Comparison and Evaluation of Findings

The findings of each reviewed study were compared in terms of their impact on adherence to inhaler therapy in COPD patients. In the analysis of results, similarities and differences in factors affecting adherence were considered to create an integrative assessment aligned with the study's objectives.

Chronic Obstructive Pulmonary Disease and Classification

In COPD, harmful gases and particles cause inflammation in the airways, leading to chronic airway obstruction, hyperinflation, mucus hypersecretion, reduced diffusion, and as a result, hypoventilation, hypoxemia, hypercapnia, and respiratory acidosis (Başyiğit, 2010). The primary risk factors contributing to these pathophysiological changes include tobacco use, passive smoking, occupational exposure to various chemical gases, air pollution, genetic factors, and malnutrition (Birol & Sütçü, 2020) (Table 1). The permanent damage caused to the airways due to COPD results in symptoms such as dyspnea, cough, and sputum production, as well as wheezing, weight loss, loss of appetite, insomnia, fatigue, activity intolerance, anxiety, and depression (Bal Özkaptan & Kapucu, 2015) (Table 2).

Table 1. Risk Factors for COPD

• Smoking • Passive smoking • Occupational exposure to various chemical gases • Air pollution • Genetic factors	• Malnutrition • Gender • Low socioeconomic status • Infections

Tablo 2. COPD Symptoms and Signs

• Dyspnoea	• Wheezing	• Insomnia	• Depression
• Cough	• Loss of appetite	• Fatigue	• Puckered lip breathing
• Phlegm	• Weight loss	• Anxiety	• Activity intolerance

The Global Initiative for Chronic Obstructive Lung Disease (GOLD) classifies COPD into four stages based on FEV1 levels, and defines COPD in pulmonary function tests as FEV1/FVC < 70% (GOLD 2021) (Table 3).

Table 3. In patients with FEV1/FVC < 70%

Stage 1	**Mild**	**FEV_1** ≥ %80 predicted
Stage 2	**Moderate**	%50 ≤ **FEV_1** < %80 predicted
Stage 3	**Severe**	%50 ≤ **FEV_1** < %80 predicted
Stage 4	**Very severe**	**FEV_1** < %30 predicted or **FEV_1**<%50 predicted plus chronic respiratory failure

Chronic Obstructive Pulmonary Disease and Treatment

The priority in the treatment of chronic obstructive pulmonary disease (COPD) is the reduction of risk factors, and both pharmacological and non-pharmacological treatment methods are applied. Additionally, the treatment of COPD patients may vary depending on whether the patient is in a stable phase or experiencing an exacerbation (Ergin & Muz, 2019).

Bronchodilators are the main agents in the pharmacological treatment of stable COPD (GOLD 2021). However, pharmacological treatment should only be given to symptomatic patients, and it is not recommended for patients diagnosed with COPD without symptoms (GOLD 2021). Pharmacological treatments include bronchodilators, inhaled corticosteroids, mucolytics (mucokinetics, mucoregulators), antioxidant agents (N-acetylcysteine, carbocisteine, erdosteine), triple combination therapies, oral glucocorticoids, antibiotics, and vaccines (GOLD 2021).

Non-pharmacological treatment methods include patient education, self-management and integrated care, physical activity, pulmonary rehabilitation, home mechanical ventilation, palliative care, end-of-life care, oxygen therapy, respiratory support, surgical interventions, bullectomy, lung transplantation, and interventional treatments such as bronchoscopy (GOLD 2021;Ergin & Muz, 2019).

The aim of treatment is to prevent the progression of the disease, improve existing symptoms, increase the patient's exercise tolerance, prevent and/or treat recurrent acute attacks, prevent and treat potential complications, prevent exacerbations, prolong life expectancy, and enhance the quality of life (GOLD 2021). To achieve these goals, patients must receive sufficient education to ensure adherence to the treatment process. This education should include topics such as smoking cessation and avoidance of risk factors, basic information about the disease, principles of medication use and effective inhalation techniques, prevention and early detection of exacerbations, dyspnea management strategies, maintaining physical activity, breathing exercises, bronchial hygiene techniques, energy conservation and techniques to simplify daily tasks, proper nutrition, hydration, and dietary recommendations (Bal Özkaptan & Kapucu, 2015).

Adherence to Inhaler Therapy in Chronic Obstructive Pulmonary Disease

Chronic obstructive pulmonary disease (COPD) requires adherence to treatment for long-term management, care, and effective health management. However, it is known that adherence to treatment is only 50% among patients, which poses a significant challenge in chronic disease management (Hamine et al., 2015). Insufficient adherence to treatment leads to increased rates of COPD exacerbations, morbidity, and mortality, resulting in an average annual cost increase of $100 billion (Aydos, 2021). Treatment adherence refers to the extent to which an individual complies with medical treatments or health recommendations. The patient's adherence to the prescribed treatment plays a crucial role in the effectiveness of the treatment administered (Özbek Yazıcı et al., 2006).

Inhaled bronchodilator and steroid medications are frequently used in the treatment of chronic obstructive pulmonary disease. Therefore, inhalation therapy is one of the primary treatment methods for COPD (Şeker, 2019; Navaie et al., 2020). The clinical management of symptoms, such as dyspnea, which commonly causes anxiety and fear in patients, primarily relies on pharmacotherapies aimed at achieving continuous bronchodilation through inhaler therapy (Navaie et al., 2020). Adherence to the dosing regimen of inhaled medications and the ability to use the device correctly enhance the bioavailability of the medication, improve treatment effectiveness, prevent COPD exacerbations, and increase appropriate symptom management and quality of life for patients (Şimşekli Bakırhan, 2018; Kara, 2002; Özkan, 2013; Ammari, 2016; Bosnic-Anticevich, 2016). To achieve these positive effects aimed at COPD treatment, it is essential to provide effective education to patients regarding the correct use of inhalation devices and dosage adjustments (Scullion, 2018). The ease of use and portability of the device enhance patient satisfaction and adherence to treatment (Dal Negro et al., 2016; Miravitlles et al., 2016). In a study by Chrystyn et al. investigating the relationship between inhaler application satisfaction, treatment adherence, and health status in 1,443 COPD patients, a significant relationship was found between inhaler application satisfaction and treatment adherence, with this significant effect reducing exacerbations and improving treatment adherence and quality of life (Chrystyn et al., 2014).

Adherence to inhaler therapy among COPD patients ranges from 20% to 60%, indicating a low level of compliance. A systematic review on this topic found that the adherence rate to inhaler therapy among COPD patients was 46%, with inattention identified as the primary reason for non-compliance (Świątoniowska et al., 2020). In a randomized controlled trial conducted in our country involving COPD patients, it was determined that the planned inhaler therapy education provided to patients reduced the level of dyspnea and increased self-efficacy and self-care ability (Ergin et al., 2019). A study conducted in Vietnam also reported that the inhaler use and medication adherence among COPD patients were low. It found that severe dyspnea, greater deterioration in health status, increased exacerbations, and higher rates of hospitalization negatively affected proper inhaler use and treatment adherence (Ngo et al., 2019). The literature indicates that patients receiving education on inhaler medication application for COPD show improved treatment adherence and medication use skills, while the frequency of application errors decreases (Özkan, 2013; Sanchis et al., 2016; Göris, 2013; Dhand et al., 2012).

Factors Affecting Adherence to Treatment in Chronic Obstructive Pulmonary Disease

Adherence to inhaler therapy impacts patients' clinical outcomes, quality of life, morbidity and mortality rates, and costs. Therefore, healthcare professionals should assess patient adherence and inhaler medication technique at each visit and identify barriers to treatment adherence, taking necessary precautions (Ceylan, 2018). Turan et al. (2016) reported that approximately 65% of COPD patients who attended regular doctor appointments did not receive guideline-concordant treatment. Moreover, patients who had not received inhaler education in the past year exhibited low inhaler skill scores. In both groups, the most common errors in inhaler use (74.3%) were related to exhalation before and after inhalation (Turan et al., 2016).

According to a report published by the World Health Organization (WHO), three types of behaviors that may hinder adherence to inhaler therapy have been identified: irregular non-compliance, unintentional non-compliance, and intentional non-compliance (WHO, 2003). Irregular non-compliance is unintentional and associated with missed doses due to forgetfulness, changing schedules, or busy lifestyles. Unintentional non-compliance arises from a lack of understanding of the prescribed regimen and/or the importance of adherence, leading to misunderstandings about how often an inhaler should be used (resulting in underuse or overuse), proper inhaler technique, and the functioning or significance of the treatment. Intentional non-compliance refers to patients deliberately modifying or discontinuing treatment because they feel better or believe they no longer need their medication. Patients may discontinue inhaled corticosteroids due to their short- or long-term side effects, unpleasant taste, complexity of use, improvement in symptoms, disruption of daily routines, or the belief that the disadvantages outweigh the benefits (Jardim & Nascimento, 2019; WHO, 2003).

Factors complicating adherence to inhaler therapy in COPD treatment include the patient's age, education level, presence of comorbidities, training on medication administration and its repetition, duration of the disease, inadequate education or information about the disease process or comorbidities, perceived negative effects of treatment, beliefs that the disadvantages of treatment outweigh the advantages, patient acceptance and preferences, medication costs, and the complexity of inhaler device usage (Restrepo, 2008; Normansell, 2017; WHO, 2003; Bryant, 2013). In a randomized controlled trial conducted by Ergin et al., it was determined that approximately 91% of COPD patients in the intervention group correctly administered their inhaler medications, while all patients in the control group used them incorrectly. A study on factors affecting the correct use of inhaler devices in COPD patients found that 74% of patients used their medications correctly, with adherence rates for metered-dose inhalers (MDI) ranging from 66.3% and between 76% and 81% for dry powder inhalers (DPI). Advanced age (over 60 years), being illiterate or only having completed primary school, a complaint duration of less than three months, and the selection of MDI devices were identified as significant factors in incorrect use (Başlılar et al., 2018). Vanoverschelde et al. (2020) investigated factors associated with poor inhaler technique and treatment non-compliance in COPD patients, concluding that age and smoking status were significant variables in treatment non-compliance, with younger patients exhibiting higher rates of non-compliance. Additionally, it was found that patients who had never smoked had 85% better treatment adherence compared to those who continued to smoke.

Clinical studies have shown that although the compliance of COPD patients with prescribed treatments ranges from 70% to 90%, the actual compliance observed in clinical settings is only between 10% and 40%. Several factors contribute to this discrepancy in compliance within clinical environments, including patient characteristics such as beliefs, psychological status, cognitive functioning, self-efficacy, and comorbid conditions; social factors including the patient-prescriber relationship, access to medication, social support, and training and follow-up on devices; as well as pharmacological treatment factors, including the application method, type of inhaler, dosing regimen, polypharmacy, and concerns about side effects (Jardim and Nascimento, 2019; Bourbeau and Bartlett, 2008).

One of the most significant pharmacological factors that can exacerbate treatment noncompliance is the use of complex inhaler devices. These devices can lead to incorrect inhaler usage, increased daily dosing frequency, polypharmacy, and adverse effects. Various factors, including the number of devices, can predict the incorrect use of inhalers among outpatient COPD patients. It has been shown that the average number of errors made is lower when only one device is used compared to when three inhaler devices are utilized (Machado et al., 2015; Jardim and Nascimento, 2019). In a study comparing two cohorts, one using similar inhalation technique devices ("similar device cohort") and

another using a "mixed device cohort," involving 16,250 COPD patients, it was demonstrated that patients using similar devices experienced an 18% reduction in the incidence of COPD exacerbations and used 46% less reliever medication compared to those using mixed devices (Bosnic-Anticevich et al., 2017). Therefore, the simplicity of inhaler device usage contributes to increased patient compliance and improved outcomes.

Conclusion

In conclusion, COPD symptoms are a difficult chronic disease to manage because they negatively affect the quality of life, mortality, and morbidity rates of patients. To prevent the disease from entering exacerbation periods and to manage the symptoms correctly, it is important to apply the treatment properly and ensure compliance with the treatment. Adherence to inhaler therapy remains a significant challenge in the management of COPD, despite the availability of effective treatments. Several factors influence patient compliance, including individual patient characteristics, the complexity of inhaler devices, and the level of education and support provided. Clinical studies indicate that while treatment adherence is reportedly high in controlled environments, real-world adherence rates are alarmingly low. Key barriers include the use of complex inhaler devices, polypharmacy, and insufficient patient education.

Patient education is essential for improving treatment outcomes. Education programs focused on inhaler techniques, symptom management, and the importance of adherence have demonstrated success in reducing exacerbations and enhancing quality of life. The results of this review highlight the need for healthcare professionals to implement structured education programs that can effectively equip patients with the necessary knowledge and skills to manage their condition.

Device simplicity also plays a critical role; the use of simpler, more user-friendly inhaler devices is associated with fewer errors and better adherence. Cohort studies suggest that patients using similar inhalation technique devices experience better outcomes, with fewer exacerbations and reduced medication use. Healthcare support is crucial for enhancing compliance. Continuous assessment of patient adherence and inhaler technique by healthcare providers, along with addressing barriers such as medication costs and psychological factors, is vital.

Training nurses should plan regular training sessions for patients, explaining inhaler training procedures through demonstration techniques. Patients should practice these techniques, with immediate corrections for any errors. Additionally, when selecting inhaler devices, it is especially important to choose devices that are simple to use to ensure patient compliance with the treatment. By addressing these factors, it is possible to improve treatment adherence, leading to better disease management, reduced healthcare costs, and improved quality of life for COPD patients. Future research should focus on developing targeted interventions that address the multifaceted barriers to adherence, ultimately contributing to more effective long-term disease management.

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Energy and Resource Modeling: A Comparative Analysis of Containers and Virtual Machines

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Abstract

This paper presents a comparative analysis of energy and resource utilization between containers and virtual machines (VMs), technologies essential for modern cloud computing environments. Containers, lightweight virtualization solutions, enable rapid deployment, efficient scaling, and reduced overhead by sharing the host OS kernel, making them ideal for microservices and agile development workflows. Conversely, VMs offer enhanced security and isolation by virtualizing entire operating systems, suiting multi-tenant and legacy applications. Through mathematical modeling, this study quantifies the differences in energy consumption and resource efficiency of these technologies. The models utilize variables such as CPU and RAM usage and server load to assess each technology's performance in various scenarios. Results from simulations indicate that containers can significantly reduce infrastructure costs by optimizing resource allocation. A sample calculation for VMs and containers was performed to assess resource and energy demands. The results indicate that running 10 VMs requires 9.2% more CPU resources, and 12.5% more RAM compared to containers. In terms of energy consumption, VMs require 82% more energy than an equivalent setup of 10 containers.

Keywords: virtual machines, containers, resource, modeling, resource allocation**.**

I. INTRODUCTION

In recent years containers and virtual machines (VMs) have gained increasing attention due to their critical roles in cloud computing, software deployment, and network function virtualization (NFV). Containers have risen in prominence due to their lightweight nature, offering advantages in performance, scalability, and resource efficiency compared to traditional VMs (Fig. 1) [1]. These technologies have become essential for deploying scalable and portable applications in various environments, from cloud infrastructure to edge computing.

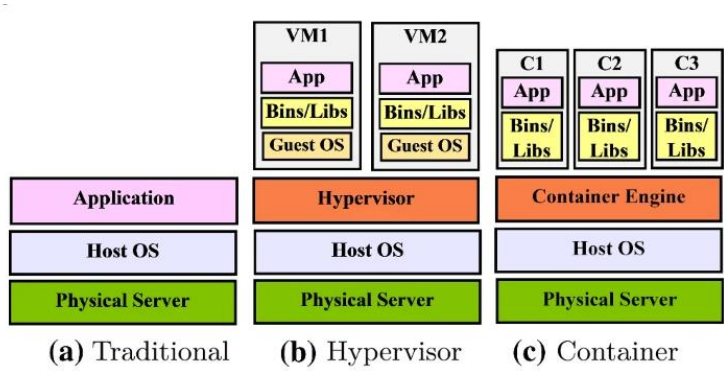

Fig 1. Comparison between application deployment using traditional hypervisor (virtual machine) and container architecture [1]

Containers, such as Docker, offer a more resource-efficient alternative to VMs because they share the host's operating system kernel, reducing overhead and enabling faster start-up times. This makes them ideal for microservices architectures and agile development cycles. However, while containers are lighter, VMs provide a higher level of isolation and security by virtualizing entire operating systems, making them more suitable for environments where strong security and isolation are critical, such as multi-tenant cloud environments [2].

Also show that containers offer better resource utilization, leading to lower infrastructure costs. The ability to spin up and down containers quickly in response to load variations makes them highly adaptable. According to Guerrero et al. (2021), containers provide more efficient resource optimization for microservices, reducing the need for additional hardware resources compared to VMs [3].

For instance, research shows that while VMs are highly secure, containers offer significant performance gains, particularly in scenarios requiring fast, scalable deployment [4]. Furthermore,

container orchestration platforms like Kubernetes have accelerated the adoption of containers in cloud-native applications, offering sophisticated tools for managing container lifecycles, scaling, and resource optimization [5].

The relevance of both technologies continues to grow as industries move toward hybrid and multi-cloud environments. VMs are often used for legacy applications requiring greater security, whereas containers are favored for new, cloud-native development due to their agility and efficiency [6]. This trend is further driven by the increasing demand for energy-efficient solutions, with containers showing promise in reducing resource consumption in cloud data centers.

One of the primary concerns is the efficient scheduling and resource allocation of containers in Kubernetes clusters. Scheduling algorithms have evolved to handle dynamic workloads, with techniques such as topology-aware scheduling improving GPU resource utilization, while other strategies optimize CPU and memory usage across distributed systems. Studies highlight that Kubernetes' scheduling algorithms can be enhanced for better performance, like in edge computing scenarios where resource constraints are tighter [7]

Task: To develop models to systematically quantify the differences in performance and resource utilization between containerized environments and virtual machines

Research goals:

Develop energy and resource models.

Quantitatively evaluate the differences between containers and virtual machines.

Methodology: literature review, computer modeling.

II. Energy and Resource Modeling

Development of Energy and Load Models

When distributing resources in a containerized environment, we will construct a mathematical model of the energy system to maximize efficiency and minimize energy consumption. The notation used is as follows:

- x_{ij} – Binary variable indicating whether container *i* is assigned to server *j* (1 – if yes, 0 – if no).
- *S* – count of servers.
- *C* – count of containers.
- *Pj* – Power consumption of server *j* in watts (energy consumption over time).
- C_i: – Resource requirements for container *i* (such as CPU, RAM, etc.).

First will describe server resource limitations:

$$\sum_{i=1}^{C} R_i \cdot x_{ij} \leq C_j, \forall j \in \{1,\ldots,S\}, \quad (1)$$

where *Rj* is the resource capacity of server *j*

Each container *i* must be assigned to exactly one server *j*j:

$$\sum_{j=1}^{C} x_{ij} = 1, \forall i \in \{1,\ldots,C\}. \quad (2)$$

Energy consumption can be calculated using the function:

$$min \sum_{j} P_j \cdot \left(\sum_{i} x_{ij} \cdot \frac{C_i}{R_j} \right). \quad (3)$$

Then the total energy consumption (E_{total}) can be described as:

$$E_{total} = \sum_{j=1}^{S} P_j \cdot \left(\sum_{i=1}^{C} \frac{R_i \cdot x_{ij}}{C_j} \right), \quad (4)$$

where (which is not mentioned above):

- R_i – resource requirement of container *i*;
- C_j – resource capacity of server j.

To measure performance, we will use the container request processing time and server load. This approach aims to maximize performance by minimizing the average request processing time. Where:

T_i – Request processing time for container *i.*

L_j – Load of server *j.*

Then, load balancing among servers *i* can be described as:

$$\sum_i T_i \cdot x_{ij} \leq L_j. \quad (5)$$

From equation (4), the performance will be equal to:

$$min \frac{1}{n} \sum_i T_i . \quad (6)$$

These equations enable the optimization of resource allocation in both containerized and virtual machine environments, aiming to reduce overall energy consumption. By using these formulas, companies can efficiently manage their infrastructure and reduce operational costs while maintaining high service quality.

III. Comparison of Virtual Machines and Containers

Next, an example with 10 VMs containers will be calculated, demonstrating that containers are more efficient compared to virtual machines, a resource demand calculation will be performed. It is known that:

Virtual Machines: Virtual machines use a hypervisor, which creates a virtualization layer between the physical hardware and the operating system. This incurs additional resources overhead.

Containers: Containers share the host operating system kernel, avoiding this overhead and thus utilizing resources more efficiently.

Hardware Overhead: Hypervisors create virtual resources (CPU, memory, storage), which leads to additional overhead. Containers, on the other hand, share the OS resources, resulting in lower overhead.

Performance of Virtualization Layers: A hypervisor manages multiple VMs, which results in added costs due to context switching and hardware abstraction. Containers operate as isolated groups of processes without an additional virtualization layer, thereby offering higher performance.

According to both Microsoft Hyper-V [8] and VMware vSphere [9], the impact of the hypervisor on CPU and memory is minimal, often estimated at about 5% overhead.

Resource Allocation: If a VM requires 80% of resources [10] and considering a 5% overhead from the hypervisor [8,9], the effective resource utilization is approximately 85%.

Energy Consumption: Assuming that the server's energy consumption is proportional to resource usage, if the base power is P_{base} and the maximum power at full load is P_{max}, energy consumption can be calculated as follows:

$$P_{VM} = P_{base} + 0.85 \cdot (P_{max} - P_{base}). \quad (7)$$

Meanwhile, containers have minimal overhead, typically around 2-3%, as they share the host OS kernel and do not require full OS installations.

Energy Consumption: For an 80% load with container workloads, the effective resource utilization is approximately 82% [11]. Then:

$$P_{Container} = P_{base} + 0.82 \cdot (P_{max} - P_{base}). \quad (8)$$

Example resource calculation

Further calculations are performed using real parameters. We have a physical server with the following specifications:

- 16 physical cores (CPU);
- 64 GB RAM.
- 1000 GB SSD storage.
- Base power P_{base}=200 W.
- Maximum power P_{max}=600 W.

Each VM uses 1 GB of RAM for the OS and 0.1 CPU core. The VM hypervisor requires an additional 5% CPU overhead for managing all VM. Total count of VM – 10.

Containers share the main OS resources, which total use 2% of CPU and 2 GB of RAM.

Effective resource usage for VM:

$$\begin{gathered}\text{CPU: } 5\% \cdot \ 16 \text{ (Cores)} \ = 0.8 \text{ Cores;} \\ \text{CPU of VM: } 10(VM) \cdot \ 0{,}1 \text{ (Core)} \ = 1 \text{ Cores;} \\ \text{RAM: } 1\text{GB/each} \cdot 10(\text{VM}) = 10 \text{ GB.}\end{gathered} \tag{9}$$

Free resources available (based (9)):

$$\begin{gathered}\text{CPU: } 16 - 0.8 - 1 = 14{,}2 \ Cores \\ \text{RAM: } 64 \ - \ 10 = 54 \text{ GB.}\end{gathered} \tag{10}$$

Efficiency percentages with VM:

$$\begin{gathered}\text{CPU: } \frac{16-14{,}2}{16} \cdot 100 = 11.25\%; \\ \text{RAM: } \frac{64-54}{64} \cdot 100 = 15.6\%.\end{gathered} \tag{11}$$

Calculations using containers:

Main OS overhead:

$$\begin{gathered}\text{CPU: } 2\%(\text{see above}) \cdot \ 16 \text{ (Cores)} \ = 0.32 \text{ Cores;} \\ \text{RAM: used by the main OS (see above): } 2 \text{ GB}\end{gathered} \tag{12}$$

Available free resources:

$$\begin{gathered}\text{CPU: } 16 - 0.32 \ = 15.68 \ Core \\ \text{RAM: } 64 \ - \ 2 = 62\text{GB.}\end{gathered} \tag{13}$$

Efficiency percentages with containers:

$$\begin{gathered}\text{CPU: } \frac{16-15{,}68}{16} \cdot 100 = 2\%; \\ \text{RAM: } \frac{64-62}{64} \cdot 100 = 3.1\%.\end{gathered} \tag{14}$$

The efficiency differences for a 10-unit run can be calculated based results (11) and (14):

$$\begin{gathered}\text{CPU: } 11{,}25\% - 2\% = 9{,}2\%; \\ \text{RAM: } 15{,}6\% - 3{,}1\% = 12{,}5\%.\end{gathered} \tag{15}$$

Calculation of energy consumption

To evaluate the energy consumption for the previously calculated 10 VM and 10 containers, we will use the next average assumptions:

- CPU power consumption: 40 Watts per Core.
- RAM power consumption: 2,5 Watts per GB.

Energy consumption for 10 VM:

$$\begin{gathered}\text{CPU: } 1.8\ (Cores)\ \cdot\ 40W = 72W;\\ \text{RAM: } 10\text{GB} \cdot 2.5W = 25\text{W};\\ \text{Total: } 72+25\text{W}=97\text{W}.\end{gathered} \tag{16}$$

Energy consumption for 10 containers:

$$\begin{gathered}\text{CPU: } 0.32\ (Cores)\ \cdot\ 40W = 17.8W;\\ \text{RAM: } 2\text{GB} \cdot 2.5W = 5\text{W};\\ \text{Total: } 17.8\text{W}+5\text{W}=17.8\text{W}.\end{gathered} \tag{17}$$

The energetic efficiency differences for a 10-unit run can be calculated based on results (16) and (17):

$$97\text{W} - 17{,}8W = 79{,}2W, \tag{18}$$

i.e. 82% of VMs need more energy than 10 containers.

It is important to note that this is a model calculation that may vary depending on the specific load of the infrastructure. In a real environment, other factors such as network usage, I/O operations, and additional system overhead can affect overall energy consumption. These calculations compare only the system support resources (i.e., they do not include what will be run within the VMs or containers).

CONCLUSION

A methodology for energy and resource calculation has been developed for the modeling of VM and container systems. Using these models, companies can estimate resource and energy requirements. A sample calculation for VMs and containers was performed to assess resource and energy demands. The results indicate that running 10 VMs requires 9.2% more CPU resources, and 12.5% more RAM compared to containers. In terms of energy consumption, VMs require 82% more energy than an equivalent setup of 10 containers.

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IMPACT OF SHOCK ABSORBERS QUALITY ON THE SAFETY OF CAR PASSENGERS AND CARGO

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Abstract

The analysis of impact of properly operating shock absorbers having a substantial influence on the vehicle safety is a main issue of this paper. A "Quarter-car suspension model" has been used in creating mathematic model for dynamic processes analysis – system of differential equations.
The dynamic processes taking place in the wheel suspension has been mathematically described using Quarter-car suspension model. A system of differential equations has been created and applied for programming Scilab Xcos. The results of modeling were verified by performing practical performance using automobile Volvo S80. The results of process modeling and practical car braking using shock absorbers of various quality evidently show the importance of their quality and significant impact on vehicle stability on the road. The simulation, applying Scilab X cos system allows to conclude that the mechanical oscillations during the braking process are quite significant (oscillation amplitude from 0.2, 0,1 m through 3 s period). In case of shock absorber malfunctioning the process simulation, when the damping force of the suspension system was 10 times reduced, the amplitude of moving masses grows up about twice and the period of oscillations lasts more than 3,5 times longer. That allows us to predict that these parameters could expand a braking time up to 20% - 30%, thus affecting the wheel's clamping force and, at the same time, the wheel's adhesion to the road. These factors directly affect the length of the braking distance, as well as the stability of the car's movement in the turn. Because, the results of practical measurements, proved the shock absorbers quality influence on so important parameters like vehicle stopping time and distance, quite often defining the vehicle safety on the road it's reasonable to stress on the importance of more strict technical quality control of shock absorbers.

Key words: car suspension, spring constant, damping constant, braking distance, oscillation processes, lumped parameters.

Introduction

All wheeled vehicles inevitably face the problem of dynamic shocks to the body. This, of course, depends both on the speed at which the vehicle moves, and on the road on which the vehicle is traveling, the smoothness and straightness of its surface. In particular, the efficiency issue of the wheel suspension design arises in car transport, because here the average speeds of traffic flows are growing most rapidly – it is dictated by the rapidly developing economic needs of various areas of logistics and the progress of innovations in technologies and, specifically, car construction nodes. [1]. However, it has to be admitted that one of the car's advantages is that the road on which it moves has much lower requirements than e.g. for railway transport, where, by the way, the dynamic forces acting on the cargo are of a different nature. On the other hand, the aforementioned lower requirements lead to inevitable road irregularities and turns, which during the movement of vehicle cause dynamic loads on the car body, which are transmitted to the cargo or passengers, and most importantly negatively affect the movement trajectory and its length (in case of braking). To neutralize dynamic loads (shocks), mechanical, hydraulic or mixed wheel suspension systems are used, the purpose of which is to at least partially absorb road shocks to the car body. [3] From the other hand the reaction of the car body, mentioned above, when affecting on movement trajectory, could significantly influence on traffic safety in general. The purpose of this study is to evaluate the processes taking place in the modern car suspension, individual nodes, i.e. the interaction between the spring and the shock absorber, as well as the influence of the suspension's performance, especially the shock absorber's functionality, on the car's movement, specifically on the quality of the braking process. It is also worth paying attention to the lack of technical control measures for shock absorbers when assessing the technical condition of the car during their regular inspection.

Problematic research questions set in the article: How intensive and how long lasting are oscillations of masses in car suspension system? How the quality drop can affect car stability on the road and how it could extend a braking distance of the vehicle?

The aim of the research - to define theoretically an impact of shock absorbers quality changes on oscillation processes of masses in car wheel suspension model and to verify practically

the scale of this impact on vehicle dynamic stability and braking distance.

The objectives of the research:

1. Mathematically describe the dynamic processes taking place in the wheel suspension.
2. Perform simulation of dynamic processes occurring in the wheel suspension using the parameters of a real Volvo S80 car with the Scilab Xcos system.
3. Practically verify the results of modeling during car braking tests in two variants - a) when new, high-quality shock absorbers are installed in the suspension of the front axle, b) when elements that technically without shock absorbing elasticity are installed.

The methods of the research

In order to evaluate objectively the influence of the shock absorber on the dynamics of the car wheel suspension, the Quarter-car suspension model was applied, when a system of differential equations is created, and it‘s solutions show the influence of the quality of the shock absorber on the oscillating transient processes. Process results were obtained using the simulation program Scilab Xcos. [13]

Experimental part of the study - Seeking to verify the results practically during car braking tests (perform 20 brakes for each braking value, taking the average of their values) in two variants - a) when new, high-quality shock absorbers are installed in the suspension of the front axle, b) when elements that technically do not have shock-absorbing elasticity are installed. Objective evaluation of the impact of a car's shock absorber on the dynamics of the wheel suspension, allowing to assess the impact of high-quality shock absorbers on the car‘s dynamic stability.

Car wheel suspension and the processes taking place in it

In order to analyze the dynamics of car movement on the road, it is appropriate to choose the so-called "Quarter-car suspension model" often used by this field researchers. “Refer to Figure 1”.

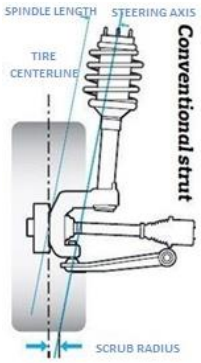

Figure 1. *Quarter-car suspension model. [1]*

Quarter-car suspension models are used to study the dynamics of a vehicle’s suspension. The model consists of: the wheel, the suspension system (damper and coil) and a quarter of the vehicle’s body mass.

The modeling approach is to use lumped parameters, which means that a quarter of the vehicle body and the wheel are concentrated in distinct single mass parameters. The stiffness and the damping of the suspension and of the wheel are also concentrated in lumped parameters. “Refer to Figure 2”.

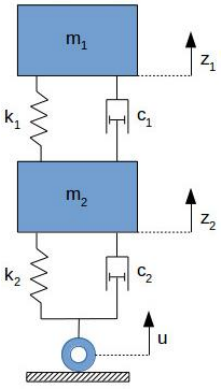

Figure 2. *Quarter-car lumped parameters model. [13]*

Where:
m_1 [kg] – the mass of a quarter of the vehicle body
m_2 [kg] – the mass of the wheel and suspension
k_1 [N/m] – spring constant (stiffness) of the suspension system
c_1 [Ns/m] – damping constant of the suspension system
k_2 [N/m] – spring constant (stiffness) of the wheel and tire
c_2 [Ns/m] – damping constant of the wheel and tire
z_1 [m] – displacement of the vehicle body (output)
z_2 [m] – displacement of the wheel (output)
u [m] – road profile change (input)

The road profile is considered to be the input into the system. The purpose of the study is to analyze the system's response (outputs) for a step input of the road profile, which can be regarded as the wheel going above a steep rigid object on the road (rock, brick, etc.)
Before writing down the equations, we need to draw the free body diagram (FBD) of the system. From this we will deduce the force equilibrium equations for both masses. Since there are two coupled masses, the dynamic system has two degrees of freedom. "Refer to Figure 3".

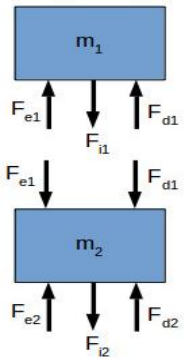

Figure 3. *Quarter-car free body diagram (FBD). [13]*

where:
F_{e1} [N] – the elastic force of the suspension system
F_{d1} [N] – the damping force of the suspension system
F_{i1} [N] – the inertial force of the vehicle body
F_{e1} [N] – the elastic force of the wheel and tire
F_{d1} [N] – the damping force of the wheel and tire
F_{i1} [N] – the inertial force of the wheel and tire

The directions of the forces are set according to the following reasoning. Imagine that the road has a bump and the wheel rolls over it. The profile change of the road will cause the tire to compress. This will generate an elastic force F_{e2} and a damping force F_{d2} which will push the wheel up. Due to inertia, the wheel will try to resist the position change through the inertial force F_{i2}. The elastic and damping forces are also acting on the road but this is not in the interest of our study.
The suspension system will oppose the upward movement of the wheel and it will push on it with the elastic force F_{e1} and a damping force F_{d1}. According to Newton's third law of motion, for each action there is a reaction. Therefore the elastic force F_{e1} and the damping force F_{d1} will push the vehicle body upwards. [7], [13]. Due to inertia, the body mass will try to resist the position change through the inertial force F_{i1}.

The equation of force equilibrium for the body mass is:

$$F_{i1} = F_{e1} + F_{d1} \tag{1}$$

The inertial force of the body, and the elastic and damping forces of the suspension system are expressed as:

$$F_{e1} = k_1(z_2 - z_1) \tag{2}$$

$$F_{d1} = c_1\left(\frac{dz_2}{dt} - \frac{dz_1}{dt}\right) \tag{3}$$

$$F_{i1} = m_1 \frac{d^2 z_1}{dt^2} \quad (4)$$

Replacing the expressions of the forces in equation (1), we get:

$$m_1 \frac{d^2 z_1}{dt^2} = k_1(z_2 - z_1) + c_1\left(\frac{dz_2}{dt} - \frac{dz_1}{dt}\right) \quad (5)$$

The equation of force equilibrium for the wheel mass is:

$$F_{i2} + F_{e1} + F_{d1} = F_{e2} + F_{d2} \quad (6)$$

The inertial force of the wheel, and the elastic and damping forces of the wheel system are expressed as:

$$F_{e2} = k_2(u - z_2) \quad (7)$$

$$F_{d2} = c_2\left(\frac{du}{dt} - \frac{dz_2}{dt}\right) \quad (8)$$

$$F_{i2} = m_2 \frac{d^2 z_2}{dt^2} \quad (9)$$

Replacing the expressions of the forces in equation (3), we get:

$$m_2 \frac{d^2 z_2}{dt^2} = k_2(u - z_2) + c_2\left(\frac{du}{dt} - \frac{dz_2}{dt}\right) - k_1(z_2 - z_1) - c_1\left(\frac{dz_2}{dt} - \frac{dz_1}{dt}\right) \quad (10)$$

The ordinary differential equations (ODE) (5) and (10) describe the dynamic behavior of the quarter-car model.

Before integration in Xcos, we need to keep on the left-hand side of the equal sign only the second derivatives of the displacements. This will give:

$$\frac{d^2 z_1}{dt^2} = \frac{1}{m_1}\left(k_1(z_2 - z_1) + c_1\left(\frac{dz_2}{dt} - \frac{dz_1}{dt}\right)\right) \quad (11)$$

$$\frac{d^2 z_2}{dt^2} = \frac{1}{m_2}\left(k_2(u - z_2) + c_2\left(\frac{du}{dt} - \frac{dz_2}{dt}\right) - k_1(z_2 - z_1) - c_1\left(\frac{dz_2}{dt} - \frac{dz_1}{dt}\right)\right) \quad (12)$$

Before building the Xcos block diagram model, we need to load the parameters of the system in the Scilab workspace or in the Set Context environment from Xcos.

```
m1 = 290;
m2 = 60;
k1 = 16200;
k2 = 191000;
c1 = 1000;
c2 = 2500;
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Based on the differential equations above we build the Xcos block diagram model: “Refer to Figure 4”.

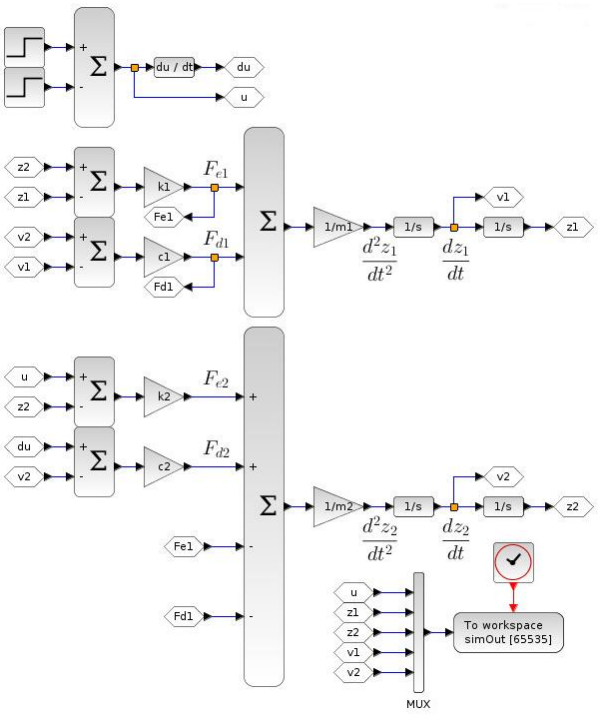


Figure 4. *Quarter-car Xcos block diagram model*

The road input u is modeled as a step input, with a rising edge and falling edge. v1 is the vertical translational speed of the body of the vehicle and v2 is the vertical translational speed of the wheel.

All the initial conditions of the integrators are set to zero. The simulation is set to run for 8 seconds. The results of the simulations are saved in the Scilab workspace, under the variable simOut. To plot the outputs we use the Scilab script.

Diagrams of the Volvo S-80 car braking transient process.The system's response is plotted in the graphical window below. "Refer to Figure 5, 6 and 7, 8".

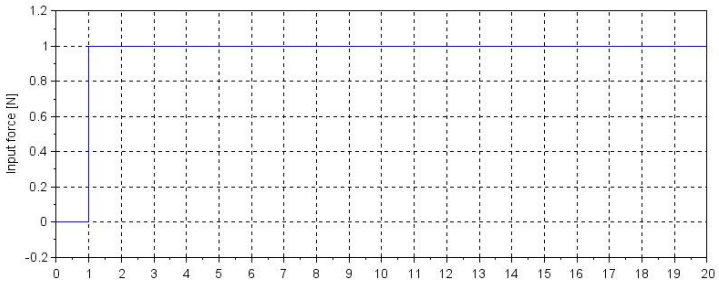
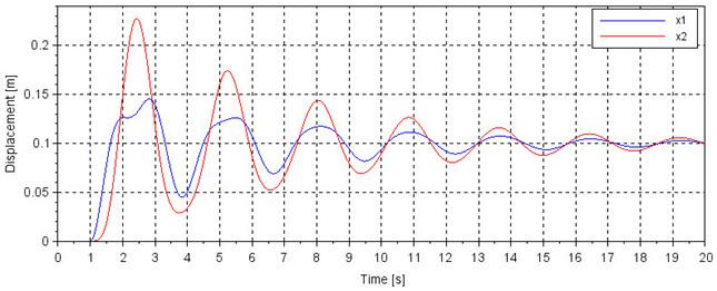
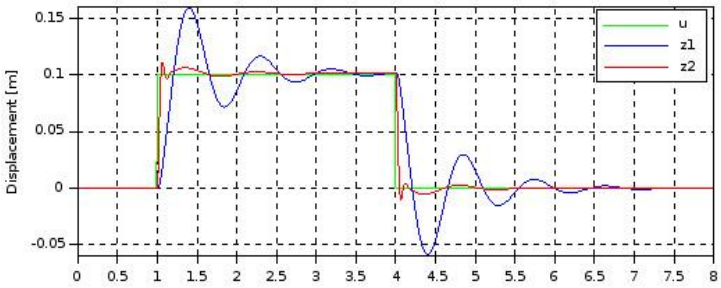


Figure 5. *System's response to step force input (force/time)*



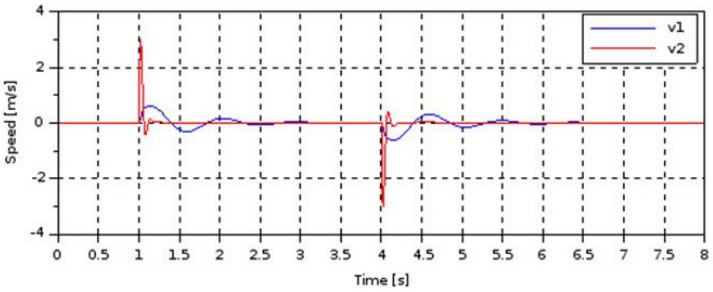
x1-vehicle body movement; x2- wheel movement.

Figure 6. *System's response to step force input (displacement/time)*



u-input movement; z1-vehicle body movement; z2-wheel movement.

Figure 7. *The system's response to double step force input is plotted in the graphical window (displacement/time)*



v1-vehicle body movement; v2- wheel movement.

Figure 8. *The system's response to double step force input is plotted in the graphical window (speed of masses/time)*

After the simulation, it can be concluded that the mechanical oscillations during the braking process are quite significant (amplitude from 0.2, 0,1 m through 3 s period), thus affecting the wheel's clamping force and, at the same time, the wheel's adhesion to the road. These factors correspond to vehicle braking time and directly affect the length of the braking distance, as well as the stability of the car's movement in the turn. To describe a case of shock absorber malfunctioning the process of simulation has been analyzed – i.e. the damping force of the suspension system was 10 times reduced. The amplitude of moving masses grew up about twice and the period of oscillations lasted more than 3,5 times longer. That allows us to predict that these parameters could expand a braking time up to 20% - 30%. It should be noted that during modeling we only get amplitudes and velocities of suspension mass oscillations, but the real path of the car depends on the adhesion of the road surface to the wheel, or on the coefficient of friction between them, but knowing what the suspension mass oscillation times and amplitudes are, it is possible to determine how much these factors influence braking process.

Practical measurements of the impact of the car shock absorber quality on real braking parameters

In order to determine the influence of shock absorber quality on real braking parameters, a technical experiment was conducted, during which the braking parameters of the Volvo S80 car were fixed. i.e. braking distance and braking time when the initial braking speed was 20 km/h, 40 km/h and 60 km/h until full stop. The second part of the experiment was carried out by measuring the same parameters after the shock absorbers of the car's front wheel suspensions has been replaced with analogous mechanisms without elasticity. According to results of mathematical modeling, we know that the time of oscillations increases by more than 2 times, and the oscillation amplitude practically does not die out, so the braking distance should be significantly longer – it should reach 20%-25% higher values (because shock absorbers has been removed from front suspension). It is also true that it is impossible to avoid the shock-absorbing or oscillation-quenching effect completely, because the wheel tire partially suppresses the oscillations by tire rubber springing.

The results of the practical effect of shock absorber quality on real braking parameters are presented. "Refer to Table 1 and Table 2".

Nr.	Initial braking speed [km/h]	Stopping time [s]	Stopping distance [m]
1.	20	1,18	2,28

2.	40	1,54	9.93
3.	60	2,36	21,04

Table 1. *Parameters of the braking process when all 4 shock absorbers are of good quality:*

Nr.	Initial braking speed [km/h]	Stopping time [s]	Stopping distance [m]
1.	20	1,41	2,75
2.	40	1,86	11,98
3.	60	3,12	27,12

Table 2. *Parameters of the braking process when the shock absorbers of the front wheels are of poor quality:*

Note:

Measurements of the parameters of the braking process were carried out during the measurement of each parameter in the table has been set performing 20 brakes for each braking value and taking the average of measured values.

The results of practical measurements, presented in tables 1 and 2 obviously show the influence on so important parameters like Stopping time and distance – increase for 18%-22%. These parameters very often define the vehicle safety. However, it's reasonable to conclude that an owner of the vehicle is unaware about the real stage of shock absorbers because technical checking procedure doesn't exist. Because the results of process modeling and practical car breaking highly correspond to each other it's reasonable to conclude the importance of more strict technical quality control of shock absorbers.

Conclusions

1. The dynamic processes taking place in the wheel suspension has been mathematically described using Quarter-car suspension model. A system of differential equations has been created.

2. After the simulation, applying Scilab X cos system it can be concluded that the mechanical oscillations during the braking process are quite significant (oscillation amplitude from 0.2, 0,1 m through 3 s period). In case of shock absorber malfunctioning the process simulation, when the damping force of the suspension system was 10 times reduced, the amplitude of moving masses grew up about twice and the period of oscillations lasted more than 3,5 times longer. That allows us to predict that these parameters could expand a braking time up to 20% - 30%, thus affecting the wheel's clamping force and, at the same time, the wheel's adhesion to the road. These factors directly affect the length of the braking distance, as well as the stability of the car's movement in the turn.

3. The results of process modeling and practical car breaking on Volvo S80 correspond to each other, so it confirms the hypothesis of the research.

4. It's reasonable to conclude that usually a vehicle owner is unaware about the real stage of shock absorbers because technical checking procedure doesn't exist. Because results of practical measurements obviously show the influence on so important parameters like vehicle stopping time and distance, quite often defining the vehicle safety on the road it's reasonable to stress the importance of more strict technical quality control of shock absorbers.

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DIVERSITY OF SECONDARY COMPONENTS OF MULTI- WORD ANATOMICAL TERMS IN *POCKET ATLAS OF HUMAN ANATOMY*

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Abstract

Medical terms in the atlas can be basically divided into one-word and multi-word terms. Compound words are individual words made from two or more words working together.

The object of the article is the relations between Latin and Lithuanian compound anatomical terms, according to diversity of secondary components.*The purpose of the article* is to reveal the similarities and differences between multi-word Latin and Lithuanian anatomical terms by structural diversity of components. To achieve the purpose, the following *research tasks* are set: to review the evolution of anatomical nomenclature; to compare Latin and Lithuanian multi-word anatomical terms according to the diversification of structure of components. *Research methods.* The method of theoretical analysis examines scientific literature, the comparative analysis of terms enables systematisation and generalisation of Latin and Lithuanian anatomical terms in the resource.

Keywords: multi-word anatomical terms, diversity of secondary components, difference of secondary components.

Human anatomy is a fundamental discipline of medicine and biology, which reveals the structure of the parts of the human body, their location and interrelationships. This science describes the norm, variability of the structure of human body parts, organs and their systemsand structural deviations from the norm. Anatomical terminology is often chosen to highlight the relative location of body structures. For instance, an anatomist might describe one band of tissue as "inferior to" another or a physician might describe a tumor as "superficial to "a deeper body structure (Dauber, 2019).

The origin of anatomical terminology dates back to the ancient period, more than 2,500 years ago, and was described in the common languages of that time: Greek, and later Latin. This principle has endured and serves as a base for the modern-day anatomical nomenclature. Greek and Latin medicine established the foundation of anatomical terminology which varied with different authors. Most of the anatomical terms are different from colloquial words, and have changed since ancient times. Hippocrates (ca. 460-370 BC), in Greece, introduced terms such as acromion, bronchus and peritoneum. Aurus Cornelius Celsus (25 BC – 50 AD), in Rome, used cartilago, patella or sutura. CladiusGalenos of Pergamon (129/130 – 199/200 AD) introduced new terms. Friedrich D. J. Henle (1809 - 1885) was the first to simplify anatomical terminology. Terms such as “medialis, and lateralis” were introduced by him to describe the appropriate orientation and direction of anatomical structures (Aghoghovwia, 2023).

A standardized language for describing body structures is also essential. Anatomical nomenclature is the main tool of communication in morphology, anatomy and other medical disciplines as well as in medical education, and thus needs to be exact, flawless, elaborate and correct. The Terminologia Anatomica (TA) is a thorough and extensive list of anatomical terms and their definitions, and the current standard for human anatomical terminology. Although several revisions to the TA have been made in the last 20 years, some important anatomical structures are still not included (Musil et al., 2018). It is estimated that about three-fourths of our medical terminology is of Greek origin. The main reason for this is that the Greeks were the founders of rational medicine in the golden age of Greek civilization in the 5th Century B.C. The Hippocratic School and, later on, Galen (the Greek from Asia Minor who lived in Rome in the 2nd century A.D.) formulated the theories which dominated medicine up to the beginning of the 8th Century. The Hippocratics were the first to describe diseases based on observation, and the names given by them to many conditions are still used today. A second reason for the large number of Greek medical terms is that the Greek language lends itself easily to the building of compounds. The fact is that about one-half of our medical terminology is less than a century old (Banay, 1948).

The paper offers an up-to-date view of the status of Latin as the language of medicine, namely in its terminological component. It is concerned in greater detail with the three basic terminological vocabularies in which a doctor cannot so far manage without its knowledge. In this sense a primary rank is occupied by anatomical nomenclature whose international version remains Latin in the full extent. A more varied picture is presented by the clinical

disciplines where, apart from Latin terms, expressions of ancient provenance have been applied in a large measure in the form of ethnic languages. In pharmaceutical terminology Latin has, for the time being, remained a functioning means of international communication, guaranteed by the European Pharmacopoeia (1996) and by the corpus of International Non-proprietary Names (1992, 1996), even though in the future an ever stronger competition of national languages should be taken into account (Mareckováet al., 2002**).**

Anatomical Terminology is a unique collection of technical terms that allow communication in anatomy and medicine worldwide. However, the current Anatomical Terminology also contains some internal inconsistencies and discrepancies in relation to clinical terminology. Thus, several terms are not directly related to the names of anatomical structures and / or the names of corresponding physiological and pathological conditions. In addition, during clinical practice, many anatomical terms have been replaced by new clinical expressions. These terminological discrepancies may hinder learning and teaching anatomy in medicine and other courses in the health field. These ‘’mismatches’’ of terms generate a lot of confusion due to different origins and languages.International Anatomical Terminology is a fundamental process for medicine and other health professions, where “the act of standardizing a term is more related to standardizing and making it uniform and even harmonizing it than the act of imposing a form through normative procedures”. It is important that students in the health area have a good knowledge and understanding of basic anatomical terms, taking into account that anatomy constitutes the basis for the practice of medicine and other health courses. Anatomical understanding makes the professional understand a patient’s illness, either by clinical examination or by using the most advanced imaging techniques. It is important not only to understand anatomical terms, but to place these terms within their own context, that is, to give an appreciation of how the human body functions both in health and in disease. The precise use of anatomical terms by health professionals allows accurate communication between colleagues, both nationally and internationally. Thus, a good knowledge of Anatomical Terminology requires an understanding of the context in which terms can be remembered (Gonçalves et al., 2020). Terminologia Anatomica „can be described as the international Standard on human anatomic terminology developed by the Federative International Programme for Anatomical Terminology and the International Federation of Associations of Anatomists and was released in 1998.

According to Gaivenis, the terminology of anatomy and medicine in general as well as of botany and zoology is Latin andis grounded on certain international codes, corpuses, which are usually approved at international congresses. These codes are used as a guide for standardising the nomenclature of the systematics of these scientific fields. The principles of managing terms in this field were approved at the 5th International Congress of Anatomists (Gaivenis, 2002).

TWO-WORD TO FIVE-WORD LATIN AND LITHUANIAN ANATOMICAL TERMS

The *POCKET ATLAS OF HUMAN ANATOMY* is filled with images originally illustrated by painter and renowned physician prof. Gerhard Spitzer, this textbook is a vivid rendering of the human anatomy which is not only detailed and accurate, but also beautiful. Concise definitions of anatomical terms enhanced with hundreds of vivid, elegant illustrations. Coverage of all of the body's major organs and systems.Easy access - clearly organized, color-coded hierarchines.Up-to-date nomenclature according to the Federative Committee on Anatomical Terminology (FCAT). Comprehensive indexes in Latin, English, Lithuanian. The perfect combination of both cutting-edge and time-tested features make the Pocket Atlas of Human Anatomy the best choice for physicians, physical therapists, medical students, nurses, dentists, physician's assistants - quite simply, anyone who works with the human body (Dauber, 2019).

The first edition in German was published in 1967 under the title *Anatomishe Bildnomenklatur*. A total of 29 editions have been published in German, Italian, Polish, Spanish, Japanese, Portuguese, English, Danish, Swedish, Czech, Dutch, French, Turkish, Greek, Chinese, Icelandic languages. The Index of Terms in Lithuanian has been published three times: in 2013, 2017, and 2019.

According to Parker, the study of the body‘s structure, how its cells, tissues, and organs are assembled, is known as human anatomy. Its elements are often shown in isolation, using techniques such as cutaways, cross-sectons, and „exploded“ views, which provide clarity and understanding. But in reality, the inside of the body is a crowded place. Tissues and organs

push and press against one another. There is no free space, no stillness either. Body parts shift continuallym in relation to each other, as we move about, breathe, pump blood, shift digestive matter, and eat. (Parker, 2019).

Compound anatomical terms are usually made up of two or three words. Multi-word (four-word and five-word) compound terms are very rare. Compound terms, as a separate type of terms, were first distinguished and named by our famous linguist J. Jablonskis when reviewing K. Jaunius'"Grammar of the Lithuanian Language" in 1913. He called terms made up of several words *combined terms* (Gaivenis, 1975).

The research object consists of 1568 Latin compound anatomical terms and Lithuanian compound anatomical terms. In this article, we dissociate ourselves from single-word derivative and compound terms, which constitute a small proportion of anatomical terms – about 0,03% of the number of Lithuanian one-word and Latin one-word terms found.
Let us compare the data presented in the figure.

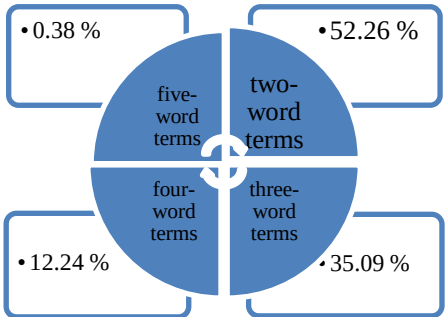

Fig. 1. Statistics of multi-wordLatin and Lithuanian anatomical terms by the variety of components (Source: Prepared by the author)

VARIETY OF SECONDARY COMPONENTS OF TWO-WORD TERMS

The largest group consists of Lithuanian and Latin two-word terms (820). Lithuanian three-word and Latin three-word terms make up a smaller part (550) (see Fig. 1).

It is believed that in most scientific fields, there are significantly more two-word terms than three-word terms. Statistically, Latin and Lithuanian two-word anatomical terms account for more than half of all compound anatomical terms found. Almost every third Latin and Lithuanian compound anatomical term is a three-word term. Only about one in seven Lithuanian and Latin term is a four-word term. Five-word Lithuanian and Latin terms do not make up evenhalf a percent.
Examples show that Lithuanian and Latin six-word to eight-word anatomical terms have not been found. They occur only in clinical terminology.

According to the usual word order in Latin, the attribute follows the determinative. In Latin, the word order is not very strict, but more often the subject goes at the beginning of the sentence; the predicate, at the end;while *the attribute, after the determinative* (Dumčius et al., 1999).Thus, it could be stated that Latin medical terminology has a reverse word order compared to Lithuanian. Usually, components of Lithuanian two-word terms are presented in a certain order – *attribute* + *determinative*; while in Latin terms,*determinative* + *attribute*. According to K. Gaivenis, this is how our anatomy, botany, and zoology nomenclature differs from Latin, in which species attributes always follow the determinative(Litevkienė, 2006).

In this paper, defining the variety of secondary components of two-word Latin terms and their Lithuanian equivalents, the following groups of Latin and Lithuanian terms were studied:
main word + attribute – agreed attribute + main word;
main word + attribute – non-agreed attribute + main word;
main word + attribute – non-agreed attribute+ non-agreed attribute+ main word attribute.

Latin two-word anatomical terms and their Lithuanian equivalents form eight types according to the variety of secondary components:

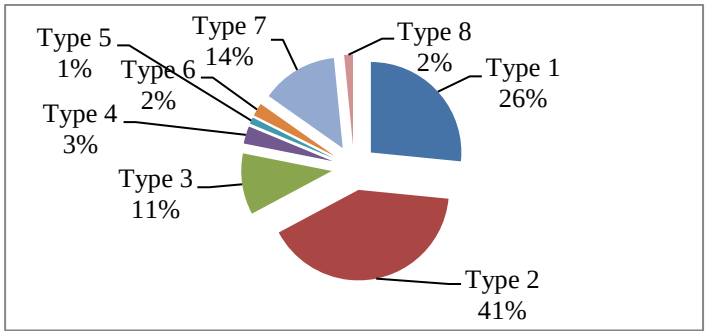

Fig. 2. *Statistics of two-word Latin and Lithuanian anatomical terms by the variety of components (Source: Prepared by the author)*

The largest group consists of the second type of Lithuanian and Latin two-word terms (40%), the first type term group accounts for more than a quarter of all found two-word terms, the seventh type term groupmakes up one seventh, and the third type term groupaccounts for one ninth of terms. The ninth, eighth, sixth, fourth, and fifth type term groups account for less than a tenth (see Fig. 2).

Type 1. Nominative of a noun (determinative) + genetive of a noun (attribute) ↔ genetive of a noun (attribute) + nominative of a noun (determinative): *agger nasiPA518 – nosies kauburysPA164; ala vomerisPA518 – norago sparnaiPA38; alveus hipppocampiPA518 – hipokampo groveliaiPA384; angulus acroniiPA518 – peties kampasPA54; angulus aortaePA518 – šonkaulio kampasPA52; angulusoris PA518 – burnos kampasPA134.*

Type 2. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) ↔ nominative of an adjective positive (attribute)+ nominative of a noun (determinative): *angulus frontalisPA518 – kaktinis kampasPA34; anulus femoralisPA518 – šlauninis žiedas120; aorta abdominalisPA518 – pilvinė aorta258; apertura medianaPA518 – vidurinė atvaraPA346;areus alveolarisPA519 – alveolinis lankasPA42; area rostralisPA519 – rombinė duobėPA370; arteria angularisPA519 – kampinė arterijaPA234.*

When discussing the aspects of the coincidence and difference of the components in the second type of terms, it is necessary to point out that secondary components of Lithuanian two-word terms with the agreed attribute are of two types:

a) secondary components can be expressed by the nominative of the pronominal adjective;

b) secondary components can be expressed by attributive adjectives with the suffixes *-inis, -ė*.

In Latin, there are no such forms as pronominal adjective and participle. In Lithuanian, pronominal adjectives have a determinative and emphatic meaning. In Latin, adjectives do not have such meanings.

The frequency of pronominal adjectives and adjectives with the suffix *-inis, -ė* as secondary components is shown in Figure 3 (see Fig. 3):

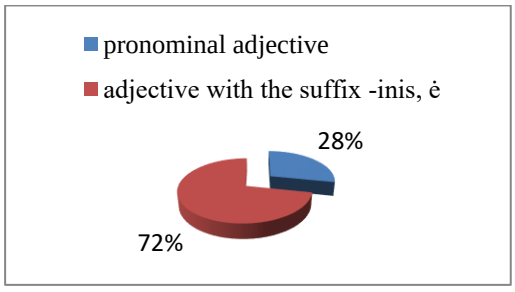

Fig. 3. Frequency of pronominal adjectives and adjectives with the suffix –inis,ė in subordinate components*(Source: Prepared by the author)*

The majority is made up of attributive Lithuanian components with the suffix *-inis, -ė* (more than two-thirds of cases). The Latin equivalents of secondary components of Lithuanian two-word terms in this group are: agreed adjectives with suffixes *-alis, e; -aris,e; icus, a, um; aceus, a, um*, which denote belonging to the object denoted by the main word or a connection with that object.

Type 3. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) ↔ genetive of a noun (attribute) + nominative of a noun (determinative): *canalis gastricusPA523 –*

skrandžio kanalasPA146; circulus arteriosusPA525 – arterijos žiedasPA17; concha auriculārePA526 – kriauklės įdubaPA14; corona ciliarisPA526 – krumplyno vainikasPA436; corpus gastricumPA526 – skrandžio kūnasPA146; cupula ampullarisPA527 – ampulės kupolasPA464; crista ampullarisPA527 – ampulės skiauterėPA464; fascia axillarisPA530 – pažasties fascijaPA116; fascia cervicalisPA530 – kaklo fascijaPA100; fornix gastricusPA532 – skrandžio skliautas; glandulae nasalesPA533 – nosies liaukosPA164.

Type 4. Nominative of a noun (determinative) + nominative of an participium (attribute) ↔ nominative of an participium (attribute) + nominative of a noun (determinative): *arteria ascendensPA519 – kylančioji arterijaPA262; cisterna ambiensPA525 – gaubiančioji cisternaPA314; ramus ascendensPA553 – kylančioji šakaPA228; aorta ascendensPA518 – kylančioji aortaPA230; aorta descendensPA518 – nusileidžiančioji aortaPA258; fascia investiensPA530 – gaubiantysis sluoksnisPA16.*

Type 5. Nominative of a noun (determinative) + nominative of numerale ordinale (attribute) ↔ nominative of numerale ordinale (attribute) + nominative of a noun (determinative): *costa primaPA527 – pirmasis šonkaulisPA52; costa secundapa527 – antrasis šonkaulisPA52.*

Type 6. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) ↔ genetive of a noun (attribute) + nominative of a noun (determinative): *arbor bronchialisPA519 – gyvybės medisPA358; arcus costalisPA519 – šonkaulių lankasPA52; arteria buccalisPA519 – žando arterijaPA236; capsula articularisPA524 – sąnario kapsulėPA14; cavitas pleuralisPA525 – krūtinplėvės ertmėPA180.*

Type 7. Nominative of a noun (determinative) + nominative of a comparative (attribute) ↔ nominative of a comparative (attribute) + nominative of a noun (determinative): *calyx inferiorPA523 – apatinė taurelėPA184; calyx superiorPA523 – viršutinė taurelė184; camera anteriorPA523 – priekinė kameraPA442; camera posteriorPA523 – užpakalinė kameraPA422; canalis anteriorPA524 – priekinis kanalasPA460; canalis posteriorPA524 – užpakalinis kanalasPA460; cornu anteriusPA526 – priekinis ragasPA18; cornu majusPA526 – didysis ragasPA46.*

Comparative adjectives in Latin terms are used in order to distinguish the determinative, because the comparative degree of the adjective means a significant or sufficiently large extent of quality. The equivalents of Latin terms whose secondary components are comparative adjectives are pronominal adjectives and adjectives with the suffix *-inis, ė*. After analysing the cases found in the source, it can be concluded that the number of Lithuanian equivalents with pronominal adjectives of secondary components in Latin terms, expressed by comparative adjectives, is twice as high as the number with the suffix *-inis, ė*.

Type 8. Nominative of a compound noun (determinative) + genitive of a noun (attribute) ↔ genitive of a noun (attribute) + genitive of a noun (attribute) + nominative of a compound noun (determinative*): aquaeductus cochleaePA519 – sraigės vandentiekio latakasPA462; aquaeductus vestibuliPA519 – prieangio vandentiekio latakasPA462; sulcus caroticusPA560 – miego arterijos vagaPA28.*

VARIETY OF SECONDARY COMPONENTS OF THREE-WORD TERMS

Three-word Latin and Lithuanian terms make up a little more than a third of compound terms found in the source. Statistically, these terms, both Latin and Lithuanian, are used quite frequently in anatomical terminology. They are surpassed only by two-word terms. Lithuanian equivalents of three-word Latin terms can also be four-word terms.

Latin three-word anatomical terms and their Lithuanian equivalents form twenty-six types according to the variety of secondary components.

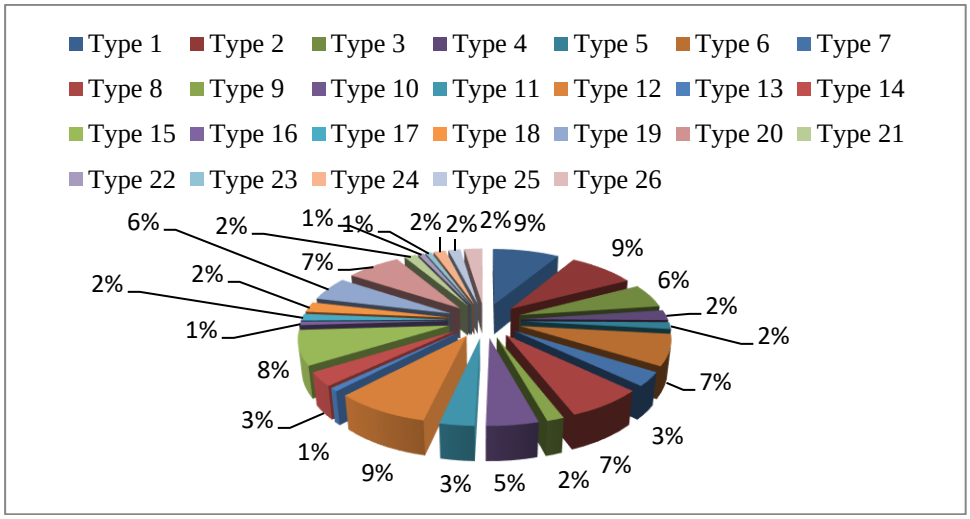

Fig. 4. *Statistics of three-word Latin and Lithuanian anatomical terms by the variety of components (Source: Prepared by the author)*

It has been observed that the following types of secondary component structures of Latin and Lithuanian three-word anatomical terms are most common:

1. Nominative of a noun (determinative) + genitive of a noun(attribute) + genitive of a noun (attribute) ↔ genitive of a noun (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative).
2. Nominative of a noun (determinative) + genitive of a noun (attribute) +nominative of a comparative(attribute) ↔ nominative of an adjective positive (attribute) + genitive of a noun (attribute) + Nominative of a noun (determinative).
3. Nominative of a noun (determinative) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) ↔ genitive of a noun (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative).
4. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + nominative of a comparative (attribute) ↔ nominative of an adjective positive (attribute) + nominative of an adjective positive (attribute) + nominative of a noun (determinative).
5. Nominative of a noun (determinative) + nominative of a comparative (attribute) + genitive of a noun (attribute) ↔ nominative of an adjective positive (attribute)+ genitive of a noun (attribute) + nominative of a noun (determinative).
6. Nominative of a noun (determinative) + nominative of an adjective positive (attribute + nominative of a comparative (attribute) ↔ nominative of an adjective positive (attribute)+ genitive of a noun (attribute) + nominative of a noun (determinative).

Every pair of the above-mentioned three-word terms can produce several combinations. In total, 26 structural types of Latin terms and Lithuanian equivalents composed of three components can be obtained. The variety of secondary Latin and Lithuanian components is presented in Table 1 (see Table 1):

Table 1

components / types	*Latin three*	*word terms*	*Lithuanian three –*	*word terms*
	I subordinate component	*II subordinate component*	*I subordinate component*	*II subordinate component*
genitive of a noun	1, 4, 5, 9, 14, 15, 18, 20	1, 2, 5, 7, 8, 13, 22	1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 20	1, 2, 4, 18, 22, 25
genitive of an adjective positive	2, 3		2	11, 20
nominative of a comparative	7, 13, 24	3, 6, 9, 10, 15, 17, 21, 26		
nominative of an adjective positive	6, 8, 10, 11, 12, 16, 21, 25, 26	4, 11, 12, 14	5, 6, 8, 15, 19, 23, 24, 26	3, 6, 7, 9, 10, 12, 13, 14, 17, 19, 23, 24, 26
nominative of a participle	17, 19, 22	16, 19	17, 21, 22	16, 21
genitive of a comparative	23	18, 20, 23		
nominative of a superlative		25	25	

Table 1. Diversity of subordinate components of Latin and Lithuanian three-word terms (Source: Prepared by the author)

In Latin three-word terms, the first secondary component is usually expressed by the genitive of the noun and the nominative of the adjective; the second secondary component, by the genitive of the noun andthe nominative of the comparative adjective. In Lithuanian equivalents, the first secondary component is usually expressed by the genitive of the noun and the nominative of the adjective; the second secondary component, by the genitive of the noun and the nominative of the adjective. In Lithuanian terms, there are no such cases where secondary components are expressed by the genitive of the comparative adjective. Superlative adjectives occur very rarely in three-word terms. Coincidences and differences of secondary components in Latin and Lithuanian terms can be summarised as follows: identical terms are of types 1, 2, 14, 19, 22 (which accounts for 16.23%).

VARIETY OF SECONDARY COMPONENTS OF FOUR-WORD TERMS

It has already been mentioned that the majority of Latin and Lithuanian anatomical terms are two-word and three-word terms, which form various groups of terms. Latin and Lithuanian four-word anatomical terms form a small group of compound terms: one in seven terms found in the source is a four-word term. Due to the variety of secondary components, only four groups of identical Latin and Lithuanian terms have been observed: the fourth, seventh, thirteenth and seventeenth groups. Lithuanian equivalents of four-word Latin terms can be four-word Lithuanian terms and in very rare cases, five-word terms occur.

The source contains 20 structural types of Latin four-wordterms and their Lithuanian equivalents. The variety of secondary Latin and Lithuanian components is presented in Table 2 (see Table 2):

Table 2

	Latin four- word terms			*Lithuanian four – word terms*		
components types	*I SB*[*]	*II SB*	*III SB*	*ISB*	*II SB*	*III SB*
nominative of an adjective	1, 2, 4, 5, 6, 8, 10, 11, 17, 18, 20, 13, 14	18, 20, 12	7, 11, 14	10, 4, 13, 14, 17	7, 10, 11, 1, 14, 15, 20	6, 7, 8, 9, 10, 11, 12, 1, 2, 6, 14, 15, 20
genitive of an adjective		7, 3, 16	12, 13, 15, 17, 5, 4	6, 7, 8, 9	5, 13, 18	3, 4, 5, 13, 16, 17, 19
genitive of a noun	1, 3, 7, 9, 16, 19	8, 2, 4, 5, 6, 9, 15, 17, 19, 13	6, 8, 9, 18, 19, 20	11, 12, 1, 2, 3, 5, 15, 16, 19, 18, 20	6, 8, 9, 12, 2, 3, 4, 16, 17, 19	18
nominative of a comparative	12, 15	1, 10, 11, 14	10			
genitive of a comparative			16, 1, 3			

[*]*SB – Subordinate component*

Table 2. Diversity of subordinate components of Latin and Lithuanian four-word terms (Source: Prepared by the author)

The variety of secondary components of four-word Latin and Lithuanian terms, which is presented in the table, shows the frequency of occurrence of the most productive terms in this group. In Latin four-word terms, the first secondary components are the nominative of the adjective (50% of all four-word terms), the genitive of the noun occurs somewhat less frequently (26,9%); the second secondary components are most often the genitive of the noun (26,9%); the third secondary components are most often the genitive of the adjective (26,9%) and the genitive of the noun (26,9%). Rarely, secondary components of Latin terms are expressed by the genitive of the comparative adjective. The first secondary components of Lithuanian four-word terms are most often expressed by the genitive of the noun (50%); the second secondary components are most often expressed by the genitive of the noun (38,5%), the nominative of the adjective (26,9%);and the third secondary components are most often expressed by the nominative of the adjective (50%) and the genitive of the adjective (26,9%).

Structural types of four-component Latin terms and their Lithuanian equivalents:

1. Nominative of a noun (determinative) + genitive of a noun (attribute)+ nominative of a comparative (attribute) + genitive of an adjective positive (attribute) ↔ nominative of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of a noun (attribute) +nominative of a noun (determinative):*nervi curvaturae minoris anteriorPA542 –priekinis mažosios kreivės nervasPA410.*

2. Nominative of a noun (determinative) + genitive of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) ↔ nominative of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of a noun (attribute) +nominative of a noun (determinative): *nervus cutaneus femoris lateralisPA542 – šoninis šlaunies odos nervasPA420.*

3. Nominative of a noun (determinative) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) + genitive of an adjective positive (attribute) ↔ genitive of an adjective positive (attribute) + genitive of an adjective positive (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative): *ostium venae cavae superioris 548PA – viršutinės tuščiosios venos angaPA224.*

4. Nominative of a noun (determinative) + genitive of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) ↔ genitive of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) +nominative of a noun (determinative): *pars anularis vaginae fibrosaePA548 – skaidulinės makšties žiedinė dalisPA116.*

5. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) ↔ nominative of an

adjective positive (attribute) + genitive of an adjective positive (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative): *pars medialis lobuli biventralisPA549 – nugarinė gretutinė skiautės dalisPA356.*

6. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) ↔ nominative of an adjective positive (attribute) + genitive of an adjective positive (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative): *apertura interna canaliculi cochleaePA518 – vidinė sraigės kanalėlio atvaraPA462.*

7. Nominative of a noun (determinative) + genitive of a noun (attribute) + nominative of an adjective positive (attribute) + nominative of an adjective positive (attribute) ↔ nominative of an adjective positive (attribute) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative): *arcus pedis transversus distalisPA519 – tolimasis skersinis pėdos skliautasPA12.*

8. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + genitive of an adjective positive (attribute) + genitive of a noun (attribute) ↔ nominative of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of a noun (attribute) +nominative of a noun (determinative): *arcus tendineus fasciae pelvisPA 519 – sausgyslinis dubens fascijos lankasPA216.*

9. Nominative of a noun (determinative) + genitive of an adjective positive (attribute) + genitive of an adjective positive (attribute) + genitive of a noun (attribute) ↔ nominative of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of a noun (attribute) +nominative of a noun (determinative):*arcus musculi levatoris aniPA519 – sausgyslinis išangės raumens lankasPA218.*

10. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + nominative of a comparative (attribute) + nominative of a comparative (attribute) ↔ nominative of an adjective positive (attribute) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative): *arteria alveolaris superior anteriorPA519 – viršutinė užpakalinė alveolinė arterijaPA236.*

11. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + nominative of a comparative (attribute) + nominative of an adjective positive (attribute) ↔ nominative of an adjective positive (attribute) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) +nominative of a noun (determinative): arteriae ciliares posteriores brevesPA519 – trumposios užpakalinės krumplyno arterijosPA240.

12. Nominative of a noun (determinative) + nominative of a comparative (attribute) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) ↔ nominative of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of a noun (attribute) +nominative of a noun (determinative): *bulbus inferior venae jugularisPA523 – apatinis jungo venos stormuoPA276.*

13. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) genitive of an adjective positive (attribute) + genitive of a noun (attribute) + nominative of an adjective positive (attribute) + nominative of a noun (determinative): *pulmo sinister lobus inferiorPA552 –kairiojo plaučio apatinė skiltisPA176.*

14. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + nominative of a comparative (attribute) + nominative of an adjective positive (attribute) ↔ nominative of an adjective positive (attribute) + nominative of an adjective positive (attribute) + nominative of an adjective positive (attribute) + nominative of a noun (determinative): *ramus alveolaris superior mediusPA553 – viršutinė priekinė alveolinė šakaPA402.*

15. Nominative of a noun (determinative) + nominative of a comparative (attribute) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) ↔ nominative of an adjective positive (attribute) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative): *semicanalis musculi tensoris tympaniPA30 –viršutinio strėlinio ančio angaPA30.*

16. Nominative of a noun (determinative) + genitive of a noun (attribute) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) ↔ nominative of an adjective positive (attribute) + nominative of a comparative (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative): *sulcus nervi petrosi majoris PA560 – didžiojo uolos nervo vagaPA32.*

17. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) ↔ genitive of an adjective positive (attribute) + genitive of a noun (attribute) + nominative of an adjective positive

(attribute) + nominative of a noun (determinative): *tractus spinalis nervi trigeminiPA562 –trišakio nervo nugarinis laidasPA328.*
18. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) ↔ genitive of a noun (attribute) + genitive of an adjective positive (attribute) + genitive of a noun (attribute) +nominative of a noun (determinative): *trigonum parietale laterale pelvisPA562 – dubens šoninės sienos trikampisPA214.*
19. Nominative of a noun (determinative) + genitive of a noun (attribute) + genitive of a noun (attribute) + genitive of a noun (attribute) ↔ genitive of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative): *vagina musculi recti abdominis PA564 – tiesioji pilvo raumens makštisPA108.*
20. Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) ↔ nominative of an adjective positive (attribute) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative): *vena dorsalis profunda clitoridisPA565 – gilioji nugarinė varputės venaPA290.*

VARIETY OF SECONDARY COMPONENTS OF FIVE-WORD TERMS

It has been mentioned in the paper that Latin and Lithuanian five-word anatomical terms are not common. They make up 0,38% of all compound terms found in the source. Terms in this group of terms differ with regard to secondary components. In Latin terms, only one secondary component is expressed by the genitive of the noun; in Lithuanian, two secondary components areagreed attributes and two are non-agreed ones.

The following five-word pairs of Latin and Lithuanian terms were found:
Nominative of a noun (determinative) + nominative of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of an adjective positive (attribute) + genitive of a superlative ↔ nominative of an adjective positive (attribute) + genitive of an adjective positive (attribute) + genitive of a noun (attribute) + genitive of a noun (attribute) + nominative of a noun (determinative): *bursa trochanterica musculi glutaei maximiPA523 – gūbrinis mažojo sėdmens raumens maišelisPA130; bursa ischiadica musculi glutaei maximiPA523 – sėdynkaulinis didžiojo sėdmens raumens maišelisPA130.*

Conclusion

Over many years, anatomical terminology has been the subject of much controversy and disagreement. Previously, the International Anatomical Nomenclature Committee has been responsible for the production of six editions of *Nomina Anatomica*. In 1998, a new corpus of anatomical terminology *Corpus, Terminologia Anatomica* was published. FCAT (Federative Committee on Anatomical Terminology) has endorsed *Latin express is verb is*as the “best (final) languageof terminology”. The goal of FCAT is to provide a high-level and easy-to-use biomedical anatomical terminology relevant to the international community of anatomists, the health sciences in general as well as scholars, educators, writers and the general public and to improve communication within and between disciplines. It can be maintained that Latin anatomical terminology is best organised as an international language of science.

Latin and Lithuanian two-word and three-word anatomical terms are used quite often: 52,26% and 35,09% of two-word terms and three-word terms were found in the sources, respectively. This makes up 87,35% of the sample of Latin and Lithuanian terms. The majority of Lithuanian and Latin anatomical terms are two-word. They account for more than half of all studied compound terms.

The majority of Lithuanian compound terms are adjectives with *the suffix -inis, -ė*;*a smaller part consists of pronominal adjectives*. The species attribute of Lithuanian anatomical terms usually precedes the determinative. Latin compound terms are characterised by an inverted order of components of compound terms.

In Latin three-word terms, the first secondary component is usually expressed by the genitive of the noun and the nominative of the adjective; the second, by the genitive of the noun and the nominative of the comparative adjective. In Lithuanian equivalents, the first secondary component is usually expressed by the genitive of the noun and the nominative of the adjective; while the second, by the genitive of the noun and the nominative of the adjective.

Latin and Lithuanian five-word anatomical terms are not common. Secondary components are usually expressed by the nominative of the adjective and the genitive of the noun.

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INFLUENCE OF HUMUS FERTILIZATION ON YIELD AND ESSENTIAL OIL ACCUMULATION OF *THYMUS × CITRIODORUS*

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Abstract

Thymus × *citriodorus* is medicinal, aromatic, essential oil bearing plant, this hybrid can accumulate commercial important chemical compound – geraniol in it's essential oil. The aim of the present study was to evaluate the effect of fertilization with humus on the yield, for parameters of some leaf epidermal structures,as well as on the quantitative and qualitative composition of essential oils of *T.* × *citriodorus* plants that were grown in an open ground for three years. The experiment was done in eight experimental plots: four experimental plots were used as control and other four– for fertilization with humus. The essential oil was isolated by hydrodistillation and analysed by GC–FID and GC–MS. The results showed that fertilization with humus significantly positive affected the height of plant, the area covered by plant and the length of inflorescences in the first experimental year, the density of stomata in both epidermis of leaf in the first and second experimental years, but significantly negative affected the density of glandular trichomes in lower epidermis of leaf in the second experimental year. Fertilization with humus did not affect the percentage and composition of essential oil.

Keywords: *Thymus* × *citriodorus;* essential oil; geraniol; humus; fertilization.

1. Introduction

Perennial interspecific hybrid *Thymus* × *citriodorus* (parental species *Thymus vulgaris* and geraniol chemotype of *Thymus pulegiodes*) is medicinal, aromatic, essential oil bearing plant (Ložienė et al., 2021). The main compound of essential oil of this hybrid is monoterpenic alcohol geraniol with pleasant rose – like aroma and used in cosmetics and in household products (Vaičiulytė et al., 2022). This monoterpenic alcohol also has antioxidant, anti–inflammatory, antimicrobial, antihelmintic and anticancer properties (Maczka et al., 2020). The raw material of *Thymus* × *citriodorus* is used for enrichment of the aroma and taste of teas and for fish dishes, ice creams and chewing gum (Toncer et al., 2017; Paslawska et al., 2020).

Humus is a major component of soil organic matter and can improves the soil fertility, physical, chemical and biological features of soil. Humus also improves uptake process of macro– and micro elements as well as water regime and reduces abiotic stress and uptake of toxic ions for plants (Aşik et al., 2009; Khaled et al., 2009; Celik et al., 2010; Muhamedyarova et al., 2020). Humus performs one of main function in creating necessary conditions for the growth and development the plants (Zymyatin et al., 2020). It can help to increase the yield of plants and improves the quality of plants production (Muhamedyarova et al., 2020).

Published data indicate that of humus can differently affect the yield of raw material, morphological, anatomical parameters and quantitative and qualitative composition of essential oils for medicinal and aromatic plants. Spraying with liquid humus significantly positively affected the number of inflorescences and the total number of leaves in *Coriandrum sativum* (Apiaceae) (Hamza et al., 2020). The humus in soil negatively correlated with the number of flowers producing nectar in *Allium ursinum* (Bodo et al., 2021). After humic acid application amounts of oxygenated terpenoids increased in *Artemisia sieberi*, but the amount of essential oil decreased. The amount of essential oil and amounts of oxygenated terpenoids increased *in Semenovia suffruticosa* after humic acid application (Sardashti et al., 2014). Humus in soil positively correlated with amount of essential oil and negatively with amount of geraniol and geranial in essential oil of *Thymus pulegioides* (Vaičiulytė et al., 2022). Therefore, the aim of the present study was to evaluate the effect of fertilization with humus on the yield, for parameters of some leaf epidermal structures as well as on the quantitative and qualitative composition of essential oils of *Thymus* × *citriodorus* plants that were grown in an open ground for three years.

2. Materials and Methods

2.1. Plant cultivation and fertilization

Vegetatively propagated plants of *T.* × *citriodorus* were grown in eight separate experimental square plots (nine plants per each separate square plot of 1.44 m^2) in the open ground at the field collection of the Nature Research Centre (Mažieji Gulbinai, near Vilnius, Lithuania) from 2018.

The fertilization experiment was started in spring of 2019 and continued three years (2019–2021). Fertilization was carried out in four separate experimental plots and four separate experimental plots were appointed as control. Plants were fertilized with humus only.

Humic acids concentrate was bought from the shop and contained humic acids (85%), potassium (12%), iron (1%), nitrogen (1.3%) and other minerals (0.7%). Fertilization experiment started at the beginning of vegetation period (from the end of April to early May) and finished two weeks before blooming. Fertilization was performed three times – once per two weeks (5 g humus was dissolved in 5 L water for one experimental plot). Fertilization was carried out only through soil on cloudy but not on rainy days.

Temperature and rainfall data were obtained from the meteorological newsletters of Vilnius meteorology station of Lithuanian Meteorological Service under the Ministry of Environment. These meteorological data of April–June period in three experimental years (2019–2021) are presented in Table 1.

Table 1. The meteorological data of April–June period in different experimental years.

Month	Average temperature, °C			Average rainfall, mm		
	2019	2020	2021	2019	2020	2021
April	9.0	6.6	6.0	0.6	6.2	24.7
May	13.3	12.4	11.2	28.6	77.8	147
June	21.1	19.7	19.5	27.5	68.5	55

2.2. Collection and analysis of soil material

For chemical analysis soil samples were taken before every fertilization and before harvesting plant materials. Three sub-samples of soil in each of the four experimental plots were taken from the depth 10–15 cm, mixed and dried at room temperature. Soil analysis was performed at the Agrochemical Research Laboratory of the Lithuania Research Centre for Agriculture and Forestry. Soil pH was determined potentiometrically in 1 M KCL extracts. Organic carbon in soil was established by a dry combustion method (in molecular form), total nitrogen by the modified Kjeldahl method (in ionic form); mobile potassium, mobile phosphorus by Egner–Rim–Doming method (in ionic forms).

2.3. Analysis of plants' yield

T. × *citriodorus* samples for morphometrical analysis were collected every year on full flowering stage. The following morphometrical parameters were estimated at the middle of blooming: height of plant, area covered by plant and the number of inflorescences per plant. Height of plant and area covered by plant were evaluated for each plant per each experimental plot. The area covered by plant estimation was examine in following manner: the diameter of every plant was measured at the widest and the narrowest locations; the mean value of plant diameter was estimated from these two parameters; every plant was considered in terms of circular shape and the area covered by plant was calculated by the formula calculating the area of the circle ($S = \pi R^2$, there S denotes the area covered by plant, and R denotes radius of plant). The number of inflorescences was estimated for three plants per each experimental plot: for the largest, medium and the smallest plant. After measuring of morphometrical parameters, the above grounded parts of plants were harvested and weighted per each experimental plot. Data about the weight of fresh plant raw material per each experimental were recorded. The length of fifty inflorescences per every experimental plot was measured. Plant raw material of each experimental plot was dried at room temperature separately.

2.4. Analysis of leaf epidermal structures parameters

Density of glandular trichomes and stomata in mm^2 and size (diameter) of glandular trichomes were estimated on the lower and upper epidermis of leaves. An imprint method (Dagys et al., 1965) was used for anatomical investigation: a thin layer of colourless nail polish was spread on the fresh leaf from the middle of flowering stem. The formed skin of nail polish was ripped off from leaf and observed with light microscope "Leica". Two leaves from each of the 12 stems (3 stems from every experimental plot) were used for evaluation of anatomical parameters. Apex, base, margins and midrib regions of leaves were not used in this analysis to avoid the effect of different parts of the same leaf causing variations in the investigated anatomical parameters.

2.5. Essential oil analysis

Cutting plant materials of each experimental plot were dried at room temperature. The essential oils from each sample (from leaves and flowers, stems were not used) were isolated

separately by hydrodistillation in Clevenger apparatus for two hours. The distillation of essential oils was carried out in 2–4 replications per each sample. Essential oil of each sample was kept in 2 mL bottles separately. The amount of essential oils was expressed by percentage (quantitative analysis of essential oils). For further investigation (qualitative analysis), essential oil solutions of 1 % were prepared in a mixture of diethyl ether and n-pentane (1:1). Analysis of essential oils was carried out using a FOCUS GC (Thermo Scientific) gas chromatograph with a flame ionisation detector (FID) and a GC-2010 Plus instrument equipped with a GC-QP 2010 Plus (Shimadzu) series mass selective detector according to methods, described by V. Vaičiulytė et al. (2022). Only those compounds that made up at least 10 % of the essential oils were analysed. The identification of compounds was based on comparison of retention indexes (Ris) (Adams, 2007), computer mass spectra library (NBS75K) and the analytical standards. Retention indexes has been determined relative to retention times of a series of alkanes (C7–C30) with linear interpolation. The percentage amounts of investigated compounds were recalculated according to the areas of FID chromatographic peaks, assuming that all constituents of essential oils comprised 100 %.

2.6. Statistical analysis

Calculation of means and standard deviations (SD) were carried out for soil elements, leaf epidermal structures and chemical parameters of *T.* × *citriodorus*, calculation of means, standard deviations (SD) and coefficients of variation (CV) were carried out for yield. The Mann-Whitney U test was used to estimate differences between the effect of fertilization with humus and control on soil, biomass and chemical parameters of *T.* × *citriodorus*. Student's t test was used to estimate differences between the effect of fertilization with humus and the control on the yield and anatomical parameters of *T.* × *citriodorus*. Statistical data processing was carried out with the STATISTICA®12 and MS Excel software.

3. Results

3.1. Influence of fertilization with humus on soil pH and main elements of soil

An analysis of soil parameters in the first experimental year showed that fertilization with humus increased the amount of potassium in soil, this amount was about 8 mg/kg higher in comparison with the control, but this result was not statistically significant. Fertilization with humus also increased the amount of potassium in soil in the second and third experimental years. The amount of potassium was 29.5 mg/kg higher in comparison with the control in the second experimental year and 20 mg/kg higher in the third experimental year and this difference was statistically significant ($p<0.05$). Fertilization with humus slightly increased the amount of sum nitrogen in the second and third experimental years. It is interesting that after fertilization with humus the amount of organic carbon in soil was 0.11 p.p lower in comparison with the control in the second experimental year. After fertilization with humus the amount of phosphorus was slightly higher in comparison with the control in the third experimental year but this result was not statistically significant (Table 2).

Table 2. Changes in soil pH and main chemical elements in soil during fertilization with humus through three experimental years. SD–standard deviation.

Fertilization		pH	Organic carbon, %	Sum nitrogen, %	K, mg/kg	P, mg/kg
First year						
Humus	Mean ± SD	5.70 ± 0.08	0.86 ± 0.12	0.083 ±0.012	115.75 ± 8.92	126.25 ± 9.21
Control		5.60 ± 0.14	0.85 ± 0.08	0.086 ± 0.018	107.75 ±1031	127.25 ± 11.34
Second year						
Humus	Mean ± SD	5.78 ± 0.13	0.81 ± 0.07	0.083 ± 0.013	130.75 ± 25.51	118.25 ± 6.40
Control		5.67 ± 0.10	0.92 ± 0.08	0.076 ± 0.007	101.25 ± 9.46	127.25 ± 12.42
Third year						
Humus	Mean ± SD	5.68 ± 0.05	0.83 ± 0.12	0.083 ± 0.012	102.50 ± 10.25*	127.75 ± 14.94
Control		5.70 ± 0.27	0.84 ± 0.16	0.072 ± 0.005	82.50 ± 1.73	116.00 ± 6.06

* – statistically significant differences.

3.2. Influence of fertilization on the yield

The results of the first experimental year showed that fertilization with humus significantly ($p<0.05$) increased the height of plant, the area covered by plant and the length of inflorescences: these morphometrical parameters were about 1.2 times higher in comparison with the control. The biomass and number of inflorescences in plant were also higher than in control plants but these differences were not statistically significant. In the first experimental year the least variable morphometrical parameter was the height of plant and the most variable – number of inflorescences (Table 3).

In the second and the third experimental years humus did not give statistically significant differences. After fertilization the height of plant, the area covered by plant were slightly higher, but biomass– slightly lower in comparison with the control in the second experimental year (Table 3). In the second experimental year as in the first experimental year the least variable morphometrical parameter was the height of plant and the most variable – number of inflorescences. In the third experimental year the area covered by plant slightly increased but the number of inflorescences slightly decreased in comparison with the control. The variation coefficient of biomass in control plants was low and the height of plant had the same mean in the control plants and plants after fertilization in the third experimental year. In the third experimental year the most variable morphometrical parameter was the number of inflorescences (Table 3).

Table 3. Descriptive statistics of yield parameters *of Thymus* × *citriodorus* depending on fertilization with humus in three experimental years. SD–standard deviation. CV–coefficient of variation.

Yield parameter		First year		Second year		Third year	
		Control	Humus	Control	Humus	Control	Humus
Biomass, g	Mean ± SD	110.3 ± 35.9	149.3 ± 86.5	282.5 ± 81.2	254.8 ± 97.9	200.0 ± 11.7	195.3 ± 124.0
	Min	72	50	216	165	188	97
	Max	158	253	396	369	213	370
	CV, %	33	58	29	38	6	63
Height of plant, cm	Mean ± SD	5.8 ± 1.3	6.9 ± 1.3*	6.0 ± 1.8	6.6 ± 1.4	6.1 ± 2.0	6.1 ± 2.1
	Min	3.1	4.6	3.5	3.8	3.0	3.0
	Max	8.5	9.1	11.2	9.5	12.0	10.5
	CV, %	22	19	30	21	33	34
Area covered by plant, cm^2	Mean ± SD	550.7 ± 164.1	641.0 ± 231.3*	1053.9 ± 397.4	1161.8 ± 335.6	1238.3 ± 461.9	1430.3 ± 890.6
	Min	143.1	248.7	397.4	706.5	547	730.2
	Max	865.3	1194	2061.9	2021.8	3316	5941
	CV, %	30	36	38	29	37	62
Number of inflorescences	Mean ± SD	133.0 ± 88.7	160.7 ± 113.9	243.8 ± 193.6	255.8 ± 150.1	141.0 ± 131.0	126.0 ± 105.6
	Min	26	6	45	94	10	2
	Max	350	350	700	490	400	300
	CV, %	67	71	79	59	93	84
Length of inflorescences, cm	Mean ± SD	1.17 ± 0.30	1.32 ± 0.32*	1.47 ± 0.65	1.40 ± 0.51	1.14 ± 0.37	1.19 ± 0.41
	Min	0.6	0.6	0.7	0.7	0.6	0.5
	Max	2.6	2.4	3.9	3.5	2.2	3.1
	CV	26	24	44	36	32	34

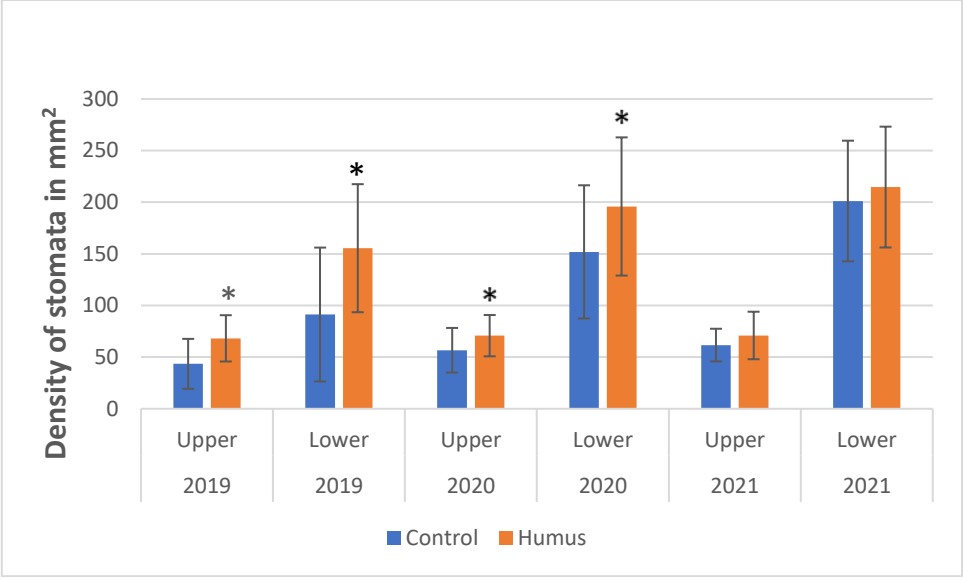
* – statistically significant differences.

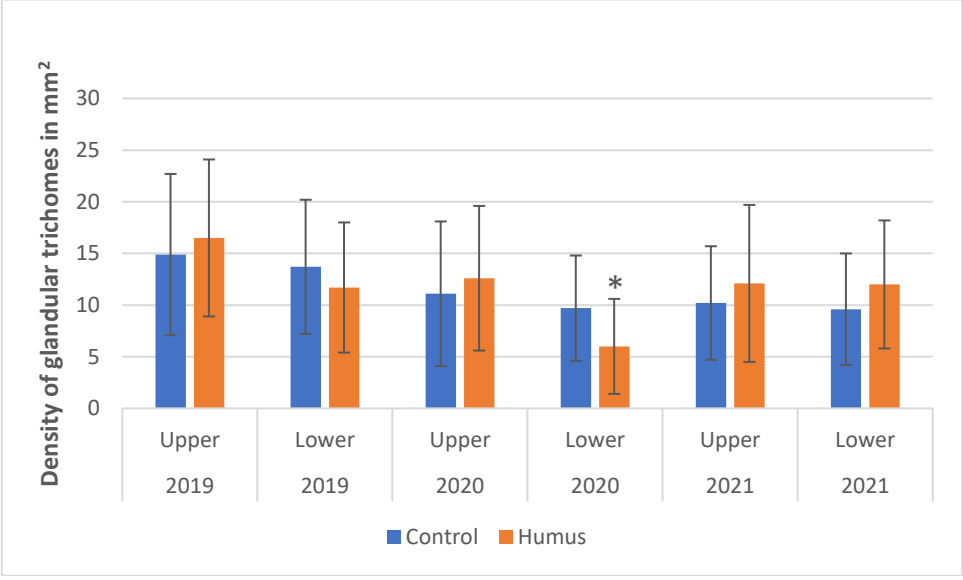
3.3. Influence of fertilization on leaf epidermal structures parameters

The fertilization with humus in the first experimental year showed significant ($p<0.05$) positive effects on stomata densities in the upper and lower epidermis of leaves: stomata density was about 1.6 times higher in the upper and about 1.7 times higher in the lower epidermis of leaves. Humus also increased the size of glandular trichomes in the lower epidermis but this result did not significantly different from the control (Figure 1).

Humus also significantly ($p<0.05$) positively affected densities of stomata in the upper and lower epidermis of leaves in the second experimental year: stomata density in 1 mm^2 was about 1.2 times higher in the upper and about 1.3 times higher in the lower epidermis. Meanwhile the density of glandular trichomes reacted negatively: after fertilization the density of glandular trichomes in the lower epidermis was significantly ($p<0.05$) 1.6 times lower than in control (Figure 1).

In the third experimental year the fertilization with humus had not significant effect for leaf epidermal structures parameters (Figure 1).





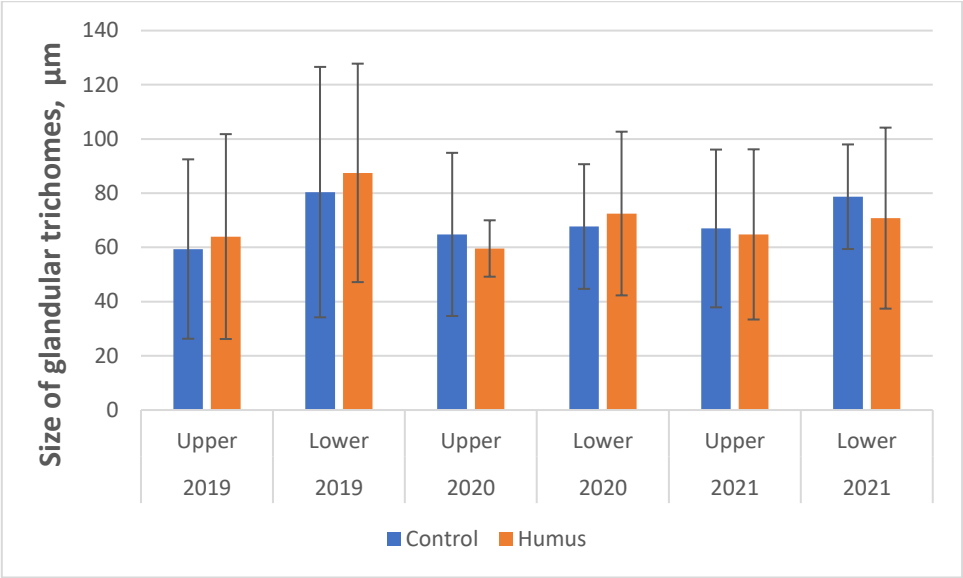


Figure 1. Variations in leaf epidermal structures parameters (a – density of stomata, b – density of glandular trichomes, c – size of glandular trichomes) of *Thymus* × *citriodorus* after fertilization with humus. * – denotes statistically significant differences, error bars denote standard deviations.

3.4. Influence of fertilization on composition of essential oil

Results of all three experimental years showed that the effect of fertilization with humus on percentage of essential oil in *T.* × *citriodorus* was negative but not statistically significant (Figure 2).

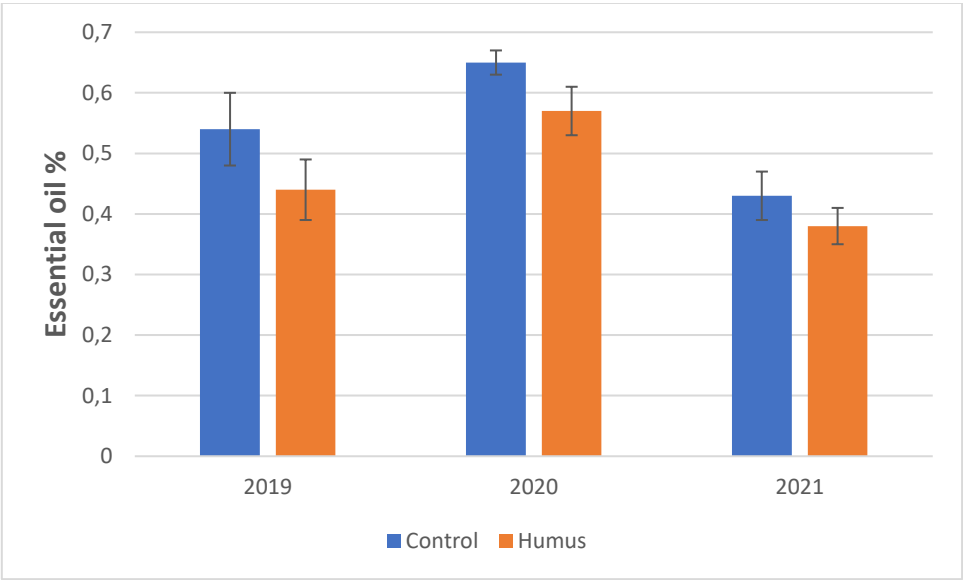


Figure 2. Variation in percentage of *Thymus* × *citriodorus* essential oil depending on fertilization with humus in different experimental years. Error bars denote the standard error of mean.

Geraniol was the main compound in the essential oil of *T.* × *citriodorus*. It composed about 22 % of essential oil in control plants and in plants after fertilization with humus. The second compound by plenty was nerol, which composed about 16 % of essential oil in the first and second experimental years, but in the third experimental year the amount of this chemical compound was lower than 15 %. The amount of geranial was 12–14 %, the highest amount of geranial was in the third experimental year. The lowest amount of neral was in the third experimental year, humus application slightly increased the amount of neral in the third experimental year. The fertilization with humus did not significantly affect the percentages of these four chemical compounds of *T.* × *citriodorus* essential oil (Figure 3).

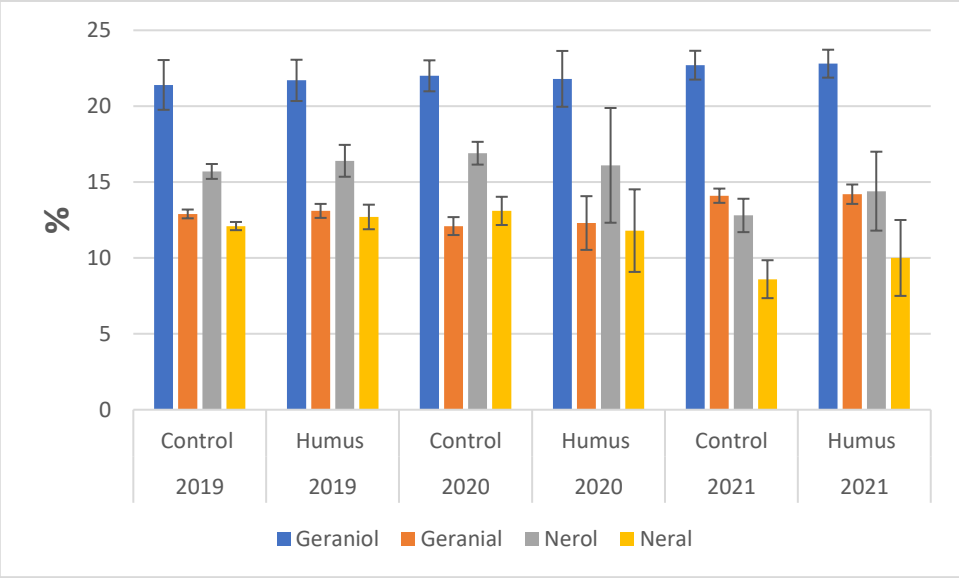


Figure 3. Variation in the percentage of main compounds in the essential oil of *Thymus* × *citriodorus* depending on fertilization with humus in different experimental years. Error bars denote standard deviations.

4. Discussion

Humus containing fertilizers can improve fertility of the soil, saturate it with minerals (Merennych et al., 2019). Present study showed that fertilization with humus significantly ($p<0.05$) increased the amount of potassium in soil: it was about 1.2 times higher in comparison with the control (Table 2). Potassium is important macronutrient element for plants: it permits the activation about 60 enzymes in lipid and protein synthesis, controls the opening and closing of stomata, maintains the balance of electrical charges in photosynthesis, promotes the translocation of sugars after photosynthesis, improves a disease resistance (Silva & Uchida, 2000; Dar et al., 2021).

Fertilization with humus also can stimulate growth of plants, increases yield of plants, intensifies biosynthesis of proteins, carbohydrates and vitamins, increases resistance to adverse environmental factors (Nardi et al., 2004; Merennych et al., 2019). Previous study with *T.* × *citriodorus* showed that humus fertilization with dose 7 g to 1 m^2 significantly negatively affected the height of plant and the amount of essential oil of this hybrid (Vaičiulyte et al., 2022). According literature data humus have to increase the yield of plants too (Muhamedyarova et al., 2020). By literature data doses of fertilisers can influenced growth and yield of plants, as well as essential oil yield and composition (Anwar et al., 2010; Garcia et al., 2017; Handayati & Sihombing, 2019). Present study demonstrated that the humus fertilization with 3.5 g to 1 m^2 significantly ($p<0.05$) increased the height of plant, area covered by plant and length of inflorescences in the first experimental year (Table 3). In the second and the third experimental years humus application did not significantly affect the yield of *T.* × *citriodorus* (Table 3). It can be related with colder springs in 2020 and 2021 years (the second and the third experimental years) and very rainy May in 2021 (Table 1). According literature data low temperatures can reduce humus accumulation (Grigal & Vance, 2000). In the third experimental year humus also could wash out from the soil due to very large rainfall in May; large moisture of soil also can reduce the aeration of soil. Humus application can to increase weight of plant, plant height and leaf area (Muhamedyarova et al., 2020). The plants of *Ocimum basilicum var. basilicum*, sprayed with humic acid, grew higher, with more leaves and side branches (Abdul et al., 2012). Fertilization with compost increased the number of branches and the weight in *Thymus vulgaris* in the first and the second seasons (Hendawy et al., 2007). Sometimes the fertilization with humus have no effect for plants yield. For example, the fertilization with humic acid did not increase the growth of lettuce (Hartz, 2007).

The main function of stomata is CO_2 uptake for photosynthesis and water loss for transpiration (Sakoda et al., 2020). Higher stomata density can improve biomass production of plants, but it can depend also from plant species and environmental conditions (Kardiman & Rœbild, 2007; Sakoda et al., 2020). Present study showed that fertilization with humus

significantly ($p< 0.05$) increased density of stomata in both epidermis of leaf in the first and the second experimental years (Figure 1 a). Humus application significantly increased the height of plant, the area covered by plant and the length of inflorescences in the first experimental year. Meanwhile colder spring in the second experimental year could limit assimilation of humus (Table 1). Fertilization with compost significantly increased the density of stomata in the adaxial side, but significantly decreased in the abaxial side of leaves in *Pogestemon cablin* Benth (Lamiaceae) (Zahara et al., 2021). The main functions of glandular trichomes are secretion and storage of secondary metabolites (Huchhellmannet al., 2017). Present study showed that humus application significantly decreased the density of glandular trichomes in lower epidermis of leaves in the second experimental year (Figure 1 b). The effect of humus fertilization on size of glandular trichomes was not significant (Figure 1 c). Fertilization with organic nitrogen (foliar fertilization) increased the density of glandular trichomes of *Humulus lupulus* L. (Rodolfi et al., 2021).

According literature data fertilization also can influence yield and composition of essential oils for medicinal and aromatic plants (Sardashti et al., 2014; Rehman et al., 2016). Humus application did not significantly affect the yield of essential oil of *T.* × *citriodorus*, but the percentage of essential oil after humus application was lower than in control plants (Figure 2). Plants use nutrient elements first for increasing the biomass and then for synthesis of secondary metabolites (Caceres et al., 2017). As was mentioned above, humus application increased the height of plant, the area covered by plant and the length of inflorescences (Table 2). Fertilization with compost increased the yield of *Thymus vulgaris* essential oil (Hendawy et al., 2010). Humic acid application increased amount of essential oil in *Semenovia suffruticosa* but decreased in *Artemisia sieberi* (Sardashti et al., 2014). The humic and fulvic acids application had no effect for the yield of essential oil in *Rosmarinus officinalis* L. (Caceres et al., 2017). Fertilization with humus did not significantly influence percentage of main compounds of *T.* × *citriodorus* essential oil – geraniol, nerol, geranial, and neral (Figure 3). Fertilization with compost increased amount of oxygenated monoterpenes in essential oil of *Thymus vulgaris* (Hendawy et al., 2010). Humic acids application increased amount of oxygenated terpenoids in *Artemisia sieberi* and *Semenovia suffruticosa* (Sardashti et al., 2014).

Conclusions

Fertilization with humus had significant effect for *T.* × *citriodorus* yield and epidermal structures parameters: fertilization with humus increased the yield of *T.* × *citriodorus* in the first experimental year, increased the density of stomata in both epidermis of leaves in the first and second experimental years, but decreased the density of glandular trichomes in the lower epidermis in the second experimental year. However, humus application did not significantly affect on the percentage and composition of essential oil.

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