ISSN 2063-2142 (Print)
ISSN 3004-3085 (Online)

JOURNAL FOR HEALTH SCIENCES

University of Miskolc

Volume 14, Issue 2 (2024)

Miskolc University Press

JOURNAL FOR HEALTH SCIENCES
Volume 14, Issue 2 (2024)

Edited by the Editorial Board of Journal for Health Sciences – University of Miskolc

CONTENTS

Norbert Pászk:
The organizational structure of the medicinal herb growing sector and its analysis 5

Andrea Lukács:
Continuous glucose monitoring (CGM): technological advancement in diabetes management 11

Hajnalka Sándor:
From skincare to surgery – South Korea's influence in beauty and health tourism 19

Csilla Lakatos – Eleonóra Juhász – Andrea Rucska:
Relationships between burnout, self-esteem and psychologicalwell-being in university students 28

Éva Kiss-Tóth Dojcsák – Dávod Németh – Adrienn J. Szalai – Bertalan Fodor:
Molecular allergen and cross-allergen component studies among people living in the northheastern Hungarian region 44

Journal for Health Sciences, Vol. 14, No. 2 (2024), pp. 5–10.
https://doi.org10.32967/etk.2024.002

THE ORGANIZATIONAL STRUCTURE OF THE MEDICINAL HERB GROWING SECTOR AND ITS ANALYSIS

NORBERT PÁSZK
University of miskolc, facukty of health sciences
University of Miskolc, Faculty of Economics

Summary: Medicinal plant cultivation is a sector that can be found both in Hungary and abroad too. However, its characteristics may be different from area to area. However, the organizational structure of the sector is the same in most countries. And the profiles of medicinal plant growing enterprises are also identical, as they can carry out the same economic activities in the sector in most countries. The purpose of this literature research is to map, analyze and present the organizational structure of the medicinal plant growing sector.

Keywords: *medicinal plant, medicinal plant cultivation, enterprise, organizational structure*

INTRODUCTION

Medicinal plants appear in many areas of life, such as the health sector (e.g.: in the case of the active ingredients of medicines), the food industry (e.g.: in the case of herbal flavorings) or even agriculture (e.g.: in the case of cultivation). Cultivation of medicinal plants is the basis of everything, because if people did not grow medicinal plants of the right quality and quantity, there would not be sufficient quantities of certain plants for the various sectors, because they cannot cover everything from the collection [1].

The medicinal plant growing sector is an extremely versatile field, which requires great knowledge, adequate infrastructure, and the existence of many other factors. However, this sector could not function without a well-organized, appropriate organizational structure and hierarchy [2].

The purpose of this literature research is to map, analyze and present the organizational structure of the medicinal plant growing sector.

THE ORGANIZATIONAL STRUCTURE OF THE MEDICINAL PLANT GROWING SECTOR

Medicinal plant growing enterprises and companies do not have a uniform profile, because not all of them perform the same activities *(Figure 1)*.

Some only grow and sell. There are those that grow, carry out primary processing and then sell. Some grow, carry out primary and secondary processing, and then sell. And there are those, in addition to cultivation, are also involved in collection or in the performance of contract operations (e.g. contract packaging, quality control) or other activities related to the sector [3].

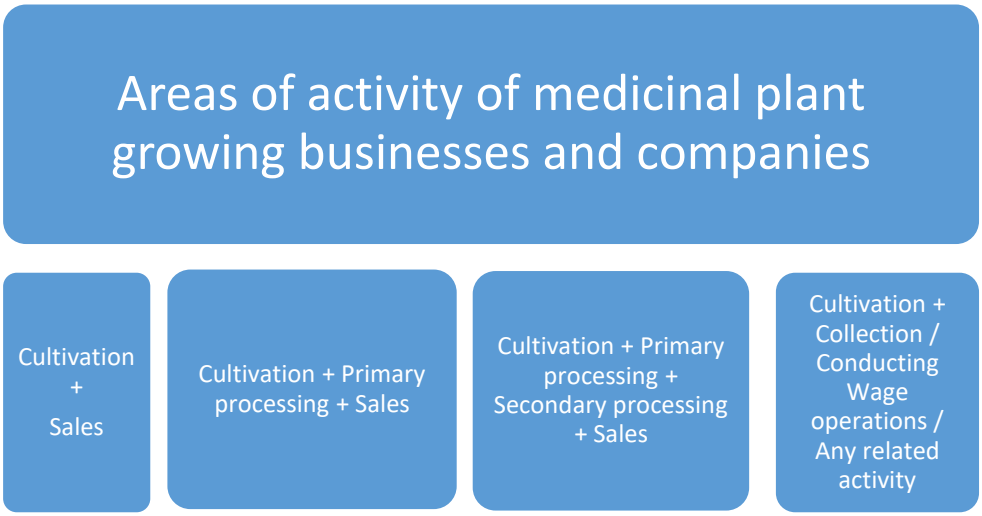

Figure 1. *Areas of activity of medicinal plant growing companies and enterprises* (source: own editing)

Cultivation and sales are the most common categories, because these activities are the simplest and require fewer permits, expertise and equipment.

During cultivation, primary processing, and sales, some processing permits are required. Fewer entrepreneurs have these permits, which means that there are fewer in the category.

Cultivation, primary and secondary processing, and sales are perhaps the rarest category, with the fewest market participants, because even food-grade medicinal products are produced here, which requires compliance with quality assurance systems, obtaining permits, and strictly controlled hygienic conditions.

In the case of the last category, when other operations are carried out in addition to cultivation, it has a variable appearance. Collection activities in addition to cultivation are limited to areas where there are a relatively large number of collectable medicinal plants. Contract work and contract operations are mostly carried out by those who have the appropriate permits and who are able to test and package medicinal plants, or who have the possibility of contract cultivation in their area. There are often cases where foreign partners ask the domestic grower to grow certain species [4].

The organizational structure of the medicinal plant growing sector is also quite complex, as shown in *Figure 2*.

It is basically made up of 4 parts, which are the follows: Raw material production; Wholesale trade; Retail trade and Export [5].

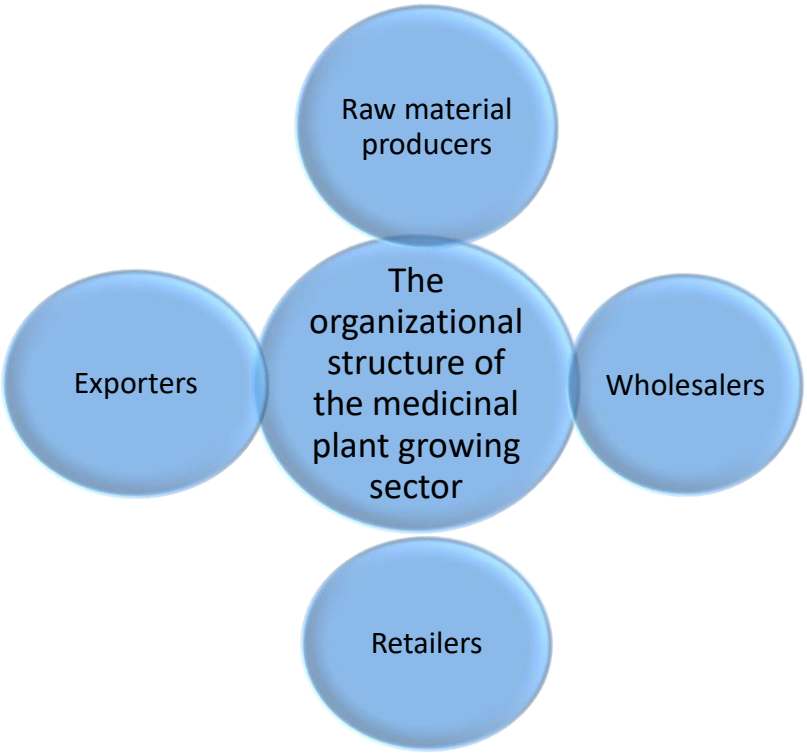

Figure 2. *The organizational structure of the medicinal plant growing sector* (source: own editing, based on [5])

Raw materials can be produced in different forms, such as family farms, agricultural producers with horticultural crops, agricultural producers with arable crops or in producer cooperatives *(Figure 3)*. Production takes place by processing species grown or collected during raw material production. According to the current trend, cultivation yields approximately 2-3 times more than collection in our country [6].

The processing of medicinal herbs can be primary or secondary processing. During primary processing, only the most basic operations are carried out with the herbs, such as harvesting and drying. During secondary processing, finished products are even produced from herbs, for example by distilling essential oils or packaging them as tea [7].

Relatively many people are engaged in the production of raw materials in our country, because it is an activity that can be carried out even without a degree and with the involvement of cheaper labor, however, the disadvantage is that it requires a lot of manual work or mechanization and the risk of exposure to the weather is quite high. Nowadays, mainly family farms deal with raw material production in our country [8].

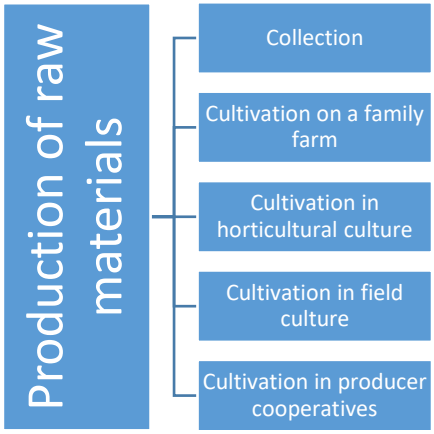

Figure 3. *Types of raw material production* (source: own editing, based on [5])

The 2nd level of the organizational structure is the level of the wholesalers, when the wholesalers purchase the produced and harvested, processed plant parts or finished products from the raw material producers. Until the early 1970s, Herbária was the only domestic wholesaler in Hungary. Then, in the following decades, other wholesalers appeared on the market. There are currently 4-5 national wholesale companies in Hungary, and 20-30 smaller regional companies. At the level of wholesalers, the level of expertise and knowledge is perhaps the highest, because in many cases engineers already work here during product production.

Then the wholesaler usually sells the products to the retailer at a higher price, which is the 3rd level of the structure. This can happen in the same state or after development, repackaging, or conversion into a product. From the 1990s, more and more herbal medicine shops opened in Hungary, the disadvantage of this was that almost anyone could open a shop, even without professional qualifications, which, among other things, led the quality, as well as the possibility of assistance and advice, in a negative direction. Nowadays, the workers in most herbal medicine shops, or at least the managers, have at least an intermediate qualification related to medicinal herbs.

The 4th structural element of the sectoral structure is export. Because domestic medicinal plants have very high quality, both in terms of cultivated and collected raw materials, they are very willing to buy them abroad. Hungary is present on the international market with many plants. For example, the medical chamomile or even the various mint species and the thyme species. Most of the exported products and plant parts come from the raw material production level, fewer finished products are sold abroad. Until the beginning of the 1980s, Medimpex had the sole right to export medicinal herbs in Hungary, in the 90s a few other companies also received this right, and since 1992 any company has been able to obtain export rights in the sector [5].

Entering the market is not easy at any structural level. At the raw material producer level, it requires expertise, experience, land, tools, machines, equipment, among other things, as well as a lot of work, that is why quite a few people choose this profession these days. In the case of the retail level, it is a minimally capital-intensive area, since opening a store and establishing a network requires more initial capital. In our country, you can often find herbal medicine shops operating in a franchise system (e.g.: Herbária). The level of wholesalers is the most difficult to enter, the few domestic herbal medicinal wholesale companies dominate the sector and do not allow new competitors. However, there would not be much opportunity for new competitors to appear, either due to the lack of capital or the lack of necessary permits since the processing, sale, and packaging of medicinal herbs is subject to numerous licenses in almost all product categories. In order to have these permits, it is necessary to establish infrastructure and comply with quality assurance systems, which neither retailers nor raw material producers can finance [9].

DISCUSSION

The herb growing sector is also present in Hungary and employs a relatively large number of people, businesses, and companies. Medicinal plants can be grown on family farms, in horticulture, in field crops, and in producer cooperatives. The main determining factor and risk factor of the sector is the weather. The production of better quality and larger quantities is necessary for the various sectors, which they can no longer manage by collecting, thus the cultivation of medicinal plants has a great future.

The organizational structure of the medicinal plant growing sector is made up from 4 parts, these are raw material producers, retailers, wholesalers, and participants in the export sector. The number, knowledge and capital of the market participants are different at each level, as some levels require a large capital investment from the participants. The organizational level of export is also significant in our country, because there is a great demand for high-quality, high-active ingredients collected and grown Hungarian medicinal plants abroad.

REFERENCES

[1] Erdész F., Kozak A. (2008). A gyógynövényágazat helyzete. *Agrárgazdasági Tanulmányok*, 4. szám, https://uni-eszterhazy.hu/public/uploads/gyogynovenyagazat-helyzete_5812354905176.pdf (retrieved: 21. 05. 2020).

[2] Pászk N. (2022). Az észak-magyarországi gyógynövény termesztő szektor steep elemzése; In: Szűcsné Markovics Klára, Horváth Ágnes (eds.). *Gazdálkodási kihívások 2022-ben*. Miskolc, Magyarország, MTA MAB Gazdálkodástudományi Munkabizottság, 202 p., pp. 147–155., 9 p.

[3] Lorette, K. (2011). *How to open and operate a financially succesful herb and herbal plant business*. London, Atlantic Publishing Group, Inc.

[4] Carpenter, J., Carpenter, M. (2015). *The organic medicinal herb farmer*. London, Chelsea Green Publishing

[5] Bernáth J., Gosztola B., Kindlovits S. et al. (2012). Korszerű gyógynövény-termesztési ismeretek file:///C:/Users/USER/Downloads/korszeru_gyogynoveny termesztesi_ismeretek.pdf (retrieved: 10. 10. 2022).

[6] Dr. Bernáth J., Czirbus Z. (2014). Gyógynövények gyűjtése és termesztése, Képzési segédlet; Gyógynövény Szövetség és Terméktanács, https://kozfoglalkoztatas.kormany.hu/download/f/43/f0000/K%C3%A9pz%C3%A9si%20Seg%C3%A9dlet%20betan%C3%ADtott%20gy%C3%B3gyn%C3%B6v%C3%A9nygy%C5%B1jt%C5%91%20%C3%A9s%20termeszt%C5%91%20szakmai%20k%C3%A9pz%C3%A9shez.pdf (retrieved: 21. 10. 2022).

[7] Bernáth J. (2013). *Vadon termő és termesztett gyógynövények*. Budapest, Mezőgazda Kiadó.

[8] Gyógynövény Szövetség és Terméktanács. Gyógynövénytermesztés Magyarországon. Megéri belevágni? https://www.gyszt.hu/hu/aktualitasok/gyogynovenyvenytermesztes-magyarszagon-megeri-belevagni--interju (retrieved: 21. 10. 2022).

[9] Gyógynövény Szövetség és Terméktanács. A gyógynövényágazat helyzete. https://docplayer.hu/2294734-A-gyogynovenyagazat-helyzete-zalaszentlaszloi-nemzetkozi-gyogy-es-fuszernoveny-napok-2013-julius-19-20-21-czirbus-zoltan-elnok.html (retrieved: 10. 08. 2023).

Journal for Health Sciences, Vol. 14, No. 2 (2024), pp. 11–18.
https://doi.org/10.32967/etk.2024.024

CONTINUOUS GLUCOSE MONITORING (CGM): TECHNOLOGICAL ADVANCEMENT IN DIABETES MANAGEMENT

ANDREA LUKÁCS
Faculty of Health Sciences, University of Miskolc
E-mail: andrea.lukacs@uni-miskolc.hu

Summary: Continuous glucose monitoring (CGM) represents a major breakthrough in diabetes management, offering real-time insights into glucose levels that help optimize glycaemic control. This review discusses the expanding role of CGM, its advantages, challenges, and future directions. Traditional methods, such as self-monitoring blood glucose (SMBG), provide only periodic glucose data, which can miss critical fluctuations and result in less effective diabetes management. In contrast, CGM delivers constant feedback, allowing timely interventions and a deeper understanding of glucose patterns. CGM systems typically comprise a sensor, transmitter, and receiver. These devices measure glucose levels in the interstitial fluid and send data to receivers or smartphones, with some systems even syncing with insulin pumps for automatic adjustments. Both real-time (rtCGM) and intermittently scanned (isCGM) systems have demonstrated benefits, including reduced HbA1c levels, increased time in range (TIR), and a lower risk of hypoglycemia for people with both type 1 and type 2 diabetes. Despite these benefits, CGM adoption faces barriers like cost, accessibility, and data overload. Additionally, occasional discrepancies between CGM readings and actual blood glucose levels highlight the need for user education and further refinement of CGM accuracy.

Advances in CGM technology, including longer sensor life, improved accuracy, and integration with artificial intelligence (AI), are propelling diabetes care forward. AI features hold promise for predictive glucose management, while integration with closed-loop (artificial pancreas) systems may transform insulin delivery. As CGM technology progresses, it is positioned to play a crucial role in managing not only diabetes but also other metabolic conditions. For CGM to achieve its full potential, issues surrounding affordability and accessibility must be addressed to ensure broad access to this life-enhancing technology.

Keywords: *Continuous Glucose Monitoring (CGM), Diabetes Management, Glycemic Control, Artificial Intelligence in Healthcare, Real-time Glucose Monitoring*

INTRODUCTION

Effective diabetes management hinges on precise blood sugar control. Diabetes mellitus, defined by chronic high blood sugar due to compromised insulin function, is one of today's most significant health challenges. The International Diabetes Federation (IDF) estimates that 537 million adults (ages 20–79) lived with diabetes in 2021, a figure that could reach 783 million by 2045 [1]. Poor glucose regulation in diabetes can lead to severe health complications, such as retinopathy, nephropathy,

cardiovascular disease, and neuropathy [2, 3]. Accurate glucose monitoring is therefore essential for maintaining blood sugar within safe limits.

The traditional method of self-monitoring blood glucose (SMBG) through fingerstick tests has long been the mainstay for tracking daily glucose levels. However, SMBG has notable limitations; it provides only sporadic data and can miss unnoticed hypoglycemic or hyperglycemic events. Moreover, frequent finger pricks can be uncomfortable, adding to the burden of diabetes care [4]. Continuous glucose monitoring (CGM), however, has transformed diabetes care by offering real-time glucose data that supports more accurate insulin dosing and improved blood sugar control. Unlike SMBG, which only captures isolated data points, CGM gives a continuous view of glucose trends throughout the day and night. Although primarily used for type 1 diabetes, CGM has also shown significant benefits for type 2 diabetes patients, especially those who use insulin [5, 6].

THE BASICS OF CONTINUOUS GLUCOSE MONITORING (CGM)

A CGM system generally comprises three parts: a sensor, a transmitter, and a receiver.

Sensor: A tiny, flexible filament inserted just under the skin, usually in the abdomen or arm, which continuously measures glucose in the fluid surrounding cells. Depending on the model, the sensor requires replacement every 7 to 14 days.

Transmitter: Attached to the sensor, this small device sends glucose readings from the sensor to the receiver wirelessly. It converts measurements to digital data, typically updating every few minutes. Transmitters are usually reusable but may need occasional recharging or replacement.

Receiver: The receiver displays glucose data for the user, which may be a dedicated device or, in many modern systems, a smartphone app. It shows real-time glucose readings, trend graphs, and alerts for high or low glucose levels. Certain receivers also link with insulin pumps for automatic insulin adjustments.

By combining these components, CGM provides users with round-the-clock glucose monitoring, helping to avoid dangerous fluctuations and manage their diabetes more effectively.

Two main types of CGM are available today: real-time CGM (rtCGM) and intermittently scanned CGM (isCGM). Both provide ongoing glucose data but differ in how this information is accessed and used.

Real-time CGM (rtCGM): These systems measure glucose continuously, sending data to a receiver or app in real time. This allows users to track their glucose trends throughout the day without needing additional steps, and rtCGM devices often feature customizable alerts for high or low glucose, facilitating immediate action.

Intermittently Scanned CGM (isCGM): isCGM systems require users to scan the sensor periodically to view glucose data. Although the sensor continuously measures glucose, data is only accessible upon scanning. While it doesn't offer real-time alerts, isCGM provides flexibility by allowing glucose checks only when needed, offering a discreet and cost-effective option for many people with diabetes [7].

A systematic review by Zhou et al. and randomised controlled trial by Visser et al indicate that rtCGM can increase TIR and improve both hypo- and hyperglycaemia management, making it a particularly valuable tool for glucose control [8, 9].

ADVANCEMENTS IN CGM TECHNOLOGY

CGM technology has advanced significantly, enhancing accuracy, convenience, and ease of use. Improvements in sensor technology have produced devices that are smaller, more comfortable, and longer-lasting. Certain CGM sensors can now be used for up to two weeks, reducing the need for frequent replacements. Many newer models also eliminate the need for calibration through fingerstick tests, which was once a limitation [10].

Smartphone and wearable integration has expanded the accessibility of CGM systems, enabling users to view their data instantly through apps. Trend analysis tools within these apps help patients identify patterns and adjust their lifestyle or medication accordingly [11]. Additionally, innovations in AI and machine learning are enriching CGM capabilities, with predictive algorithms that anticipate glucose trends and deliver personalized recommendations expected to enhance CGM in the future [12].

BENEFITS OF CONTINUOUS GLUCOSE MONITORING

CGM's capacity to provide a constant flow of glucose data offers a level of insight that SMBG cannot. Research has shown that CGM use leads to reductions in HbA1c, an important marker for long-term glucose control. Real-time data enables both patients and healthcare providers to make well-informed decisions regarding diet, physical activity, and medication, including insulin adjustments [13, 14].

CGM is particularly valuable in preventing hypoglycemia. Low blood sugar episodes can be dangerous, especially nocturnal hypoglycemia, which may go unnoticed. CGM alerts for falling glucose levels allow users to take corrective measures early, offering peace of mind and reducing anxiety related to hypoglycaemia [15].

In addition to improving glycemic control, CGM has led to the development of new clinical parameters that offer a more comprehensive picture of glucose management. Time in range (TIR), time above range (TAR), and time below range (TBR) are now considered valuable metrics for evaluating how well a patient is managing their blood sugar levels. These parameters provide a clearer understanding of glycemic control than HbA1c alone, offering insights into glucose variability and the frequency of hyperglycemic or hypoglycemic events.

TIR reflects the percentage of time a person's glucose levels remain within the target range (usually 70–180 mg/dL), and is increasingly recognized as an important indicator of overall glucose stability. Clinical studies suggest that higher TIR is associated with a lower risk of developing diabetes-related complications such as retinopathy and cardiovascular issues [16, 17]. TAR and TBR provide additional insights into the frequency and severity of hyperglycemic and hypoglycemic events,

respectively. Together, these metrics allow for more individualized and precise management strategies, offering real-time feedback that helps optimize treatment and lifestyle interventions [18, 19].

IMPACT OF CGM TECHNOLOGIES ON USERS' LIVES

Differences between rtCGM and isCGM

Between real-time CGM (rtCGM) and intermittently scanned CGM (isCGM), it is essential to consider how these differences affect users' daily life and overall quality of life. For example, rtCGM offers continuous, real-time glucose data that alerts you to hypo- or hyperglycemia. This capability is particularly beneficial for individuals who experience frequent episodes of hypoglycemia, as it facilitates timely intervention and potentially reduces anxiety related to glucose variability [19, 20]. In contrast, the isCGM requires users to scan the sensor to access glucose data, making it a simpler and more cost-effective solution for individuals who may not need continuous monitoring or are looking for a more discreet method of glucose management [21].

The strengths of each technology serve different patient populations. For example, the tighter glucose monitoring of rtCGM may benefit those who require tight glycemic control, such as those with type 1 diabetes or those prone to severe hypoglycemia. In contrast, isCGM's ease of use and affordability may appeal to patients who require less intensive monitoring, such as certain type 2 diabetics, or those who prefer convenience and lower costs.

Age-specific needs and unique aspects

For children and adolescents, rtCGM has proven to be particularly beneficial. Studies like those conducted by Forlenza et al. (2019) show that caregivers rely heavily on rtCGM's real-time alert systems to prevent nocturnal hypoglycemia, which is a critical safety concern for this demographic [22]. Additionally, the ability to monitor glucose remotely via linked apps offers parents or guardians peace of mind.

CHALLENGES AND LIMITATIONS

Despite its advantages, CGM adoption faces obstacles. One of the primary barriers is cost. CGM devices and sensors require regular replacement, and expenses can be prohibitive, especially for individuals without comprehensive insurance. Accuracy can also vary, with occasional discrepancies between CGM and blood glucose readings, particularly during rapid glucose changes. While calibration needs have decreased with newer models, some systems still recommend occasional fingerstick testing [19].

The volume of data generated by CGM can also be overwhelming. Proper training is crucial for users to interpret the data accurately and avoid over-correction or unnecessary responses to glucose fluctuations [18].

CONCLUSION

Continuous glucose monitoring has transformed diabetes management by providing timely data that allows for more precise insulin dosing, reduced hypoglycemic episodes, and increased time spent in target glucose ranges. However, challenges related to cost, access, and data interpretation must be overcome to maximize CGM's benefits. As technology evolves, CGM is poised to play an even greater role in diabetes care, especially as AI-driven features become more integrated.

REFERENCES

[1] Saeedi, P., Petersohn, I., Salpea, P., Malanda, B., Karuranga, S., Unwin, N., Colagiuri, S., Guariguata, L., Motala, A. A., Ogurtsova, K., Shaw, J. E., Bright, D., Williams, R. (2019). IDF Diabetes Atlas Committee. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. *Diabetes Res. Clin. Pract.* Nov., 157, 107843. https://doi.org/10.1016/j.diabres.2019.107843 Epub 2019 Sep 10. PMID: 31518657

[2] Zaccardi, F., Webb, D. R., Yates, T., Davies, M. J. (2016). Pathophysiology of type 1 and type 2 diabetes mellitus: a 90-year perspective. *Postgrad. Med. J.* Feb., 92 (1084), 63–69. https://doi.org/10.1136/postgradmedj-2015-133281 Epub 2015 Nov 30. PMID: 26621825.

[3] Alqahtani, A. A., Alzidany, A. M., Alenazi, S. M., Alotaibi, T. D. B., Bakhsh, A. J., Bin, Shalhoub, N. M., Alsawas, A. T. U., Charbatje, L. A., Alshareef, H. A. S., Bawazeer, M. O., Almutairi, N. S., Alharbi, W. A., Buqurayn, M. H. (2020). Long term complication of poor glycemic control in diabetic patients. *EC Microbiol.* 16 (2), 1–7. Retrieved from https://api.semanticscholar.org/CorpusID:214139694 (12th September 2024).

[4] Serrano-Ríos, M., Suárez, E. (2020). Self-monitoring of blood glucose in diabetes: Limitations and challenges. *Avances en Diabetología* 28 (3), 64–71. https://doi.org/10.1016/S1134-5934(12)70021-8

[5] Lin, R., Brown, F., James, S., Jones, J., Ekinci, E. (2021). Continuous glucose monitoring: A review of the evidence in type 1 and 2 diabetes mellitus. *Diabet Med.* May, 38 (5), e14528. https://doi/org/10.1111/dme.14528

[6] Jancev, M., Vissers, T. A. C. M., Visseren, F. L. J. et al. (2024). Continuous glucose monitoring in adults with type 2 diabetes: A systematic review and meta-analysis. *Diabetologia* 67 (5), 798–810. https://doi.org/10.1007/s00125-024-06107-6

[7] Edelman, S. V., Argento, N. B., Pettus, J., Hirsch, I. B. (2018). Clinical implications of real-time and intermittently scanned continuous glucose monitoring. *Diabetes Care* Nov., 41 (11), 2265–2274. https://doi.org/10.2337/dc18-1150, PMID: 30348844

[8] Zhou, Y., Sardana, D., Kuroko, S., Haszard, J. J., de Block, M. I., Wenig, J., Jefferies, C., Wheeler, B. J. (2024). Comparing the glycaemic outcomes between real-time continuous glucose monitoring (rt-CGM) and intermittently scanned continuous glucose monitoring (isCGM) among adults and children with type 1 diabetes: A systematic review and meta-analysis of randomized controlled trials. *Diabet. Med*. March, 41 (3), e15280. https://doi.org/10.1111/dme.15280

[9] Visser, M. M., Charleer, S., Fieuws, S., De Block, C., Hilbrands, R., Van Huffel, L., Maes, T., Vanhaverbeke, G., Dirinck, E., Myngheer, N., Vercammen, C., Nobels, F., Keymeulen, B., Mathieu, C., Gillard, P. (2021). Comparing real-time and intermittently scanned continuous glucose monitoring in adults with type 1 diabetes (ALERTT1): a 6-month, prospective, multicentre, randomised controlled trial. *Lancet* June 12, 397 (10291), 2275–2283. https://doi.org/10.1016/S0140-6736(21)00789-3 Epub 2021 Jun 2. PMID: 34089660

[10] Almurashi, A. M., Rodriguez, E., Garg, S. K. (2023). Emerging Diabetes Technologies: Continuous Glucose Monitors/Artificial Pancreases. *J. Indian Inst. Sci*. March 28, 1–26. https://doi.org/10.1007/s41745-022-00348-3 Epub ahead of print. PMID: 37362851; PMCID: PMC10043869

[11] Chmayssem, A., Nadolska, M., Tubbs, E., Sadowska, K., Vadgma, P., Shitanda, I., Tsujimura, S., Lattach, Y., Peacock, M., Tingry, S., Marinesco, S., Mailley, P., Lablanche, S., Benhamou, P. Y., Zebda, A. (2023). Insight into continuous glucose monitoring: from medical basics to commercialized devices. *Mikrochim. Acta* Apr. 6, 190 (5), 177. https://doi.org/10.1007/s00604-023-05743-w, PMID: 37022500.

[12] Vettoretti, M., Cappon, G., Facchinetti, A., Sparacino, G. (2020). Advanced Diabetes Management Using Artificial Intelligence and Continuous Glucose Monitoring Sensors. *Sensors (Basel)* July 10, 20 (14), 3870. https://doi.org/10.3390/s20143870 PMID: 32664432; PMCID: PMC7412387

[13] Cho, S. H., Kim, S., Lee, Y. B., Jin, S. M., Hur, K. Y., Kim, G., Kim, J. H. (2023). Impact of continuous glucose monitoring on glycemic control and its derived metrics in type 1 diabetes: a longitudinal study. *Front Endocrinol (Lausanne)* May 15, 14, 1165471. https://doi.org/10.3389/fendo.2023.1165471 PMID: 37255973; PMCID: PMC10225713

[14] Dorando, E., Haak, T., Pieper, D. (2022). Continuous glucose monitoring for glycemic control in children and adolescents diagnosed with diabetes type 1: A systematic review and meta-analysis. *Exp. Clin. Endocrinol. Diabetes* Jan., 130 (1), 61–72. https://doi.org/10.1055/a-1268-0967

[15] Šoupal, J., Petruželková, L., Grunberger, G. et al. (2020). Glycemic outcomes in adults with T1D are impacted more by continuous glucose monitoring than by insulin delivery method: 3 Years of follow-up from the COMISAIR Study. *Diab. Care* 43 (1), 37–43. https://doi.org/10.2337/dc19-0888

[16] Aleppo, G. (2021). Clinical application of time in range and other metrics. *Diabetes Spectr*. May, 34 (2), 109–118. https://doi.org/10.2337/ds20-0093 Epub 2021 May 25. PMID: 34149251; PMCID: PMC8178724

[17] Wright, E. E. Jr, Morgan, K., Fu, D. K., Wilkins, N., Guffey, W. J. (2020). Time in range: How to measure it, how to report it, and its practical application in clinical decision-making. *Clin. Diabetes* Dec., 38 (5), 439–448. https://doi.org/10.2337/cd20-0042, PMID: 33384469; PMCID: PMC7755049

[18] Battelino, T., Danne, T., Bergenstal, R. M., Amiel, S. A., Beck, R., Biester, T., Bosi, E., Buckingham, B. A., Cefalu, W. T., Close, K. L., Cobelli, C., Dassau, E., DeVries, J. H., Donaghue, K. C., Dovc, K., Doyle, F. J. III, Garg, S., Grunberger, G., Heller, S., Heinemann, L., Hirsch, I. B., Hovorka, R., Jia, W., Kordonouri, O., Kovatchev, B., Kowalski, A., Laffel, L., Levine, B., Mayorov, A., Mathieu, C., Murphy, H. R., Nimri, R., Nørgaard, K., Parkin, C. G., Renard, E., Rodbard, D., Saboo, B., Schatz, D., Stoner, K., Urakami, T., Weinzimer, S. A., Phillip, M. (2019). Clinical targets for continuous glucose monitoring data interpretation: Recommendations from the international consensus on time in range. *Diabetes Care* Aug., 42 (8), 1593–1603. https://doi.org/10.2337/dci19-0028
Epub 2019 Jun 8. PMID: 31177185; PMCID: PMC6973648

[19] Quah, P. L., Chai, S. M. H., Tan, K. H. (2024). Differences in glucose readings between the continuous glucose monitoring calibration free interstitial sensors versus capillary blood glucose monitoring by glucometer: An analysis of two cases. *Metabol. Open* Apr. 18, 22, 100282. https://doi.org/10.1016/j.metop.2024.100282
PMID: 38690155; PMCID: PMC11059339.

[20] Beck, R. W., Riddlesworth, T., Ruedy, K., Ahmann, A., Bergenstal, R., Haller, S., Kollman, C., Kruger, D., McGill, J. B., Polonsky, W., Toschi, E., Wolpert, H., Price, D. (2017). DIAMOND Study Group. Effect of continuous glucose monitoring on glycemic control in adults with type 1 diabetes using insulin injections: The DIAMOND Randomized Clinical Trial. *JAMA* Jan. 24, 317 (4), 371–378. https://doi.org/10.1001/jama.2016.19975, PMID: 28118453

[21] Haak, T., Hanaire, H., Ajjan, R., Hermanns, N., Riveline, J. P., Rayman, G. (2017). Flash glucose-sensing technology as a replacement for blood glucose monitoring for the management of insulin-treated type 2 diabetes: A multicenter, open-label randomized controlled trial. *Diabetes Ther*. Feb., 8 (1), 55–73. https://doi.org/10.1007/s13300-016-0223-6
Epub 2016 Dec 20. PMID: 28000140; PMCID: PMC5306122

[22] Forlenza, G. P., Li, Z., Buckingham, B. A., Pinsker, J. E., Cengiz, E., Wadwa, R. P., Ekhlaspour, L., Church, M. M., Weinzimer, S. A., Jost, E., Marcal, T., Andre, C., Carria, L., Swanson, V., Lum, J. W., Kollman, C., Woodall, W., Beck, R. W. (2018). Predictive low-glucose suspend reduces hypoglycemia in adults, adolescents, and children with type 1 diabetes in an at-home randomized crossover study: Results of the PROLOG Trial. *Diabetes Care* Oct., 41 (10), 2155–2161. https://doi.org/10.2337/dc18-0771
Epub 2018 Aug 8. PMID: 30089663

Journal for Health Sciences, Vol. 14, No. 2 (2024), pp. 19–27.
https://doi.org/10.32967/etk.2024.025

FROM SKINCARE TO SURGERY – SOUTH KOREA'S INFLUENCE IN BEATUY AND HEALTH TOURISM

HAJNALKA SÁNDOR
University of Miskolc, Faculty of Health Science

Summary: South Korea's beauty ideals are not only culturally significant; they are also the driving force behind the nation's thriving K-Beauty industry and medical tourism sector. Historically, beauty in Korea has been associated with Confucian values of inner strength and duty. Over time, there has been an increasing emphasis on appearance, leading to the development of specific beauty standards such as the "three whites" (skin, teeth and eyes) and the "three blacks" (hair, eyebrows and pupils). Nowadays, these ideals are amplified by the influence of K-pop and K-dramas, promoting features such as pale skin, V-shaped faces and heart-shaped lips. The global popularity of K-Beauty products and skincare routines has made South Korea a leading destination for beauty tourism. Tourists are flocking to Korea for skincare treatments and beauty workshops, supported by social media and beauty industry influencers. In addition, South Korea has become a top destination for medical tourism, particularly plastic surgery. In 2023, a record 606,000 foreign patients sought medical treatment, with more than half of them seeking dermatological or cosmetic procedures. The South Korean government aims to further promote medical tourism and expects 700,000 foreign patients per year by 2027. The financial impact is significant, with medical tourists spending 10 times more than the average tourist.

Keywords: *K-beauty, South Korea, Health Tourism, Medical Tourism*

INTRODUCTION

South Korean beauty standards have deep cultural roots and have developed into a significant part of the nation's social fabric. Today, South Korean beauty ideals, often embodied by K-pop idols and actors, emphasise flawless skin, slender physiques and symmetrical facial features. The obsession with achieving these standards has led to South Korea becoming a global centre for cosmetic procedures and beauty tourism. This article examines the evolution of South Korean beauty ideals and the powerful role of K-Beauty and medical tourism in promoting inbound tourism.

THE KOREAN IDEAL OF BEAUTY

South Korea is the not the only country in South East Asia that takes beauty seriously. However this country has the strongest industry supporting the achievement of beauty. They have built an entire industry around the concept. Moreover, it's not necessarily treated as a subjective concept. Boyé Lafayette, in his book The Korean Mind, mentions the thinking behind the worship of beauty. "Institutionalized norms

of aesthetics have been an important element of Korean culture from the very beginning of the country's recorded history. Like other Asian cultures, Korean beliefs and practices of an aesthetic nature drew from and were nourished by animism, and then by Buddhism and Taoism, which were adopted from China between the fourth and sixth centuries." [1] The Korean ideal of beauty first emphasized inner beauty and strength based on Confucian teachings. In the male-dominated Neo-Confucian society of the time, ideals of the wise mother and the good wife were created. According to Elise Hu's Flawless: Lessons in Looks and Culture from the K-Beauty Capital, "For women, beauty equated to being dutiful to their elders, serving their husbands, and spending time with their children" [27].

Later, chroniclers of the Joseon dynasty (1392–1910) also wrote down the outward traits of the idealised female ideal of beauty. This was the famous rule of three. The sambaek, 'the three whites', emphasised the whiteness of the skin, teeth and eyes. Samheuk, 'the three blacks', emphasised the charcoal black pupils, eyebrows and hair. Finally, samhong, 'the three reds', emphasised the redness of the face and lips and the peach-coloured nails [3].

The current South Korean beauty ideal is represented mainly by actors and K-pop idols. Therefore, they are expected to look as perfect and clean as possible. The contemporary beauty ideal in Korea reflects ideals such as flawless, pale skin, large eyes and a slender, V-shaped face, often achieved through elaborate skincare routines and increasingly plastic surgery [3]. Currently, a small, heart-shaped face, heart or strawberry-shaped lips, a slim physique and white skin are trendy [3]. At press events and official appearances, a so-called "white wash" technique is used, retouching the images to make the idol or actor's skin look as white as possible. White skin represents a sense of superiority and value. "The skin of wealthier, upper-class ladies used to be white because they could spend their time indoors until late at night, without having to toil in the fields in the blazing sun. Traditionally, pale skin was not only a sign of beauty but also of higher social status. White skin is also more popular among Korean women because the harmful effects of sun exposure are now well known." [12. p. 204] The high expectations of beauty are so ingrained in Korean society today that it is not uncommon to be bullied at school or not be offered a job because you don't measure up. In fact, Koreans openly tell each other that if they don't like something about the other person, they should lose some weight, for example. In Western cultures, this is considered rude or inconsiderate, but in South Korea it is part of everyday life. Hyemin and colleagues conducted primary research on the perception of beauty in South Korea in 2017. Among other things, they wanted to know whether the survey subjects had been negatively discriminated against because of their appearance. 95% of the respondents stated that they had experienced some negative discrimination about their appearance or appearance in their lifetime [6]. In South Korea, beauty is not only an individual aspiration, but also a social and economic concern. The rise of 'lookism', or discrimination based on appearance, is a notable social phenomenon, with physical attractiveness often correlating with better job prospects, social mobility and overall success [16]. The emphasis on beauty is so strong that Korea has one of the highest

rates of cosmetic surgery per capita in the world, with procedures such as double blepharoplasty, rhinoplasty and facial contouring in high demand.

K-BEAUTY

K-Beauty, as a term, encompasses all beauty products and skincare routines originating in South Korea, which have become a global phenomenon. Thanks to the global spread of Hallyu, or Korean culture, the world has become familiar with K-pop, Korean pop music and K-dramas, Korean TV series. It is through the latter that the concept of K-Beauty, i.e. Korean beauty care and beauty products in particular, became known. The series became potential advertising content for K-Beauty products. The rapid rise of the Korean beauty industry is closely linked both to the innovative product range and to the sophisticated cultural narrative that holds flawless, youthful skin as the standard of beauty. The industry's global market presence has grown significantly, with exports increasing by 61.6% in 2016 alone [15].

Skincare rituals associated with K-Beauty are often defined by meticulous, multi-step routines that include products designed to address specific skin concerns such as acne, hydration and anti-aging. The '10-step skincare regimen', for example, has become a popular export product that emphasises a complex series of double cleansing, exfoliation, sheet masks and multi-layered moisturisation [15]. This level of attention to skin health is a tradition in Korean culture, where skin has historically been deeply valued as a symbol of beauty and health.

The rise of K-Beauty is not just about cosmetics, but about the creation of a lifestyle brand that suggests a disciplined, ritualized approach to personal beauty, which has found a loyal following among consumers worldwide. Products such as snail slime, bee venom and fermented ingredients have become popular in Korean skincare, combining traditional practices with modern cosmetic science. A holistic approach to beauty has contributed significantly to the attractiveness and expansion of K-Beauty in markets such as the US and China, resulting in an export value of around USD 6.69 billion in 2022 [23].

HEALTH TOURISM AND PLASTIC SURGERY IN KOREA

South Korea's dominance in plastic surgery is well documented. The country is globally recognised for its advanced medical technologies and expertise in cosmetic procedures, which have made it a top destination for health tourism. Plastic surgery in Korea is deeply rooted in social beauty norms, where procedures such as double blepharoplasty, jaw reduction and skin whitening are considered routine surgery [17].

The popularity of plastic surgery in Korea is partly fuelled by the same media (idols, actors) and cultural forces that promote K-Beauty products. The influence of Korean celebrities, who often undergo plastic surgery to achieve their iconic looks, further reinforces these beauty standards both domestically and internationally. In addition, Korean health tourism is supported by government initiatives such as special medical visas that make it easier for international tourists to access treatments [13]. The number

of foreign tourists visiting Korea for medical treatment increased by 30.5% between 2009 and 2015, and demand for plastic surgery continues to grow [23].

CRITIQUE OF KOREAN BEAUTY STANDARS AND PLASTIC SURGERY

The South Korean beauty industry, although influential worldwide, has come under considerable criticism for promoting rigid and often unrealistic beauty standards. The pervasive influence of the media, especially K-pop and K-dramas, reinforces ideals such as flawless skin, V-shaped faces and big eyes. This social phenomenon, known as "lookism", has a strong influence on social mobility and job opportunities, which has led to the normalisation of plastic surgery. South Korea has one of the highest rates of plastic surgery per capita in the world, with procedures such as double eyelid surgery and rhinoplasty being particularly common [14].

SOCIAL IMPACT

The emphasis on appearance in society creates both individual and collective insecurity, especially among young people, who are under enormous pressure to conform. Research highlights that these beauty norms contribute to lower self-esteem and body image issues, with many resorting to extreme means, including surgery, to conform to societal expectations [11]. Furthermore, this culture exacerbates gender inequality by placing disproportionate emphasis on women's physical appearance as a measure of their social and professional worth [4]. More broadly, the culture raises ethical concerns as it commodifies beauty and perpetuates a cycle in which physical perfection becomes normalised and, in some cases, expected. Although initiatives have emerged to challenge these norms, deeply ingrained social values about beauty remain a major obstacle to change [5].

MATERIAL AND METHOD

The literature review revealed that the Korean ideal of beauty has shaped Korean society for centuries, significantly influencing everyday life. This research aims to answer the following questions:

Q1: How does the Korean beauty industry influence inbound tourism to Korea?

Q2: Is plastic surgery popular not only among Koreans but also among international visitors, particularly in the context of medical tourism?

For this research, the author chose desk research method or conducted secondary research and searched statistical data on Statista, korea.net, KOFICE, and other official Korean platforms.

RESULTS

In 2022, K-Beauty products were particularly popular in European countries such as the UK (42.3%), Germany (36.7%) and France (34.1%), creating a significant global market that encourages tourism to South Korea (Statista, 2022). The impact of K-

Beauty goes beyond mere product sales, encouraging international consumers to visit Korea to experience beauty treatments on their own skin.

Beauty tourism has become a special form of travel, with many tourists visiting South Korea for skincare treatments, consultations and beauty workshops. This trend is particularly evident in the proliferation of beauty travel packages and experiences that combine sightseeing with beauty services, further increasing the economic impact of K-Beauty on tourism [17]. Social media influencers and K-Beauty advocates also play a critical role in driving tourism as consumers increasingly seek to replicate beauty routines and standards advertised online [26].

According to data from the South Korean Ministry of Health and Welfare, beauty-related medical services such as dermatology are among the most popular services sought by foreign tourists. Dermatology accounted for 12.3% of all medical tourists in 2022, indicating that cosmetic treatments, especially skin care, are a major attraction for inbound travellers [10]. The Korean beauty industry's influence on inbound tourism is further enhanced by government initiatives to promote South Korea as a global beauty hub, with various beauty events and festivals being organised to attract international visitors [28].

South Korea is renowned for its expertise in plastic surgery and attracts thousands of medical tourists every year. In 2022, 15.8% of foreign medical tourists visiting South Korea were visiting plastic surgery, making it the second most popular medical specialty after internal medicine [10]. Plastic surgery is popular not only among Koreans but also among international visitors, especially from the United States, China, Japan and Southeast Asia. These regions account for the largest share of plastic surgery patients visiting Korea, with US tourists accounting for around 18% of the total medical tourist population in 2022 [24].

Figure 1. *Foreign Patient's Place of Origin visiting South Korea*
(Source: medicalkorea.or.kr)

Foreign patients are attracted to South Korea because of its advanced medical technology, skilled surgeons and competitive pricing compared to Western countries [7]. Seoul's Gangnam district in particular is famous for its concentration of cosmetic surgery clinics, where international tourists undergo procedures ranging from double eyelid surgery to rhinoplasty and facial contouring [17]. Between 2009 and 2022, the number of foreign patients seeking plastic surgery in Korea increased steadily, peaking at more than 46,000 patients in 2022, despite a temporary decline due to the COVID-19 pandemic [10].

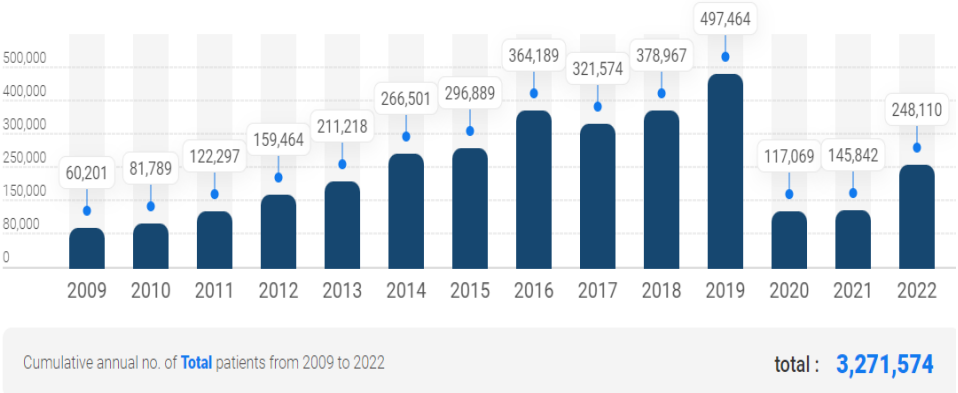

Figure 2. *Foreign patient's numbers from 2009 to 2022 visiting Korea (Source: medicalkorea.or.kr)*

Tourists often combine their medical procedures with leisure activities, further boosting South Korea's economy. The average expenditure per medical tourist is substantial, with Southeast Asian patients paying an average of $ 12,500 per person for services, highlighting the significant economic contribution of medical tourism [10]. In addition, Korea has a special website for medical tourism, which not only lists the medical institutions that welcome foreigners, but also includes a special brochure indicating, for example, whether they can provide interpreters to accompany medical services [18].

In 2023, South Korea attracted a record number of 606,000 foreign patients, according to the Ministry of Health and Welfare. This represents a 2.4-fold increase from 2022, when 248,000 international patients were recorded. The previous record was set in 2019 with 497,000 patients, but numbers dropped significantly during the COVID-19 pandemic, reaching a low of 117,000 in 2020. Over half of these foreign patients in 2023 sought dermatological and plastic surgery treatments. Dermatology patients increased from 12.3% in 2022 to 35.2% in 2023, and those seeking plastic surgery rose slightly from 15.8% to 16.8%. Japanese nationals constituted the largest group of foreign patients, comprising 31% of the total, followed by individuals from China, the U.S., Thailand, and Mongolia. The South Korean government aims to further boost the medical tourism sector, targeting 700,000 foreign patients annually by 2027. The global medical tourism market is expected to grow substantially, from

$115.6 billion in 2022 to $346.1 billion by 2032, making this a strategic economic focus. Medical tourists reportedly spend 10 times more than general tourists, highlighting the financial significance of this industry [8].

CONCLUSIONS

The author concluded that the market presence, marketing and media coverage of K-Beauty products and the spread of Korean culture and thus beauty culture have a significant impact on inbound tourist traffic to South Korea. (Q1) Furthermore, according to official information on Medical Korea and a recent Korea Herald summary, it is a dynamic industry that is attracting a significant number of foreign tourists to the country. (Q2)

RECOMMENDATIONS

Monitoring the statistical data, it would be worthwhile to examine the travel motivation of travellers from Hungary to South Korea and to create a K-Beauty themed programme package that could be in demand. Assuming that K-Beauty services are a demand for the Hungarian travelling public when travelling to Korea. I suggest further research in this regard.

REFERENCES

[1] Boyé Lafayette De Mente (2022). *The Korean Mind.* Hongkong, Tuttle Publishing.

[2] Cho, C. (2021). *A bőrápolás kiskönyve: Koreai szépségtitkok az egészséges, ragyogó bőrért.* Budapest, Lettero Kiadó, 15–27.

[3] Center for the Study of Women. (2018). *The cost of beauty: The economics of plastic surgery in South Korea.* Center for the Study of Women. https://csw.ucla.edu/2018/11/14/the-cost-of-beauty-the-economics-of-plastic-surgery-in-south-korea/.

[4] Elfving-Hwang, J. (2013). *Gender, globalization, and aesthetic surgery in South Korea*. https://doi.org/10.1177/1357034X12440828

[5] Elfving-Hwang, J. (2021). *The body, cosmetic surgery, and the discourse of Westernization of Korean bodies*. https://doi.org/10.4324/9780429283734-31

[6] Hyemin, K., Lee, S., & Park, J. (2017). Perception of beauty and its societal impacts in South Korea: Primary research on appearance-based discrimination. *Korean Journal of Social Psychology*, 14 (2), 189–203.

[7] IMARC Group (2023). *South Korea medical tourism market report 2023*. IMARC Group. Retrieved from https://www.imarcgroup.com/south-korea-medical-tourism-market.

[8] Jaeeun, K. (2024). Medical tourists to Korea rises to record high of 606,000 – The Korea Herald. The Korea Herald. https://www.koreaherald.com/article/3381969 [19 Dec. 2024].

[9] Jha, M. R. (2018). *The global beauty industry, colorism, racism and the national body.* Usfca. Retrieved from https://www.academia.edu/81042321/The_global_beauty_industry_colorism_racism_and_the_national_body.

[10] KHIDI (2022). *Statistics on medical tourism in South Korea: A report from 2009 to 2022.* Korea Health Industry Development Institute. Retrieved from https://www.mohw.go.kr

[11] Kim, H., & Lee, J. (2019). *Cosmetic surgery and self-esteem in South Korea: A systematic review and meta-analysis*. https://doi.org/10.1007/s00266-019-01515-1

[12] Kim, K. (2020). *Skin whitening and its cultural significance in South Korea*. *Journal of Cultural Studies*, 24 (3), 203–217.

[13] Korea.net (2024). Medical tourism in South Korea. Korean Ministry of Culture, Sports, and Tourism. Retrieved from https://www.medicalkorea.or.kr/en/global.

[14] Jasmine K. (2021). The Influence of Western Culture on Plastic Surgery Consumption in South Korea. *J. Gynecol. Women's Health*, 21 (2), 556059. https://doi.org/10.19080/JGWH.2021.21.556059

[15] Kwon, E. (2018). The impact of K-Beauty on global skincare: A cultural and economic analysis. *Journal of Asian Business*, 27 (4), 34–48.

[16] Lee, J. H., & Park, S. (2017). The rise of lookism in South Korea: Societal impacts of physical appearance. *Korean Journal of Social Psychology*, 19 (1), 45–61.

[17] Smith, N. (2023). Why South Korea's cosmetic surgery empire is both a source of pride and pain. *The Telegraph*, https://www.telegraph.co.uk/global-health/women-and-girls/south-korea-cosmetic-surgery-double-eyelid/.

[18] Ministry of Health and Welfare (2020). *Medical tourism statistics. Korea Ministry of Health and Welfare*. Retrieved from https://www.mohw.go.kr/board.es?mid=a20401000000&bid=0032&act=view&list_no=1481263&tag=&nPage=1.

[19] Kim, S., Arcodia, C., & Kim, I. (2019). Critical success factors of medical tourism: The case of South Korea. *International Journal of Environmental Research and Public Health*, 16 (24), 4964. https://doi.org/10.3390/ijerph16244964/

[20] Kim, H., & Lee, Y. (2023). South Korea's medical tourism competitiveness and future strategy: Focused on cancer treatment: A review. *Iranian Journal of Public Health*, 52 (12), 2484–2495. https://doi.org/10.18502/ijph.v52i12.14310/

[21] ResearchGate (2021). The impact of K-beauty social media influencers, sponsorship, and product exposure on consumer acceptance of new products. *ResearchGate*. Retrieved from https://www.researchgate.net/publication/350638343_The_impact_of_K-beauty_social_media_influencers_sponsorship_and_product_exposure_on_consumer_acceptance_of_new_products.

[22] Seoul Cosmetic Surgery (2020). The booming medical tourism industry in Korea – plastic surgery. Seoul Cosmetic Surgery. Retrieved from https://seoulcosmeticsurgery.com/the-booming-medical-tourism-industry-in-korea-plastic-surgery/.

[23] Statista (2022). Distribution of K-Beauty popularity in Europe by country. Statista. Retrieved from https://www.statista.com/statistic_id1274781_k-beauty-popularity-in-europe-2022-by-country.pdf.

[24] Statista (2022). Distribution of medical tourists in South Korea in 2022 by department. Statista. Retrieved from https://www.statista.com/statistic_id1113913_distribution-of-medical-tourists-in-south-korea-in-2022-by-department.pdf.

[25] The History of Korean Beauty Part 2: Goryeo Dynasty. (n.d.). Asia Society. Retrieved from https://asiasociety.org/korea/history-korean-beauty-part-2-goryeo-dynasty.

[26] Wang, L., & Lee, J. H. (2021). The impact of K-Beauty social media influencers on consumer behavior. *Journal of Consumer Studies*, 32 (2), 56–71.

[27] The Yonsei annals (n.d.). *The Yonsei Annals*. http://annals.yonsei.ac.kr/

[28] Korea Tourism Organization. (n.d.). Visit Korea: Official Korea Tourism Organization. Retrieved November 7, 2024, from https://knto.or.kr/eng/index.

Journal for Health Sciences, Vol. 14, No. 2 (2024), pp. 28–43.
https://doi.org/10.32967/etk.2024.026

RELATIONSHIPS BETWEEN BURNOUT, SELF-ESTEEM AND PSYCHOLOGICALWELL-BEING IN UNIVERSITY STUDENTS

CSILLA LAKATOS* – ELEONÓRA JUHÁSZ – ANDREA RUCSKA
University of Miskolc, Faculty of Health Science

Summary: The authors conducted a quantitative cross-sectional study to investigate the relationships between burnout, self-esteem and psychological well-being among university students in the health sciences. The aim of the study was to uncover the psychosocial risk factors that may influence students' health behaviors and mental health status. A total of 281 full-time students (n = 281; 14.9% male; 85.1% female) from the Faculty of Health Sciences at the University of Miskolc took part in the study (mean age: 21.1 years; standard deviation: 2.9). According to its composition, 54.1 of the sample consisted of physiotherapists, 15.8% of public health nurses, 14.3% of medical diagnosticians, 10% of health tourism managers and 5.7% of nurses. In addition to socio-demographic questions, the survey used the Student Burnout Inventory to measure burnout, the Rosenberg Self-Esteem Scale (RSES-H) to measure self-esteem, the Perceived Stress Scale (PSS-10) to measure the subjective experience of stress and the Depression Anxiety Stress Scales (DASS-21) to assess mental health. The results indicate that the self-esteem and psychological well-being of university students are strongly correlated with the likelihood of burnout. Furthermore, these things have a significant impact on their health behaviors and health status. An inappropriate career choice and a lack of support from the environment can lead to a change of subject or even dropping out of college. The findings highlight the complex issues of student burnout and dropout and emphasize the role of educational institutions in providing early detection and appropriate support, which are essential for maintaining student well-being and achieving academic success.

Keywords: *student burnout, self-esteem, psychological well-being, health-science students*

1. INTRODUCTION

Student burnout is a condition in which students experience emotional, mental and physical exhaustion due to prolonged stress and overwork. This condition is particularly common in higher education, where academic demands, exam preparation and personal life issues can lead to the development of burnout symptoms. A negative consequence of prolonged, untreated stress and failure is that students may give up their studies. Although burnout and dropout are complex problems resulting from the interaction of multiple factors, early identification and appropriate support within the institutional environment are crucial to ensure student

* Corresponding autor: dr. Lakatos Csilla, 3515 Miskolc-Egyetemváros B3-B4 épület, 209., csilla.lakatos@uni-miskolc.hu

wellbeing and successful completion of studies. Educational institutions have an important role to play in this, as they can help students manage stress, maintain mental wellbeing and achieve academic success by developing and maintaining appropriate support systems.

2. LITERATURE REVIEW

Burnout is a health disorder that develops in a work environment as a result of unsuccessfully coping with chronic stress in the workplace [1]. Research into burnout syndrome has come a long way in the last fifty years. Originally, it was considered a psychological phenomenon that affected healthcare professionals [2]. It was later observed in other human service professions and eventually defined as a work-life management difficulty affecting a wide range of people [3]. Although the concept of burnout originally referred to the consequences of work-related interpersonal chronic stress, in recent decades it has been extended to other fields, including education, where it is defined as academic burnout [4]. The concept of academic burnout is based on the observation that institutional educational functions are similar to a workplace. Research data suggest that symptoms can occur as early as elementary school students, and longitudinal studies suggest that these symptoms worsen in high school and university [5]. The structured schedule, the obligation to attend classes, the need to fulfill practical requirements, and the need to pass exams can collectively be considered "work" and can exert psychological pressure that occasionally leads to overload [6, 7, 8]. The symptoms caused by chronic overload in the university environment are very similar to the work-related burnout symptoms experienced by adults: emotional exhaustion related to academic demands, decreased interest in university activities, cynical reactions, indifferent attitudes, dissatisfaction with performance, decreased personal effectiveness, and a sense of inadequacy [4, 9]. In addition to the theoretical basis, research in this area shows that among the three different areas, emotional exhaustion and cynicism stand out as the core of the burnout syndrome [10].

Academic burnout is associated with numerous negative factors. Previous studies have identified several individual and institutional characteristics as risk factors. Among the individual characteristics, socio-demographic factors such as gender, age and financial wealth are noteworthy. When examining gender differences, higher prevalence rates have been found in girls in high school [11] and boys in university [12]; in the latter group, longitudinal studies have shown a faster escalation of symptoms [13] (Salmela-Aro and Tykkynen, 2012). Age and length of study are also linked to burnout: younger students in their first year of study were found to have more symptoms at the beginning of their studies [14]. When examining the financial background of students, those who work alongside their studies appear to be more prone to burnout [15]. Recently, a comprehensive study confirmed higher levels of burnout among university students in low- and middle-income countries [16]. Furthermore, it is important to emphasize the role of interpersonal factors. The

presence of social support experienced by university students decreases the risk of burnout, while its absence increases the risk [8, 17].

The symptoms of academic burnout are linked to certain intrapersonal factors. Research shows that self-esteem generally has a negative correlation with burnout [18], and accordingly, students with higher self-esteem are less likely to be affected by burnout symptoms [11, 19, 20, 21]. In addition, certain forms of perfectionism are associated with the occurrence of burnout symptoms: maladaptive perfectionism and the desire to fulfill external expectations in particular are considered risk factors for the development of burnout. Symptoms are most likely to occur in students who strive for excellent results primarily due to external expectations and experience predominantly negative feelings when their performance is evaluated [22].

Studies conducted in recent years have shown that burnout in university students is associated with poorer academic performance, more frequent absenteeism, higher dropout rates, sleep disturbances, more frequent substance use and poorer mental and physical health characteristics [6, 7, 16, 23]. At the same time, the results of longitudinal studies underline the persistence of the effects after graduation and the worsening of burnout symptoms [24]. Although international and Hungarian studies on academic burnout have primarily focused on medical students in recent years [23, 25, 26, 27, 28], some studies have also reported data on nursing students [29,30,31]. However, researchers warn that it would be a mistake to assume that students in other disciplines are not affected by burnout, so an investigation of the phenomenon in other university students also seems necessary [27], especially in light of recent data indicating a worldwide worsening of student burnout during the COVID-19 pandemic [32].

3. THE AIM OF EMPIRICAL RESEARCH AND THE METHODOLOGY APPLIED

The main objective of our research is to investigate and deepen the relationships between burnout, self-esteem and psychological well-being in university students studying in the field of health sciences. We also wanted to explore various psychosocial risk factors that may influence students' health behaviors and mental health status. The online questionnaire contains questions aimed at capturing socio-demographic background variables and health behaviors and includes a standardized, validated questionnaire in Hungarian closely related to the research topic.

1. The Student Burnout Questionnaire [33, 34], Hungarian version [35] is a self-administered measuring instrument consisting of nine items. Respondents rate their answers on a six-point Likert scale (1 = "Does not apply to me at all"; 6 = "Applies to me completely"). The questionnaire divides the burnout symptoms into three subscales: emotional exhaustion, cynicism and the feeling of incapacity.

2. The Rosenberg Self-Esteem Scale [36], Hungarian version [37] is a ten-point scale that measures general self-esteem on a four-point Likert scale (1 = strongly disagree, 4 = strongly agree).

3. The Perceived Stress Scale (PSS-10) [38] Hungarian version [39] measures the subjective perception of stress. The questionnaire consists of 10 items, which are

rated on a 5-point Likert scale (0–4). Higher scores indicate a greater frequency of stressors and a perceived effectiveness in coping with these stressors.

4. The Depression, Anxiety and Stress Scale (DASS-21) is a self-assessment questionnaire consisting of 21 items, with seven items each measuring symptoms of depression, anxiety and stress. The symptoms are rated on a 4-point scale (0 = Does not apply to me at all to 3 = Applies to me most of the time) and reflect the experience of the last week before completing the questionnaire. Each scale ranges from a minimum value of 0 to a maximum value of 21 [40].

The data collection was conducted online among full-time students of the Faculty of Health Sciences at the University of Miskolc in February 2024, after the winter examination period. Students were invited to participate voluntarily and anonymously through the university's Neptune system.

Data analysis included frequency and relative frequency distributions as well as analysis of associations using chi-square tests, correlation analysis and ANOVA. Data processing was performed using the SPSS 25.0 software package.

The research was approved by the Regional/Institutional Ethics Committee for Science and Research of the Central Hospital and University Teaching Hospital of Borsod-Abaúj-Zemplén County (license no.: BORS-08/2024).

4. RESULTS

4.1. Characteristics of the sample

The socio-demographic characteristics of the sample can be seen in *Table 1*.

Table 1

The socio-demographic characteristics of the sample

The size of the sample	n = 281	
Gender distribution	Male:14.9%	Female:85.1%
Age	21.1±2.9 years	
Department Health visitor Physiotherapist Nurse Medical diagnostic analyst Health tourist manager	 15.8% 54.1% 5.7% 14.3% 10%	
Place of habitation Budapest Miskolc Other large city City Village	 5.0% 25.3% 9.6% 31.7% 28.5%	
Place of residence Home (Miskolc) Commuter	 24.3% 28.2%	

Dormitory	33.6%
Rented apartment	12.5%
Relatives	1.4%
The family's financial situation	
Good	25.9%
Average	48.2%
Satisfactory	14.2%
Poor	3.6%
Do not wish to provide information	8.0%
Is there a member of your family with a higher education?	
Yes, both parents	17.4%
Yes, one parent	27.8%
Yes, one sibling	14.2%
Yes, grandparent	1.1%
No	39.5%
Work alongside studies	26.6%
Average travel time between university and current place of residence	52.1 minute ±49.8

4.2. Academic performance

Students enrolled on average in 2022 ±1.23, with the earliest enrollment dating back to 2018. The decision to apply for a particular degree program was influenced by various reasons, but the vast majority made a conscious decision based on their interest (84.7%). However, some were influenced by family (39.5%) or friends (30.1%). Some students chose their degree program because they did not know where else to apply (14.9%), while another 18.1% were not admitted elsewhere.

During their studies, 6.8% of students changed their major, primarily because they realized that their career choice was not well thought out. The most frequent change of major was observed among students in the Organization of Health Tourism students. The academic performance achieved by students students was slightly below the performance requirements specified in the sample curriculum *(Table 1)*. The expected performance record according to the sample study plan is 30 credits per semester.

Table 2

Average credit completion by year

Year	Average credits completed
I.	27.55 ±3.7
II.	90.46 ±20.6
III.	148.29 ±52.5
IV.	201.38 ±34.6

In the first year there is an average deficit of 3 credits, which is made up in the second year. In the third year there is also a minimal credit deficit, which increases in the fourth year.

In the breakdown of credits achieved by program *(Table 3)*, it is clear that students in the Health Tourism Management and Public Health Nursing programs are making the most progress according to the model curricula.

Table 3

Average credit completion by year and major

Year (credit completion in curriculum)	Health visitor	Physiotherapist	Nurse	Medical diagnostic analist	Health tourist manager
I. (30cr)	30 ±0.7	26.4 ±4.2	29.0 ±3.7	26.5 ±2.4	30.0 ±0.0
II. (90cr)	–	87.5 ±17.9	–	93.2 ±9.5	96.4 ±34
III. (150cr)	166 ±106.1	143.1 ±29.5	156.6 ±5.7	141.6 ±42.0	150.0 ±48
IV. (210cr)	192 ±40.4	215.5 ±9.7	–	210.1 ±12.1	165.0 ±91

The physiotherapy students fall the farthest behind in meeting the credit requirements set forth in the standard curriculum, followed by radiography students. The health tourism organizer program is 7 semesters long. The students who indicated that they are in their 4th semester are the most likely to complete the program.

4.3. Self-esteem

A maximum of 40 points can be achieved on the four-point Likert scale, which means that a higher total score reflects a more positive self-esteem. The average total score of the students is 28.1 points, which indicates good self-esteem.

A significant correlation is observed in relation to gender ($p = 0.02$): Boys have better self-esteem than girls (see *Table 4*).

Table 4

Self-esteem in relation to gender

Gender	Self-esteem average point
Male	30.24
Female	27.80

The chi-square test shows that the financial situation of the family ($p = 0.018$) has a significant influence on self-esteem, with young people who live in larger cities and have good financial conditions having better self-esteem.

There is no significant difference ($p > 0.05$) in self-esteem between students of different majors, but nursing students have the highest self-esteem *(Table 5)*, while health visitor students have the lowest.

Table 5
Self-esteem in relation to major

Major	Self-esteem average point
Health visitor	26.96
Physiotherapist	28.40
Nurse	30.31
Medical diagnostic analyst	28.23
Health tourism manager	27.82

4.4. Mental state

We measured the students' mental state using the DASS-21 scale, which measures levels of depression, anxiety and stress. The majority of students had good mental health *(Table 6)*.

Table 6
Mental state of students according to DASS-21

Areas	Depression (%)	Anxiety (%)	Stress (%)
Normal	68.9	59	76.2
Mild	18.7	11.4	16.1
Moderate	11.7	15.8	7.7
Severe	0.7	11.4	–
Extremely severe	–	2.6	–

The majority of students have good mental health, but it is notable that 31.1% have some level of depression, 38.5% have some level of anxiety, and 23.8% have symptoms of stress. The mental health of students shows a significant correlation with gender ($p < 0.001$), residence ($p = 0.015$), and family financial situation ($p = 0.002$). We observed poorer mental health among female students, those living in dormitories or with relatives, and those from poorer financial backgrounds.

While there were no significant differences observed when comparing individual majors ($p > 0.5$), the mental health of physiotherapy students appears to be worse compared to other majors. When examining the study programs on the basis of subscales, it can be seen that students on the Health Tourism Management study program exhibit depression more frequently, while anxiety and stress symptoms are significantly higher among physiotherapy students *(Table 7)*.

Table 7

The mental state of students by majors based on the DASS-21 subscale scores

Major	Depression average point	Anxiety average point	Stress average point	DASS-21 percentil average
Health visitor	6.78	6.78	9.51	23.07
Physiotherapist	7.61	7.95	11.05	26.60
Nurse	7.06	6.75	10.00	23.81
Medical diagnostic analyst	6.97	6.85	9.21	23.03
Health tourism manager	8.12	7.50	9.19	24.81

A significant correlation ($p = 0.037$) between mental health and years of study was found using the chi-square test. The mental state of students in the first year of study is significantly worse compared to the other years of study.

There is a moderate, negative correlation between mental health and self-esteem for all subscales of mental health (depression $r = –0.60$; anxiety $r = –0.49$; stress $r = –0.48$).

4.5. Perceived stress

The Perceived Stress Scale assesses the stress-inducing events that the respondent has perceived in the past month. The questionnaire focuses on individual, subjective perceptions of the difficulty of events experienced in the past month. Higher scores indicate a higher level of perceived stress.

The average score on the perceived stress scale for the students was 20.2 ±2.7. The maximum score achieved by the students was 28 points. The median score was 20 points, with 44% of students scoring above the median (from 21 points).

With regard to the degree programs, it can be seen that the nursing students experienced the most stressful examination phases, followed by the radiography students *(Table 8)*.

Table 8

Perceived strees between students in different majors

Majors	PSS averages
Health visitor	20.18 ±2,6
Physiotherapist	20.17 ±2,6
Nurse	20.81 ±2,8
Medical diagnostic analyst	20.37 ±3,1
Health tourism manager	19.60 ±2,8

The perceived stress investigated with Anova showed a significant correlation with self-esteem ($p < 0.01$), depression ($p < 0.05$), anxiety ($p < 0.05$) and age ($p < 0.001$) *(Table 9)*.

Table 9

The averages of perceived stress in relation to age

Age sections	PSS average values
under 19	23.15 ±2,5
20–21 years	19.99 ±3,0
22–23 years	19.92 ±2,4
24–25 years	20.63 ±2,7
over 25 years	18.5 ±2,2

Stress is particularly high among students under the age of 19, i.e. first-year students. An increased level of stress was also found in students aged 24–25.

There is no significant correlation at the 0.05 significance level between stress level and motivation. However, we found a higher level of stress in students who were unsure about their further education intentions (did not know where to apply) (PSS: 20.7) and in students who were not admitted anywhere (PSS: 20.5).

There is no significant correlation at the 0.05 level of significance, but the lowest stress index is observed among young people whose both parents have a higher education (PSS: 19.9). Higher values are observed among those who work alongside their studies (PSS: 20.3) and live in average or above-average financial circumstances (PSS: 20.4). Similarly, no significant correlation is observed ($p > 0.8$), but young people who sleep less than 5 hours have higher stress indexes (PSS: over 21). Conversely, those who exercise more than 7 hours per week have the lowest stress (PSS: 19.7).

4.6. Student burnout

Student burnout is a condition that can result from long-term stress, excessive workload and emotional exhaustion in university or college students. This condition often occurs due to excessive academic demands, deadline pressure, social expectations and other stressors. Student burnout often manifests itself in the form of anxiety, depression, sleep disturbances, a feeling of decreased efficiency and academic performance. One of the most common causes is the feeling of not being able to meet expectations. Individuals can feel overly tired, frustrated and demotivated, which can have a long-term impact on health and well-being.

A total score of 48 was achieved on the burnout questionnaire. In this study, the students had an average score of 21.5 ±8.5 points. The scores showed high variability, with some students scoring at or near the maximum score. The exhaustion subscale of the burnout questionnaire had the highest scores *(Table 10)*.

Burnout showed a moderate, negative correlation with self-esteem at the 0.05 level of significance (r = –0.52). When examining the subscales, the strongest correlation was observed with inefficiency (r = –0.55), followed by cynicism (r = –0.43) and emotional exhaustion (r = –0.36). The inefficiency subscale showed a significant correlation with the change of study subject (p = 0.044).

Burnout and each mental state subscale showed significant correlations (p < 0,001). The girls' scale score (21,8 ±8,9) is not significantly (p > 0.05), but it is higher than that of the boys (19.3 ±6.9).

When examining the subscales, it can be seen that students specializing in the organization of health tourism have the highest burnout. This is followed by students studying medical diagnostic analytics *(Table 9)*. Based on the results of the subscales, emotional exhaustion is most pronounced among physiotherapy students, followed by medical diagnostic analyst students.

Table 10

Average subscale scores of student burnout questionnaire by fields of study

Major	Student burnout total averagepoint (max. 48)	Emotional exhaustion averagepoint (max. 18)	Cinizm averagepoint (max. 18)	Inefficiency averagepoint (max. 12)
Health visitor	18.9 ±8.4	8.0 ±3.3	5.6 ±3.5	5.3 ±2.6
Physiotherapist	21.8 ±8.4	9.7 ±3.5	6.4 ±3.9	5.6 ±2.6
Nurse	20.1 ±7.9	8.5 ±3.8	6.3 ±2.7	5.3 ±2.6
Medical diagnostics analytics	22.5 ±9.9	9.2 ±4.2	7.0 ±4.0	6.2 ±2.9
Healt tourism manager	22.8 ±8.4	7.5 ±3.2	9.1 ±4.4	6.1 ±2.5
ALL	21.52 ±8.7	9.10 ±3.6	6.71 ±3.9	5.69 ±2.6

When examining the cynicism subscale by year of study, a significant correlation (p < 0.01) is found, which indicates that students in higher years of study perceive their studies as less meaningful. Burnout shows a significant correlation (p = 0.002) with year of enrollment, suggesting that students who enrolled earlier experience more pronounced burnout.

Support has a significant effect on student burnout: those who receive support from their family (p < 0.01) or their lecturers (p < 0.01) cope significantly better with obstacles.

The burnout of working students (22.2 ±8.8) and those living in dormitories (24.4 ±9.2) is more pronounced, although not statistically significant (p > 0.05).

There is a significant association (p < 0.01) between the time spent commuting to university and burnout, with students who commute more than 180 minutes per journey daily (we encountered students who commute up to 300 minutes daily)

exhibiting significantly more pronounced burnout symptoms compared to those who live closer.

The correlation is not significant ($p > 0.05$), but the majority of students with high burnout scores sleep less than 5 hours per night (30.5 ±12.7), smoke more, typically a half to a full pack of cigarettes (24 ±8.7), and self-report consuming alcohol 5-6 times per week (26 ±11.9). Students who exercise regularly have lower scores on the burnout scale (20.3 ±9.0).

Only 6.3% of students know that there are psychological/mental health services at the university.

5. DISCUSSION AND CONCLUSIONS

Students studying at the Faculty of Health Sciences envision their professional development and future in various fields of health sciences. Within the university environment, their education is characterized by strict adherence to curricula, which implies a rigorous expectation for the completion of each semester. In recent years, striking trends have been observed not only at the faculty level, but also at the level of the institution as a whole, in terms of student performance, dropout rates, rates and directions of change of major, and specific life situations. These phenomena clearly point to the need to investigate and understand their possible causes.

Young people with higher self-esteem find it easier to fulfill high expectations. Residents from the surrounding small towns and villages choose our university as a place to study. Although the proportion of students from Budapest is high, not so many young people choose our university, and this fact has a great influence on self-esteem.

Based on our results, the characteristics of students' mental health can be considered adequate. This is particularly favorable because we found a significant relationship between mental health and student burnout, which can result from long-term stress. However, first-year students have significantly poorer mental health than students in higher years, and they also have significantly higher stress indices. These factors may contribute to their higher risk of dropping out and changing courses. A third of our students live in halls of residence and we consider the poorer mental health measured among them to be unfavorable. Improving the facilities within the institution, such as double-bed apartments, larger living spaces and communal areas, could partially remedy this.

From our results it can be concluded that bad choice of carrier leads to a change of subject. In such cases, our students clearly opt for the shortest program offered by our faculty. This choice is probably more about completing the degree in the shortest time possible rather than staying in the field they are interested in.

We believe that the results of achieving 30 credits are above expectations. Any shortfalls at the year level are quickly made up. However, this pattern does not hold true when analyzed by individual degree program. Physiotherapy students consistently lag behind, achieving adequate credits particularly in the final year of study. In contrast, Health Tourism Management students consistently achieve an

adequate number of credits throughout their program. These program-specific differences warrant further analysis and likely require discipline-specific strategies and interventions to achieve a more even graduation rate.

In the case of the Physiotherapy program, where credit completion is slow, we observed the most unfavorable psychological characteristics among students, particularly high levels of anxiety and stress. The program has a high number of students in all years of study. The mentoring program, which is currently being intensively implemented as part of the degree program, could potentially uncover the specific background factors of the field, the understanding and analysis of which could mitigate these characteristics.

In the top-performing Health Tourism Manager program, students reported the least difficulties during the exam period prior to the research phase; however, we measured high levels of depression among them. Our results suggest a significant correlation between perceived stress and depression. Specific factors related to the course of study could exacerbate the unfavorable factors observed in the students, which warrants further analysis.

When examining students' self-esteem, psychological well-being, and burnout characteristics, it became clear that these characteristics significantly influence students' health behaviors and health status. Our study emphasized the important role of regular physical activity in promoting positive effects.

Student burnout is a condition that is particularly prevalent in higher education, where academic expectations, exam preparation and a balanced personal life can contribute to its development. This condition often leads to students giving up their studies. Burnout and dropout are complex problems that result from a combination of factors. Early recognition and appropriate support are crucial to ensure student wellbeing and success. Educational institutions play an important role in this process by establishing and maintaining support systems that help students manage stress and achieve academic success.

6. ACKNOWLEDGMENTS

The research was prepared in the "National Laboratory for Social Innovation" project (RRF-2.3.1-21-2022-00013), within the framework of Hungary's Recovery and Resilience Plan, with the support of the Recovery and Resilience Facility of the European Union.

REFERENCES

[1] WHO (2019). Burn-out an 'occupational phenomenon': International Classification of Diseases. *WHO*, May 28, https://www.who.int/standards/classifications/frequently-asked-questions/burn-out-an-occupational-phenomenon (accessed Jan. 19, 2024).

[2] Freudenberger, H. J. (1974). Staff Burn-Out. Journal of Social Issues. Jan., 30 (1), 159–65. https://doi.org/10.1111/j.1540-4560.1974.tb00706.x

[3] Maslach, C., Schaufeli, W. B., Leiter, M. P. (2001). Job Burnout. *Annual Review of Psychology*, Feb., 52 (1), 397–422.

[4] Schaufeli, W. B., Martínez, I. M., Pinto, A. M., Salanova, M., Bakker, A. B. (2002). Burnout and Engagement in University Students. *Journal of Cross-Cultural Psychology*, Sep., 33, (5) 464–81. https://doi.org/10.1177/0022022102033005003

[5] Kiuru, N., Aunola, K., Nurmi, J-E., Leskinen, E., Salmela-Aro, K. (2008). Peer Group Influence and Selection in Adolescents' School Burnout: A Longitudinal Study. *Merrill-Palmer Quarterly*, 54 (1), 23–55. https://doi.org/10.1353/mpq.2008.0008

[6] Risa, N. A. (2022). Literature Review of AcademicBurnout. *American Research Journal of Humanities & Social Science*, 5 (2), 6–13.

[7] Rosales-Ricardo, Y., Rizzo-Chunga, F., Mocha-Bonilla, J., Ferreira, J. P. (2021). Prevalence of burnout syndrome in university students: A systematic review. *Salud mental*, Apr. 9, 44 (2), 91–102. https://doi.org/10.17711/SM.0185-3325.2021.013

[8] Ye, Y., Huang, X., Liu, Y. (2021). Social Support and Academic Burnout Among University Students: A Moderated Mediation Model. *Psychology Research and Behavior Management*, March, Vol. 14, 335–44. https://doi.org/10.2147/PRBM.S300797

[9] Salmela-Aro, K., Kiuru, N., Pietikäinen, M., Jokela, J. (2008). Does School Matter? *European Psychologist*, Jan., 13 (1), 12–23. https://doi.org/10.1027/1016-9040.13.1.12

[10] Purvanova, R. K., Muros, J. P. (2010). Gender differences in burnout: A meta-analysis. *Journal of Vocational Behavior*, Oct., 77 (2), 168–85. https://doi.org/10.1016/j.jvb.2010.04.006

[11] Herrmann, J., Koeppen, K., Kessels, U. (2019). Do girls take school too seriously? Investigating gender differences in school burnout from a self-worth perspective. *Learning and Individual Differences*, Jan., 69, 150–61. https://doi.org/10.1016/j.lindif.2018.11.011

[12] Chunming, W. M., Harrison, R., MacIntyre, R., Travaglia, J., Balasooriya, C. (2017). Burnout in medical students: a systematic review of experiences in Chinese medical schools. *BMC Medical Education*, Nov. 16, 17 (1). https://doi.org/10.1186/s12909-017-1064-3

[13] Salmela-Aro, K., Tynkkynen, L. (2012). Gendered pathways in school burnout among adolescents. *Journal of Adolescence*, Aug., 35 (4), 929–39. https://doi.org/10.1016/j.adolescence.2012.01.001

[14] March-Amengual, J. M., Cambra Badii, I., Casas-Baroy, J. C., Altarriba, C., Comella Company, A., Pujol-Farriols, R. et al. (2022). Psychological Distress, Burnout, and Academic Performance in First Year College Students. *International Journal of Environmental Research and Public Health*, Jan., 1, 19 (6), 3356. https://doi.org/10.3390/ijerph19063356

[15] Galbraith, C. S., Merrill, G. B. (2014). Academic performance and burnout: an efficient frontier analysis of resource use efficiency among employed university students. *Journal of Further and Higher Education*, Jan. 14, 39 (2), 255–77. https://doi.org/10.1080/0309877x.2013.858673

[16] Kaggwa, M. M., Kajjimu, J., Sserunkuma, J., Najjuka, S. M., Atim, L. M., Olum, R. et al. (2021). Prevalence of burnout among university students in low- and middle-income countries: A systematic review and meta-analysis. *PLOS ONE*, Aug. 30, 16 (8), e0256402. https://doi.org/10.1371/journal.pone.0256402

[17] Kim, B., Jee, S., Leem J., An,S., Lee, S. M. (2017). Relationships between social support and student burnout: *A meta-analytic approach. Stress and Health*, June 22, 34 (1), 127–34. http://doi.org/10.1002/smi.2771

[18] Rosse, J. G., Boss, R. W., Johnson, A. E., Crown, D. F. (1991). Conceptualizing the Role of Self-Esteem in the Burnout Process. *Group & Organization Studies*, Dec., 16 (4), 428–51. https://doi.org/10.1177/105960119101600406

[19] Becerra, M. B., Arias, D., Cha, L., Becerra, B. J. (2020). Self-esteem among college students: the intersectionality of psychological distress, discrimination and gender. *Journal of Public Mental Health*, Sep. 17, 20 (1), 15–23. https://doi.org/10.1108/jpmh-05-2020-0033

[20] Kupcewicz, E., Jóźwik, M. (2019). Association of burnout syndrome and global self-esteem among Polish nurses. *Archives of Medical Science*. https://doi.org/10.5114/aoms.2019.88626

[21] Gallardo, P. N. (2022). The Relationship Between Self-Esteem and Burnout Among College Students Amidst the Online Learning Modality. *Zenodo*, June 16 [cited 2022 Sep 6]. https://doi.org/10.5281/zenodo.6654371

[22] Chang, E., Lee, A., Byeon, E., Seong, H., Lee, S. M. (2016). The mediating effect of motivational types in the relationship between perfectionism and academic burnout. *Personality and Individual Differences*, Jan., 89, 202–10. https://doi.org/10.1016/j.paid.2015.10.010

[23] Győrffy, Z., Birkás, E., Sándor, I. (2016). Career motivation and burnout among medical students in Hungary – could altruism be a protection factor? *BMC Medical Education*, July 18, 16 (1). https://doi.org/10.1186/s12909-016-0690-5

[24] Salmela-Aro, K., Tolvanen, A., Nurmi, J. E. (2009). Achievement strategies during university studies predict early career burnout and engagement. *Journal of Vocational Behavior*, Oct., 75 (2), 162–72. https://doi.org/10.1016/j.jvb.2009.03.009

[25] Ádám, S., Hazag, A. (2013). High prevalence of burnout among medical students in Hungary: Engagement and positive parental attitudes as potential protective factors. *Mentálhigiéné és Pszichoszomatika*, March, 14 (1), 1–23. https://doi.org/10.1556/mental.14.2013.1.1

[26] Almutairi, H., Alsubaiei, A., Abduljawad, S., Alshatti, A., Fekih-Romdhane, F., Husni, M. et al. (2022). Prevalence of burnout in medical students: A systematic review and meta-analysis. *International Journal of Social Psychiatry*, July 1, 68 (6), 1157–70. https://doi.org/10.1177/00207640221106691

[27] Frajerman, A., Morvan, Y., Krebs, M. O., Gorwood, P., Chaumette, B. (2019). Burnout in medical students before residency: A systematic review and meta-analysis. *European Psychiatry*, Jan., 55, 36–42. https://doi.org/10.1016/j.eurpsy.2018.08.006

[28] Ilic, I., Ilic, M. (2023). The relationship between the burnout syndrome and academic success of medical students: a cross-sectional study. *Arhiv Za Higijenu Rada I Toksikologiju*, June 1, 74 (2), 134–41. https://doi.org/10.2478/aiht-2023-74-3719

[29] Admin, Alfia Nuriil Firdausi, Fitryasary R. I., Tristiana, D., Rista Fauziningtyas, Deena Clare Thomas. (2023). Self-efficacy and social support have relationship with academic burnout in college nursing students. *Journal of Pakistan Medical Association*, Feb. 1, 73 (02), S63–6. https://doi.org/10.47391/JPMA.Ind-S2-15

[30] Kong, L. N., Yao, Y., Chen, SZ., Zhu, J. L. (2022). Prevalence and associated factors of burnout among nursing students: A systematic review and meta-analysis. *Nurse Education Today*, Dec. 23, 121, 105706. Available from: https://pubmed.ncbi.nlm.nih.gov/36577286/#:~:text=In%20the%20random-effects%20model%2C%20the%20pooled%20prevalence%20of.

[31] Tomaschewski-Barlem, J. G., Lunardi, V. L., Lunardi, G. L., Barlem, E. L. D., Silveira, R. S. da, Vidal, D. A. S. (2014). Burnout syndrome among undergraduate nursing students at a public university. *Revista Latino-Americana de Enfermagem*, Dec., 22 (6), 934–41. https://doi.org/10.1590/0104-1169.3254.2498

[32] Abraham, A., Chaabna, K., Sheikh, J. I., Mamtani, R., Jithesh, A., Khawaja, S. et al. (2024). Burnout increased among university students during the COVID-19 pandemic: a systematic review and meta-analysis. *Scientific Reports*, 14 (1), 2569. https://doi.org/10.1038/s41598-024-52923-6

[33] Salmela-Aro, K., Kiuru, N., Pietikäinen, M., Jokela, J. (2008). Does School Matter? *European Psychologist*, Jan., 13 (1), 12–23. https://doi.org/10.1027/1016-9040.13.1.12

[34] Salmela-Aro, K., Kiuru, N., Leskinen, E., Nurmi, J. E. (2009). School Burnout Inventory (SBI). *European Journal of Psychological Assessment*, Jan, 25 (1), 48–57. https://doi.org/10.1027/1015-5759.25.1.48

[35] Jagodics, B., Kóródi, K., Szabó, É. (2021). A Diák Kiégés Kérdőív szerkezetének vizsgálata magyar mintán. *Magyar Pszichológiai Szemle*, Oct. 15, 76 (1), 1–22. https://doi.org/10.1556/0016.2021.00020

[36] Rosenberg, M. (1965). Society and the AdolescentSelf-Image. Princeton NJ., Princeton University Press, 338.

[37] Sallay, V., Martos, T., Földvári, M., Szabó, T., Ittzés, A. (2014). Hungarian version of the Rosenberg Self-esteem Scale (RSES-H): An alternative translation, structural invariance, and validity. *Mentálhigiéné és Pszichoszomatika*, Sep., 15 (3), 259–75. https://doi.org/10.1556/Mental.15.2014.3.7

[38] Cohen, S., Kamarck, T., Mermelstein, R. (1983). A Global Measure of Perceived Stress. *Journal of Health and Social Behavior*, Dec., 24 (4), 385–96. https://doi.org/10.2307/2136404

[39] Martos, T., Filep, O., Fényszáros, É. (2022). Észlelt Stressz Kérdőív (Percieved Stress Scale, PSS). In: Horváth, Zs., Urbán, R., Kökönyei, Gy., Demetrovics, Zs. editors. *Kérdőíves módszerek a klinikai és egészségpszichológiai kutatásban és gyakorlatban*. Budapest, Medicina Könyvkiadó, 233–237.

[40] Horváth, Zs. (2022). Depresszió Szorongás Stressz Kérdőív (Depression, Anxiety Stress Scale, DASS). In: Horváth, Zs., Urbán, R., Kökönyei, Gy., Demetrovics, Zs. editors. *Kérdőíves módszerek a klinikai és egészség-pszichológiai kutatásban és gyakorlatban*. Budapest, Medicina Könyvkiadó, 415–421.

Journal for Health Sciences, Vol. 14, No. 2 (2024), pp. 44–59.
https://doi.org/10.32967/etk.2024.027

MOLECULAR ALLERGEN AND CROSS-ALLERGEN COMPONENT STUDIES AMONG PEOPLE LIVING IN THE NORTHEASTERN HUNGARIAN REGION

ÉVA KISS-TÓTH DOJCSÁK[1] – DÁVID NÉMETH[1] – ADRIENN J. SZALAI[1] – BERTALAN FODOR[1, 2]

[1]*Institute of Clinical Methodology, Faculty of Health Sciences, University of Miskolc, Miskolc*

[2]*Borsod-Abaúj-Zemplén County Hospital and University Teaching Hospital, Department of Laboratory Medicine.*

Summary: Background: The availability of multiplex microarray-based diagnostic systems in the field of allergology contributes to the determination of personalized, component- based diagnosis. It enables allergen source and accurate allergen component identification even in patients with ambiguous symptoms and Prick skin test suggesting simultaneous positivity of two or more related allergens. **Aim:** In our study, we determined the presence and type of sensitization in the adult population of northeastern Hungary using a new type of multiple allergy diagnostic system and identified the molecular components most frequently involved in the background of sensitization and cross sensitization. **Methods:** The study was a cross-sectional study involving 229 adult volunteers. An ELISA- based multiplex molecular diagnostic system was used to determine sensitization. **Results:** Sensitization to an allergen was confirmed in nearly 70% of the subjects. 22.70% were sensitized to a single allergen, while 46.72% were sensitized to multiple allergens simultaneously. The degree of sensitization and total IgE were moderately correlated. In both groups, significant seasonal inhaled allergens were the molecular components of ragweed, grasses and birch. As perennial allergens, dust and food mite proteins caused frequent sensitization. The most common components responsible for cross-sensitization were proteins from ragweed, Timothy grass, birch and dust mite. **Discussion:** Multiplex technology and component-based diagnosis can assist the clinician in determining targeted, patient-centred and cost-effective allergy treatment.

Keywords: *allergy, sensitization, allergenic component, molecular diagnostics, cross-allergen*

INTRODUCTION

Foreign structures, antigens, which enter our body from outside, trigger a regulated immune response to restore or maintain immune homeostasis. In the meantime, certain cells of the immune system produce allergen-specific immunoglobulin E (IgE) antibodies to ensure a humoral immune response to the allergen. This process is called allergen sensitization. In some cases, however, the immune system does not respond adequately to the antigen and a hypersensitivity reaction develops. A hypersensitivity

(allergic) reaction is usually the result of a second or repeated exposure to the same allergen. [1]

Several epidemiological studies have found that atopic sensitization is a strong risk factor for asthma, hay fever or allergic conjunctivitis. In a person sensitized to an allergen, the specific IgE produced against the allergen is the initial triggering component for the activation of a complex inflammatory cascade that can lead to the development of specific symptoms. However, it should be noted that not all sensitized individuals develop allergy. [2]

The presence of IgE produced in response to a particular allergen is considered a qualitative response, but it can also be interpreted as a quantitative marker. Some people show a positive immune response to only one allergen (monosensitized), while others are sensitized to a wide range of allergens (polysensitized). It is also necessary to distinguish between the two phenotypes because they are characterised by important clinical and immunological differences. [2–3] Monosensitized children often become polysensitized in adulthood, but the trend persists in monosensitized adults. However, polysensitized patients do not necessarily develop an allergic symptom complex, but several studies have demonstrated the presence or development of polysensitization in allergic individuals over time. [4]

In the case of a polysensitized individual, it is useful to distinguish cross-reactivity from cosensitization. [4] The term cosensitization was introduced to describe multiple, independent sensitization to multiple, structurally unrelated groups of allergens. This is particularly important in the case of panallergenic groups, where the proteins representing each group are evolutionarily conserved molecules that show a high degree of molecular identity and are found in members of several different plant genus. Although the representatives of the panallergens are not numerous, the high degree of homology can cause problems in making the correct diagnosis.

Cross-reactivity to a particular allergen may develop if its three- dimensional structure is similar to that of another allergen previously encountered by the immune system. In this case, the same IgE may bind to several different allergens. In general, at least 70% amino acid sequence identity is required for this phenomenon to occur.[4] A practical example of this is the development of cross-allergies associated with pollen-food (Oral Allergy Syndrome – OAS). In such cases, it is difficult to identify the initial sensitizing allergen responsible for hypersensitization by conventional diagnostic methods. [5]

Further complicating the identification of the main allergenic component are cross- reactive carbohydrate components (CCDs), which are non-protein molecules but can induce IgE- driven cross-reactivity. These glycoprotein-based asparagine-related oligosaccharides are found in varying amounts in insect venoms, plant pollen, house dust mites, crustaceans and vegetables. [4, 6]

The Prick Skin Test (SPT) and extract-based allergen-specific IgE blood tests have been at the front line of allergy diagnostics for decades. The latter procedures are quantitative and cost-effective, but the number of allergens that can be tested is limited and in many cases detection of sensitization is either missed or underestimated. [7–8]

Over the past two decades, important innovations in allergy diagnostics have taken place. One direction of progress has been the identification, characterization and production of an increasing spectrum of molecules representing unique allergens of clinical relevance. These recombinant components have enabled the availability of molecular-resolution diagnostics and component- resolved diagnosis (CRD) in the field of allergy. [9] In addition, multiplex microarray- based diagnostic systems have been developed, which can detect specific IgE antibodies produced against 100–300 different allergens from small samples. The whole allergen extract helps to identify the allergen source to which the patient is sensitized, while the allergen component allows the separation of specific and cross-reactive sensitization in polysensitized individuals. [7] The microarray technique can represent an added value for diagnosis when symptoms are ambiguous and SPT indicates the simultaneous positivity of two or more related allergens.

The objective of our cross-sectional study was to determine the extent and type of sensitization among the population living in the Northeastern Hungarian region and to identify the molecular components most frequently involved in the background of sensitization and cross-sensitization.

MATERIALS AND METHODS

Study design and study population

The study obtained approval from the Regional/Institutional Scientific and Research Ethics Committee of the Borsod-Abaúj-Zemplén County Central Hospital and University Teaching Hospital, with approval number IG-117-24/2020. The subjects for the study were selected from the citizens of the University of Miskolc by recruitment through voluntary application. The 229 subjects recruited received verbal and written information and completed a patient consent form. They were assured of their anonymity, the voluntary nature of their participation, and their right to withdraw from the survey at any point. Patient data were collected by completing a questionnaire. To perform molecular allergy testing, 2 tubes of blood per person were collected and the tests were performed at the Clinical Diagnostic Laboratory of the Faculty of Health Sciences between February 2020 and June 2021.

Questionnaire recording

Our questionnaire recorded demographic and lifestyle data. Patients provided information about their self-assessed health status, family history of diseases and allergies.

Multiplex microarray analysis

A serum sample was obtained from whole blood drawn in a BD Vacutainer Native sterile blood collection tube by centrifugation (15 min, 2700 rpm). The samples were stored at –80 °C until use. For sample preparation, an ALEX2 Allergy Explorer kit (Macro Array Diagnostics, Vienna, Austria) was used, following the manufacturer's

protocol. The solid phase of the ALEX2 Allergy Explorer consists of allergens (295 allergens, including 117 allergen extracts and 178 molecular components) bound to nanoparticles on a nitrocellulose membrane on the surface of a chip. For sample preparation, 100 µl of serum was transferred to the solid phase with the addition of 400 µl of serum diluent. The serum diluent contains an inhibitor of CCDs. After two hours of incubation, the chip was washed thoroughly and alkaline phosphatase-labelled anti-human IgE solution was added and incubated for 30 minutes. After further washing, the enzyme substrate was added, and the reaction was stopped after eight minutes. The membrane was dried at room temperature and the intensity of the colour reaction for each allergen was measured using the Image Xplorer instrument (Macro Array Diagnostics, Vienna, Austria) and evaluated using Raptor v1.5.4.16 software. Total IgE and specific IgE were determined. The measurement range of ALEX2 Allergy Explorer is 0.35–50 kUA/L for specific IgE (quantitative determination) and 1–2500 kU/L for total IgE (semi-quantitative determination).

Data evaluation and statistical analysis

Results were considered negative if the specific IgE produced against any allergen did not exceed 0.35 kUA/L. For positive results, a person with specific IgE antibodies against an allergenic protein was considered monosensitized. A person was considered polysensitized if two or more specific IgE antibodies to different allergenic proteins were detected simultaneously. Among the polysensitized, a result where specific IgE antibodies were detected against several different proteins with no structural homology or relatedness to each other was considered to be cosensitized. Cross-sensitization was considered to be results where specific IgE antibodies directed against structurally homologous allergens from taxonomically related allergen sources gave positive results.

In advance of analyzing the data, we observed a partial non-response for the questionnaire item concerning family allergies. A logical imputation technique was used for the treatment of the missing data.

Before starting the analysis of the datasets, the conditions for the parametric tests were always checked. Normality testing (e.g. Shapiro–Wilk test) and variance homogeneity testing (e.g. Levene's test) were performed.

Clinical parameters and demographic data are presented as means and standard deviations of continuous variables. Relative frequencies of categorical variables were compared using an χ^2 test for dichotomous variables. Unpaired Student's t-test was utilized for continuous variable analysis, alongside a one-way ANOVA for the assessment of three group comparisons, both employing a 95% confidence interval. Spearman correlation analysis was used to determine the correlation between two variables. The effect size metrics (e.g., Cohen's d for t-tests, eta-squared for ANOVA, and Cramer's V for χ^2 tests) are presented exclusively for differences that reach statistical significance. In instances where the conditions of normality and homogeneity were not satisfied, non-parametric alternatives, including the Mann–Whitney U-test and Kruskal–Wallis's test, were employed.

GraphPad Prism 8.0.1 statistical software (GraphPad Software, San Diego, USA) was used for statistical analysis of the results. Differences were considered statistically significant at $p < 0.05$.

RESULTS

Characterisation of the study population

The study population consisted of 229 people, divided into two groups based on the results obtained. The non-sensitized group included 30.56% of the subjects, while the sensitized group included 69.43%. No significant differences were found in the mean age, gender distribution and number of family members with allergies *(Table 1)*. The sensitized group had significantly higher total immunoglobulin E (t-IgE) values (23.94 ±15.04 kU/L vs. 80.86 ±146.52 kU/L, p = 0.0001, Cohens' *d* = 3.8333).

Table 1

Characterisation of patient sample by sensitization

	Non sensitized	**Sensitized**	**p- value**
Number of patients n, (%)	70 (30.56)	159 (69.43)	
Age (years), mean (SD)	44.32 (14.11)	43.39 (11.31)	0.3873
Gender M/F n, (%)	20/50 (28.57/71.43)	65/94 (40.88/59.12)	0.0757
Serum t-IgE, kU/L mean (SD)	23.94 (15.04)	80.86 (146.52)	**<0.0001**
Allergic in the family, n (%)	39 (55.71)	93(58.49)	0.8053

Serum total Immunoglobulin E (t-IgE); A person who showed a positive reaction to at least 1 allergenic protein was considered sensitized. $p < 0.05$, n = 229

Characterisation of the study population by degree of sensitization

Table 2 illustrates the characteristics of the groups sensitized to one allergen, sensitized to several allergens and not sensitized. Of the 229 subjects, 70 (30.56%) showed no sensitization, 52 (22.70%) showed sensitization to one allergen, while 107 (46.72%) showed sensitization to 2 or more allergens. The age distribution of the groups was homogeneous. In general, more females enrolled in the study, which was typical in the non-sensitized and monosensitized groups, whereas the proportion of males in the polysensitized group was almost equal to the proportion of females.

Table 2

Characterisation of the study population by degree of sensitization

		Sensitized (n = 159)			
	Non sensitized	**Mono-sensitized**	**Poly-sensitized**	***p-value****	***p-value*** **
Number of patients n, (%)[1]	70 (30.56)	52 (22.70)	107 (46.72)		
Age (year), mean (SD)	44,33 (14.11)	45.32 (10.63)	42.47 (11.52)	0.1355	0.3361
Gender, n (%)					
M, n (%)	20 (28.57)	12 (23.1)	55 (51.40)	**0.001**	0.3713
F, n (%)	50 (71.43)	40 (76.9)	52 (48.60)	**0.001**	0.3713
Total IgE ≥100 kU/L, n (%)	0 (0)	1 (1.92)	27 (25.23)	**0.0001**	0.2338
Serum t-IgE, kU/L (SD)	23.94 (15.04)	21,80 (11.93)	109.57 (171.43)	**<0.0001**	**<0.0001**
Allergic in the family, n (%)	39 (55.71)	26 (50.98)	67 (62.6)	0.1298	0.2924

Serum total immunoglobulin E (t- IgE). Those who showed a positive reaction to only 1 allergen were considered monosensitized, those who showed positive reaction to 2 or more unrelated allergens were considered polysensitized. $p < 0.05$, [1] n = 229, p-value* comparison between mono- and polysensitized groups. p-value** comparison between non sensitized, mono- and polysensitized groups.

We observed significantly higher t- IgE levels in the sensitized groups compared to the non sensitized group ($p < 0.0001$, $R^2 = 0.1198$), and in the polysensitized group compared to the monosensitized group ($p < 0.0001$, Cohens' $d = 0.73$) (*Table 2* and *Figure 1*).

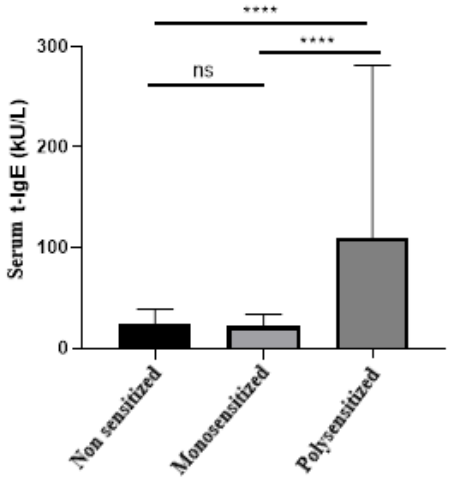

Figure 1. *Serum t-IgE values in the different sensitization groups*

In the polysensitized group, there were significantly (p = 0.0001, Cramer *V* = 0,0581 (CI 0,0055–0,3331) more people with t-IgE levels above 100 kU/L. A correlation test between the degree of sensitization and t- IgE levels demonstrated a moderate degree of association (r = 0.5138, p = 0.0001, 95% CI 0.4084–0.6057) between the two variables.

The most frequently occurring molecular components in the two sensitized groups

The prominent seasonal inhalation allergen in the monosensitized group was the protein of ragweed pectate lyase (Amb a 1), to which 4 individuals was sensitized. The birch pollen- derived protein PR-10 (Bet v 1) induced sensitization in only one person in this group, and the same rate of sensitization was observed for grass allergens *(Table 3)*. The dust mite and yeast proteins, which are perennial inhaled allergens, were equally detected in this population. Sensitization to common wasp antigen 5 (Ves v 5) was detected in 10 individuals. Sensitization to the 2S protein of sesame seed albumin (Ses i 1) was found in 5 individuals. Additional sensitizations were detected to allergenic extracts and are not included in the table.

In the polysensitized group, the most common seasonal inhaled molecular allergen components were mainly pollen from weeds, grasses and trees (Amb a 1, Phl p 1, Lol p, 1Cyn d 1), while in the group of perennial inhaled allergens, they were NPC2 proteins from dust mites (Der p 2, Der f 2, Lep d 2). The cat uteroglobin protein (Fel d 1) was highly abundant among the perennial inhalant allergens. The frequency of sensitization to common wasp Antigen 5 was equally high in this group.

Table 3

Molecular allergen frequency in the mono- and polysensitized group

Monosensitized (n = 52)			
Allergen source	**Molecular allergen**	**Protein family**	**Number of cases (n =)**
Seasonal inhalation allergens			
Ragweed	Amb a 1	Pectate lyase	4
Birch tree	Bet v 1	PR-10	1
Bermuda grass	Cyn d 1	A Beta-expansin	1
Saltwort	Sal k 1	Pectin methyl esterase	1
European ash	Fra e 1	Ole e-1-family	1

Perennial inhalation allergens			
Malassezia sympodialis	Mala s 11	Mn superoxide dismutase	1
American house dust mite	Der f 2	NPC2	1
Nutritive allergens			
Sesame seeds	Ses i 1	Albumin 2S	5
Kiwi	Act d 1	Cysteine protease	1
Insect venom			
Common wasp	Ves v 5	Antigen 5	10
Common wasp	Ves v 1	Phospholipase A1	1
European paper wasp	Pol d 5	Antigen 5	1

Polysensitized (n = 107)			
Allergen source	**Molecular allergen**	**Protein family**	**Number of cases (n =)**
Seasonal inhalation allergens			
Ragweed	Amb a 1	Pectate lyase	36
Timothy grass	Phl p 1	A Beta-expansin	35
Perennial ryegrass	Lol p 1	A Beta-expansin	31
Bermuda grass	Cyn d 1	A Beta-expansin	26
Timothy grass	Phl p 5.0101	Grass group 5/6	21
Japanese cedar	Cry j 1	Pectate lyase	21
Birch tree	Bet v 1	PR-10	19
Timothy grass	Phl p 6	Grass group 5/6	17
European beech	Fag s 1	PR-10	16
European hazelnut	Cor a 1.0103	PR-10	15
Timothy grass	Phl p 2	Expansin	15
Ragweed	Amb a 4	Plant defensin	14

Perennial inhalation allergens			
European domestic dust mite	Der p 2	NPC2 family	32
American house dust mite	Der f 2	NPC2 family	29
Lepidoglyphus destructor	Lep d 2	NPC2 family	23
Cat	Fel d 1	Uteroglobin	21
European domestic dust mite	Der p 23	Peritrophin-like protein domain	21
European domestic dust mite	Der p 1	Cysteine protease	18
American house dust mite	Der f 1	Cysteine protease	16
Nutritive allergens			
European hazelnut	Cor a 1.0401	PR-10	16
Cantaloupe	Cuc m 2	Profilin	15
Insect venom			
Common wasp	Ves v 5	Antigen 5	20

Molecular components most involved in cross-sensitization

In the monosensitized group, cross sensitization was detected in a total of 9 individuals (17.30%). Cross-sensitization was observed in 3 cases with the major component of ragweed Amb a 1 and the antigen of common wasp Ves v 5. The major component Bet v 1 of birch pollen induced cross-sensitization in only one case, similar to American house dust mite and Malassezia yeast *(Table 4)*.

Table 4

Most frequent molecular components underlying cross-sensitization in the two sensitized groups

Monosensitized (n = 52)			
Allergen source	**Molecular allergen**	**Protein family**	**Number of cases (n =)**
Seasonal inhalation allergens			
Ragweed	Amb a 1	Pectate lyase	3
Birch tree	Bet v 1	PR-10	1
Perennial inhalation allergens			
American house dust mite	Der f 2	NPC2 family	1
Malassezia sympodialis	Mala s 11	Mn superoxide dismutase	1

Insect venom			
Common wasp	Ves v 5	Antigen 5	3

Polysensitized (n = 107)			
Allergen source	**Molecular allergen**	**Protein family**	**Number of cases (n=)**
Seasonal inhalation allergens			
Timothy grass	Phl p 1	A Beta-expansin	28
Ragweed	Amb a 1	Pectate lyase	22
Birch tree	Bet v 1	PR-10	16
Timothy grass	Phl p 12	Profilin	12
Common mugwort	Art v 1	Plant defensin	5
Timothy grass	Phl p 5.0101	Grass group 5/6	4
Olive	Ole e 1	Ole e 1- family	3
Perennial inhalation allergens			
American/European domestic dust mite	Der p 2/Der f 2	NPC2 family	28
American/European domestic dust mite	Der p 1/ Der f 1	Cysteine protease	9
Cat	Fel d 4	Lipocalin	3
European domestic dust mite	Der p 10	Tropomyosin	3
Cat	Fel d 1	Uteroglobin	3
German cockroach	Bla g 9	Arginine kinase	3
Insect venom			
Common wasp	Ves v 5	Antigen 5	6

In the polysensitized group, only 31 (28.97%) were found to be cosensitized, while 76 [71.03%, $p < 0.0001$, Cramer *V*: 0,1224 (CI 0,0558–0,2642)] were also found to be cross- sensitized. Only the most common cross- allergenic components are shown in *Table 4*. The most frequent major components causing cross-sensitization were found to be β- expansin (Phl p1) of Timothy grass pollen and NPC2 proteins (Der p2/ Der f 2) of dust mites.

The main allergenic component of ragweed (Amb a 1) was responsible for cross-sensitization in 22 cases, the main component of birch pollen Bet v 1 in 16 cases and the profilin component of Timothy grass Phl p 12 in 12 cases. Among the perennial allergens, lipocalin and uteroglobin proteins of feline outer coat origin were also cross-sensitising components in the population.

DISCUSSION

The MeDALL international study on the mechanisms underlying the development of allergy found that the presence of allergen specific IgE is important for the development of allergic disease, with many cases of IgE sensitization occurring without symptoms. [2] In 2018, a new multiplex-based molecular diagnostic system, the MADX ALEX2 Allergy Explorer, was introduced as a laboratory diagnostic tool for allergy. It has made available at the University of Miskolc the possibility to perform component-based allergy testing among the inhabitants of the region.

Specific IgE antibodies to a molecular component were detected in almost 70% of the subjects. The serum t-IgE level was significantly higher in sensitized individuals ($p < 0.0001$). 22.7% of the subjects showed positivity to only one molecular component, they were monosensitized. Our results agree with the study of Kadocsa and Juhász published in 2000. They investigated the changes in the allergen spectrum of hay fever sufferers in the Southern Great Plain among young adults between 1990 and 1998 using the Prick Skin Test. In their study, 17.3% of the subjects were monosensitized, a value that did not change significantly over the 9-year study period. [10] The higher value we found can be partly explained by the more sensitive diagnostic method and the increasing number of allergic patients.

Clinical studies have demonstrated that a small proportion of symptomatic individuals are monosensitized, while more than 70% are polysensitized, even when cross-reactivity between allergens and panallergens is considered. [11] The proportion of polysensitized individuals increases with age. [12] In our case, the study population consisted of adults of working age and polysensitization was confirmed in nearly 46.72% of the subjects by multiplex testing. Despite the female predominance in the study population, the sex ratio was balanced in this group. Serum t-IgE levels showed an increase depending on the degree of sensitization, being significantly higher in the polysensitized group. However, this group also had the highest number of cases with t-IgE levels above 100 kU/L. Based on the MeDALL study, mono- and polysensitized individuals differ in their IgE immune response, suggesting a dichotomy of low and high IgE responders. Monosensitized individuals have lower serum t-IgE and in many cases allergen specific IgE levels. [2–3] In our study, a moderate positive correlation between polysensitization and serum t-IgE levels was found by correlation analysis, which is in agreement with the literature. [11, 13] The trend of association between IgE sensitization levels and the risk of allergic symptoms is general, however, IgE thresholds are far from absolute. [14]

In the case of polysensitization, we should expect simultaneous immune responses to several allergenic components and a high rate of positivity. It is important to identify the marker components, the main allergen, cross-sensitization and cosensitization for accurate diagnosis and appropriate treatment.

In Hungary, studies have been carried out since the 1970s, mostly to identify the allergenic components underlying hay fever. Most of the studies were conducted among children and in a defined geographical area (Southern Great Plain, Somogy County, Budapest). These studies were most often performed by questionnaire and Prick Skin Test, rarely by specific IgE determination. [15–16] Without exception, the studies concluded that the most common seasonal inhaled allergens in our country belong to the group of weeds, grasses and tree pollens.

Mezei and colleagues found weeds (64.8%), including ragweed (59.0%), to be the most common seasonal inhalant allergen among children with rhinitis in Budapest. Grass pollen allergy was confirmed in 67.6% of patients, and wood pollen allergy was also detected in 7.6%. They found that weed and grass pollen allergy were of equal importance in the population, whereas the allergenicity of wood pollen had clinically minor importance. [15] In 1997, Balogh and colleagues identified the allergens underlying the symptoms of rhinitis in 105 adults in Budapest. Again, the most common allergen was found to be ragweed (70%), followed by grass (50%) and mugwort (45%) pollen. [17] Based on allergological studies in Debrecen in 2005, Sipka and colleagues also ranked ragweed, lawn grass and mugwort in the top three of the most common seasonal inhalant allergens in Hungary. [16] Kadocsa and colleagues in their study covering a 9-year period found that ragweed, grasses and early tree pollen were the most common causes of hay fever symptoms in young adult hay fever sufferers. [10]

The most common seasonal inhalant allergen component in both the mono- and poly- sensitized groups we studied was ragweed Amb a 1. In the monosensitized group, molecular allergens of trees and grasses were equally prevalent, whereas in the polysensitized group, grass pollens (Phl p 1, Lol p1, Cyn d 1) were more predominant. Among the polysensitized, the pollen of Japanese cypress (pectate lyase protein), which is not a native flora constituent in our country, stands out in the tree group. In this case, the cross-sensitizing effect of the main component of ragweed is suggested. In addition, the sensitising effect of birch, beech and hazelnut can be highlighted.

There is no consensus among national studies on the order of prevalence of perennial inhalant allergens. According to Gállfy, the prevalence of house dust mite allergy has varied over the years of the study, while mould positivity has shown an upward trend. [18] Balogh et al. reported a 40% prevalence of dog and cat hair hypersensitivity among Budapest residents, while house dust mite showed a 30% prevalence in the population. [17] In a study published in 2005 concluded that, the prevalence of mould allergies showed an increase compared to the previous decade, while the prevalence of house dust mite allergy did not change significantly, although its prevalence is significant everywhere in Hungary. [19] In our study, we found equal levels of yeast and house dust mite sensitization in monosensitized

individuals. However, in the polysensitized individuals, sensitization to house dust mite and food mite, and sensitization to cat hair were prominent.

Cross-reactivity is a common phenomenon, especially among those sensitized to pollen, which can lead to misdiagnosis and inappropriate immunotherapy. [20] The polysensitized group had a markedly higher incidence of cross- sensitization. The major allergenic component of Timothy grass (Phl p 1) and proteins of dust mites (Der f 2, Der p 2) were confirmed as the most common components. Cross-sensitization of ragweed is significant in both groups. In total, the Amb a 1 (pectate lyase protein) component of ragweed caused cross- sensitization to fruit (e.g. banana, melon) in 25 individuals. This invasive weed species appeared in Hungary in the 1920s. Due to its rapid spread, the Carpathian Basin is now the most contaminated region in Europe. In a representative questionnaire survey carried out in autumn 2013, Márk and colleagues found that 22% of adult respondents suffer from hay fever symptoms during the period of ragweed flowering. The proportion of people with ragweed allergy in Borsod-Abaúj-Zemplén County was 13% at the time of the survey. Their study also showed that 29% of people with ragweed allergies also had other allergies.[21] In our study, the most common cross- sensitizing allergen of the tree group was the major birch pollen component (Bet v 1 – PR10 protein family), which caused cross-sensitization mostly to hazelnut, apple and strawberry. Nearly 70% of people with birch pollen allergy experience the "birch-fruit-vegetable syndrome" mainly when eating Rosacea fruits (apples, cherries, peaches, pears), nuts (hazelnuts) and vegetables of the Apiacea family (carrots, celery). [5]

Some potential limitations of the study should be considered when interpreting the results. The study is not a large population study. The recruitment of individuals was based on voluntary enrolment, resulting in a predominance of female sex. Allergen testing was not preceded by a specialist examination and Prick Skin Test. Blood samples were not taken at the same period of year. In addition to the hundreds of allergenic components, the system does not provide the detection of allergens related to drugs, bird feathers, metals, contrast agents. Due to their absence, marker identification is incomplete.

CONCLUSION

The present cross-sectional study is the first allergen study based on multiplex microarray technology in Hungary, which found a correlation between the degree of sensitization and the amount of total IgE in serum. It revealed the prevalence of different allergens among people living in the northeastern Hungarian region and identified the allergen components most frequently responsible for cross-sensitization. The described technology will greatly facilitate and support specialist decision- making and the determination of targeted immunotherapy. In the future, it is proposed to introduce component-based diagnostics into precision medicine approaches in allergy, as it provides individual molecular data for better phenotyping and selection of personalized treatments.

ACKNOWLEDGEMENTS

The research was made possible by the EFOP-3.4.3-16 project "Healthy University", sub-project 7 "Higher Education Institutional Development for the Joint Improvement of Quality and Accessibility of Higher Education".

REFERENCES

[1] Erdei, A., Sármay, G., Prechl, J. (eds.) (2012). Túlérzékenységi reakciók. In: Erdei A, Sármay G, Prechl J. *Immunológia.* chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/http://zsuzsanna.emri.uni-eger.hu/public/uploads/2011-0001-524-immunologia_59f039dfa2d5c.pdf

[2] Bousquet, J., Anto, J. M., Wickman, M. et al. (2015). Are allergic multimorbidities and IgE polysensitization associated with the persistence or re-occurrence of foetal type 2 signalling? The MeDALL hypothesis. *Allergy*, 70 (9), 1062–1078. https://doi.org/10.1111/all.12637

[3] Anto, J. M., Bousquet, J., Akdis, M. et al. (2017). Mechanisms of the Development of Allergy (MeDALL): Introducing novel concepts in allergy phenotypes, *J. Allergy. Clin. Immunol*., 139 (2), 388–399. https://doi.org/10.1016/j.jaci.2016.12.940

[4] Migueres, M., Dávila, I., Frati, F. et al. (2014). Types of sensitization to aeroallergens: definitions, prevalences and impact on the diagnosis and treatment of allergic respiratory disease. *Clin. Transl. Allergy*, 4, 16. https://doi.org/10.1186/2045-7022-4-16

[5] Faber, M. A., Van Gasse, A. L., Decuiper, I. (2018). Cross-Reactive Aeroallergesns: Which need to cross our mind in food allergy diagnosis? *J Allergy Clin Immunol Pract*., 6, 1813–1823. https://doi.org/10.1016/j.jaip.2018.08.010

[6] Melioli, G., Puggioni, F., Racca, F., Descalzi, D., Canonica, G. W., Heffler, E. (2019). Clinical outcomes related to molecular allergy diagnosis. *Curr. Opin. Allergy Clin. Immunol*., 19 (3), 204–208. https://doi.org/10.1097/ACI.0000000000000526

[7] Williams, P., Önell, A., Baldracchini, F., Hui, V., Jolles, S., El-Shanawany, T. (2016). Evaluation of a novel automated allergy microarray platform compared with three other allergy test methods. *Clin. Exp. Immunol*., 184 (1), 1–10. https://doi.org/10.1111/cei.12721

[8] Buzzulini, F., Da Re, M., Scala, E. et al. (2019). Evaluation of a new multiplex assay for allergy diagnosis. *Clin. Chim. Acta*, 493, 73–78. https://doi.org/10.1016/j.cca.2019.02.025

[9] Lucas, J. M. (2010). Microarrays: molecular allergology and nanotechnology for personalised medicine (I). *Allergol Immunopathol*., 38 (3), 153–161. https://doi.org/10.1016/j.aller.2010.03.001

[10] Kadocsa, E., Juhász, M. (2000). A szénanáthás betegek allergénspektrumának változása a Dél- Alföldön (1990–1998). *Orvosi Hetilap*, 141 (29), 1617–1620.

[11] de Bot, C. M., Röder, E., Pols, D. H. et al. (2013). Sensitisation patterns and association with age, gender, and clinical symptoms in children with allergic rhinitis in primary care: a cross-sectional study. *Prim. Care Respir. J*., 22 (2), 155–160. https://doi.org/10.4104/pcrj.2013.00015

[12] Wickman, M., Asarnoj, A., Tillander, H. et al. (2014). MeDALL consortium. Childhood-to-adolescence evolution of IgE antibodies to pollens and plant foods in the BAMSE cohort. *J. Allergy Clin. Immunol*., 133 (2), 580–582. https://doi.org/10.1016/j.jaci.2013.09.009

[13] Kuperstock, J. E., Brook, C. D., Ryan, M. W., Platt, M. P. (2017). Correlation between the number of allergen sensitizations and immunoglobulin E: monosensitization vs polysensitization. *Int. Forum Allergy Rhinol*., 7(4), 385–388. https://doi.org/10.1002/alr.21890

[14] Bousquet, J., Anto, J. M., Bachert, C. et al. (2006). Factors responsible for differences between asymptomatic subjects and patients presenting an IgE sensitization to allergens. A GA2LEN project. *Eur. Journ. All Clin. Immunol*., 61 (6), 671–680. https://doi.org/10.1111/j.1398-9995.2006.01048.x

[15] Mezei, Gy., Járainé, K. M. (1995). Szezonális allergiás rhinitis- és pollenszám (Ötéves felmérés Budapesten). *Orvosi Hetilap*, 136 (32), 1721–1724.

[16] Sipka, S. (2016). Az allergia jelenlegi előfordulása és kezelése Debrecenben. *Debreceni Szemle*, 24. évf., 4. szám, 4429–436. https://epa.oszk.hu/04600/04620/00036/pdf/EPA04620_debreceni_szemle_2016_04_429-436.pdf Access:15. 08. 2024.

[17] Balogh, K., Bea, J. et al. (1997). Az allergiás rhinitis prevalenciájának vizsgálata Budapest III. kerületében 1997-ben. *Allergol. Klin. Immunol*., 1, 201–204.

[18] Gállfy, G., Németh, Gy. et al. (2002). Hogyan változott az inhalációs allergének előfordulási gyakorisága az elmúlt 11 év alatt Budapesten. *MAKIT 30. Kongresszusa*, Sopron.

[19] Sóti, L., Endre, L. (2005). A pozitív Prick-reakciót kiváltó leggyakoribb légúti allergének gyakoriságának alakulása 1992 és 2000 között, 2124 légúti allergiában szenvedő gyermek vizsgálata alapján. *Orvosi Hetilap*, 146 (18), 833–837.

[20] Koch, L., Laipold, K., Arzt-Gradwohl, L. et al. (2023). Molecular allergy diagnosis is sensitive and avoids misdiagnosis in patients sensitized to seasonal allergens. *Clin. Transl. Allergy*, 13 (3), e12231. https://doi.org/10.1002/clt2.12231

[21] Márk, Zs., Bikov, A., Gálffy, G. (2016). A parlagfű okozta légzőszervi allergiás megbetegedések előfordulása Magyarországon. *Orvosi Hetilap*, 157 (50), 1989–1993. https://doi.org/10.1556/650.2016.30615

Responsible: Prof. dr. Péter Szűcs Vice-Rector
Published by the Miskolc University Press under leadership of Attila Szendi
Responsible for duplication: Erzsébet Pásztor
Technical editor: Csilla Gramantik
Proofreader: Zoltán Juhász
Number of copies printed:
Put to the press: 2025
Number of permission: MERT-2025-39-ME