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Telemedicine based physical training monitoring integrated in the physiotherapy of Metabolic syndrome patients

PhD Thesis

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III. **Máthéné Köteles É**; Domján A; Barnai M: Fizikai tréning ajánlások összefoglalása metabolikus szindrómás betegeknél. *FIZIOTERÁPIA*. 2019;28(1):18-25.

LIST OF PUBLICATIONS

related to the subject of the dissertation

Vágvölgyi A., Ábrahám JE., **Máthéné Köteles É.,** Korom A., Barnai M., Szűcs M., Orosz A., Kempler P., Menyhárt A., Nemes A., Várkonyi T., Baczkó I., Kósa I., Lengyel Cs. (2023). A three-month physical training program improves cardiovascular autonomic function in patients with metabolic syndrome with and without diabetes - a pilot study. *Front. Endocrinol.14:1224353. doi: 10.3389/fendo.2023.1224353*
SJR indicator: Q1, IF: 5,2

Máthéné Köteles Éva, Kiszely I, Szabó LA, Lada Sz, Bolgár T, Szálka B, Korom A, Staberecz DT, Ábrahám JE, Szűcs M, Seffer P, Biliczki V, Rafael B, Barnai M, Várkonyi T, Nemes A, Lengyel Cs, Kósa I.: Telerehabilitáció hatásossága metabolikus szindrómás személyek rizikótényezőire. *CARDIOLOGIA HUNGARICA*. 2022; 52: 292–300.

Máthéné Köteles É; Ábrahám J; Vágvölgyi A; Korom A; Szálka B; Barnai M; Bilicki V; Lengyel Cs; Kósa I: Első tapasztalatok kardiometabolikus betegek kombinált tréning és táplálkozás monitorozásával. In: Vassányi I; Fogarassyné Vathy Á (szerk.) Orvosi informatika. A XXXIV. Neumann Kollokvium konferencia-kiadványa, Neumann János Számítógép-tudományi Társaság. 2021;71-76.

Barnai, M; **Máthéné Köteles É**; Korom A; Pozsár E; Vágvölgyi A; Ábrahám JE; Domján A; Kósa I: A metabolikus szindróma rizikófaktorainak vizsgálata: a has/törzs arány összefüggése az abdominális zsírtömeggel. *FIZIOTERÁPIA.* 2021;30 (4)17-23.

Ábrahám JE; **Máthéné Köteles É**; Korom A; Vágvölgyi A; Szűcs M; Rafael B; Lengyel Cs; Barnai M; Kósa I: Ambuláns versus otthoni telemonitorozott tréning. A választást befolyásoló tényezők. *CARDIOLOGIA HUNGARICA.* 2020;50:337-342.

Ábrahám JE; **Máthéné Köteles É**; Vágvölgyi A; Szűcs M; Rafael B; Lengyel, Cs; Barnai M; Kósa I: Telemonitorozott tréninggel elérhető változások a metabolikus szindrómás betegeken. In: Vassányi I; Fogarassyné Vathy Á (szerk.) Orvosi informatika. A XXXII. Neumann Kollokvium konferencia-kiadványa, Neumann János Számítógép-tudományi Társaság. 2019;79-83.

LIST OF PUBLICATIONS

not related to the subject of the dissertation

Bálint B; Császárné Mészáros I; Kissné Galamb J; **Máthéné Köteles É**: Pulmonológiai rehabilitáció ápolási vonatkozásai. In: Klauber A (szerk.): Ápolás a rehabilitációban, Medicina Könyvkiadó, Budapest, 2017; pp. 233-254., 12 p.

PRESENTATIONS

related to the subject of the dissertation

Máthéné Köteles É; Kiszely I; Szabó L; Lada Sz; Szálka B; Korom A; Staberecz DT; Ábrahám JE; Szűcs M; Seffer P; Biliczki V; Nemes A; Barnai M; Várkonyi T; Lengyel Cs; Kósa I. Metabolikus szindrómás betegek telemedicinával felügyelt 3 hónapos életmód programjának hatása az antropometriás és a terheléses paraméterekre. A Magyar Elhízástudományi Társaság 30 éves Jubileumi Kongresszusa, Gárdony, 2022.11.18-19.
OBESITOLOGIA HUNGARICA (1586-7935): 20 Supplementum 1. p. 35. (2022)

Máthéné Köteles É; Kiszely I; Szabó L; Lada Sz; Szálka B; Korom A; Staberecz DT; Ábrahám J; Szűcs M; Seffer P; Biliczki V; Rafael B; Barnai M; Várkonyi T; Nemes A; Lengyel Cs; Kósa I. Mobiltelefonnal támogatott életmódi intervenció hatása metabolikus szindrómás betegek fiziológiai paramétereire. Magyar Diabetes Társaság XXX. Kongresszusa, Szeged, 2022.09.08-11.
DIABETOLOGIA HUNGARICA (1217-372X 2560-0168): 30 Suppl. 2 pp 66-67 (2022)

Máthéné Köteles É; Korom A; Vágvölgyi A; Ábrahám JE; Szűcs M; Barnai M; Kósa I: Metabolikus szindrómás betegek 3 hónapos otthoni fizikai tréningjének telemonitorozása: kutatásunk és részeredményeink. A Magyar Kardiológusok Társasága 2022. évi Tudományos Kongresszusa, Balatonfüred, 2022.05.04-07.
CARDIOLOGIA HUNGARICA (0133-5596) 52 Suppl. pp 271-271 (2022)

Máthéné Köteles É; Korom A; Vágvölgyi A; Ábrahám JE; Szűcs M; Barnai M; Kósa I: A telemedicina használata Metabolikus szindrómás betegek 12 hetes otthoni fizikai tréningjének felügyeletére
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Barnai M; **Máthéné Köteles É**; Korom A; Pozsár E; Vágvölgyi A; Ábrahám JE; Domján A; Kósa I: A metabolikus szindróma rizikófaktorainak vizsgálata: a has/törzs arány összefüggése az abdominális zsírtömeggel. In: Barnai M; Finta R; Máthéné Köteles É: Kihívások a 21. században. 30 éves a szegedi gyógytornászképzés: Kongresszusi kiadvány Szeged, SZTE Egészségtudományi és Szociális Képzési Kar, 2021. p. 10

Korom A; **Máthéné Köteles É**; Vágvölgyi A; Szűcs M; Ábrahám JE; Barnai M; Kósa I: Egyéni és csoportosan vezetett dinamikus tréning hatásainak vizsgálata a testösszetételre és az artériás stiffness értékekre metabolikus szindrómában
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Máthéné Köteles É: A telemedicina lehetőségei: 12 hetes otthoni, távmonitorozott fizikai tréning hatásai Metabolikus szindrómás betegeknél. Az ezerarcú sporttudomány. MTA Szegedi Területi Bizottság, IX. Orvostudományi Szakbizottság, Sporttudományi Munkabizottságának éves tudományos ülése 2020.12.17. Szeged

Kósa I; Ábrahám JE; **Máthéné Köteles É**; Vágvölgyi A; Szűcs M; Rafael B; Lengyel Cs; Barnai M: Különböző tréning monitorozási rendszerek használatát elfogadó metabolikus szindrómás személyek karakterisztikája. In: Dvorák, M (szerk.) Magyar Életmód Orvostani Társaság II. Kongresszusa, Budapest, Magyar Életmód Orvostani Társaság, 2020;55:34-36.

Ábrahám JE; **Máthéné Köteles É**; Vágvölgyi A; Szűcs M; Barnai M; Rafael B; Lengyel Cs; Kósa I: Három hónapos telemonitorozott tréning hatása metabolikus szindrómás személyek fiziológiai paramétereire. In: Dvorák, M (szerk.) Magyar Életmód Orvostani Társaság II. Kongresszusa, Budapest, Magyar Életmód Orvostani Társaság, 2020;55:33-34.

Barnai M; **Máthéné Köteles É**; Korom A; Kósa I: Otthoni tréning-monitorozás eredményei metabolikus szindrómás betegek körében. IME XVII. Országos Egészségügyi Infokommunikációs Konferencia, Budapest, 2019.05.22.

Korom A; Barnai M; **Máthéné Köteles É**; Kósa I; Vágvölgyi A; Ábrahám JE; Arató E: Egyéni és csoportosan vezetett dinamikus tréning hatásainak vizsgálata a testösszetételre metabolikus szindrómában. A Magyar Gyógytornász-Fizioterapeuták Társasága XII. Kongresszusa és a 14. Pre-Kongresszusa, Eger, 2019.09.18-21.

Szlatárovics O; Tóth K; Korom A; **Máthéné Köteles É**; Barnai M; Domján A: A kombinált tréning fizioterápiás protokollja a metabolikus szindrómában. A Magyar Gyógytornász-Fizioterapeuták Társasága XII. Kongresszusa és 14. Pre-Kongresszusa, Eger, 2019.09.18-21.

Máthéné Köteles É; Korom A; Vágvölgyi A; Ábrahám JE; Szűcs M; Rafael B; Barnai M; Kósa I: Metabolikus szindrómás betegek terheléses paramétereinek változása telemedicinával felügyelt 3 hónapos otthoni tréning hatására. *KARDIO-VASZKULÁRIS IRÁNYTŰ*, 2019; 1:3 pp. 5-6.

Korom A; Ábrahám JE; Barnai M; Kósa I; **Máthéné Köteles É**; Rafael B; Szűcs M; Vágvölgyi A; Arató E: A dinamikus tréning hatásainak vizsgálata az artériás stiffness értékekre metabolikus szindrómában. *KARDIO-VASZKULÁRIS IRÁNYTŰ*, 2019; 1:3 pp. 6-7.

Ábrahám JE; **Máthéné Köteles É**; Korom A; Vágvölgyi, A; Szűcs M; Rafael B; Barnai M; Kósa I: Metabolikus szindrómás betegek laboratóriumi paramétereinek változása 3 hónapos telemedicinával felügyelt otthoni, illetve ambuláns tréning hatására. *KARDIO-VASZKULÁRIS IRÁNYTŰ*, 2019; 1:3 p.13

Máthéné Köteles É; Korom A; Kósa I; Barnai M: A fizikai tréningek hatásai és telemedicinális lehetőségek Metabolikus szindrómában. IV. Pécsi Kardiológiai Prevenciós és Rehabilitációs Kongresszus és a VII. Pécsi Kardiológiai Napok közös rendezvénye. Pécs, 2018.09.27-29.

Barnai M; Pozsár E; Korom A; **Máthéné Köteles É:** A fizikai aktivitás szerepe a metabolikus szindróma korai prevenciójában. IV. Pécsi Kardiológiai Prevenciós és Rehabilitációs Kongresszus és a VII. Pécsi Kardiológiai Napok közös rendezvénye. Pécs, 2018.09.27-29.

Korom A; Arató E; Barnai M; **Máthéné Köteles É:** A fizikai aktivitás kontrollja telemedicinás eszközökkel metabolikus szindróma esetén. III. Módszertani Konferencia, Debrecen, 2018.09.15.

Korom A; Barnai M; **Máthéné Köteles É**; Arató E: A különböző típusú fizikai aktivitások hatásainak vizsgálata a testösszetételre metabolikus szindrómában
In: Egyetemi Tavasz 2018: "Tudomány a fizioterápiában": I. Predoktori Konferencia: Absztrakt füzet, 2018;20 p. 5-5.

PRESENTATIONS

not related to the subject of the dissertation

Kardos K, Szendrő G, Horváth M, Mayer Á, Várnagy A, Barnai M, **Máthéné Köteles É**, Kovács Attila: Irányelvek a kardiológiai fizioterápiában. *CARDIOLOGIA HUNGARICA*. 2022;52:269-269

Barnai M; Finta R; **Máthéné Köteles É**: Kihívások a 21. században. 30 éves a szegedi gyógytornászképzés: Kongresszusi kiadvány, SZTE Egészségtudományi és Szociális Képzési Kar, 2021., ISBN: 9789633068175

Máthéné Köteles É: Kardiovaszkuláris megbetegedések mozgásterápiája. In: Dvorák, M (szerk.) Magyar Életmód Orvostani Társaság II. Kongresszusa, Budapest, Magyar Életmód Orvostani Társaság; 2020;55 pp. 13-13.

Vágvölgyi A; Kósa I; **Máthéné Köteles É**; Korom A; Barnai M; Ábrahám JE; Orosz A; Szűcs M; Várkonyi T; Varró A: Neuropathiás szövődmények előfordulása metabolikus szindrómás betegekben - pilot vizsgálat. *KARDIO-VASZKULÁRIS IRÁNYTŰ*, 2019; 1:3 pp. 13-14.

Máthéné Köteles É: Fizioterápia a kardiológiai rehabilitáció során: Mellkasvibrálás, ingeráram kezelés, masszázs, széndioxid kezelés, degeneratív mozgásszervi betegségek fizioterápiája. Kardiológiai Rehabilitáció Szakvizsga Előkészítő Tanfolyam és Kardiológiai Rehabilitáció Kötelező Szintentartó Tanfolyam, Szeged, 2018.

Máthéné Köteles É: A gyógytornász feladatai a kardiológiai rehabilitációban. "Szívügyeink a szívügyek?! - A fizioterápia jelentősége a kardiológiai betegségek megelőzésében és kezelésében, Szeged, 2018. 03.24.

Aranyász K; Varga J; **Máthéné Köteles É**; Szilágyi L; Molnár E; Kozma Á; Somfay A: Állóképességi légzőizomtréning COPD-ben. In: Orvosi Rehabilitáció és Fizikális Medicina Magyarországi Társasága XXIX. Vándorgyűlése, 2010. p.184

Máthéné Köteles É; Varga J: A körtréning hatása COPD-s betegek rehabilitációjában (angliai tapasztalatok). In: Magyar Tüdőgyógyász Társaság Légzésrehabilitációs Szekcióülése, 2009; pp. 32-33., 2 p.

Máthéné Köteles É; Szilágyi L; Aranyász K; Tokaji Zs; Somfay A: Az expectoratio hatása a légzésfunkciós paraméterekre COPD akut exacerbációjában. In: Magyar Tüdőgyógyász Társaság 55. Nagygyűlése, Balatonfüred, 2008. június 4-7. 80 p. p. 48.

Máthéné Köteles É; Somfay A: Belégzőizom tréning hatása súlyos COPD-ben. Poszter, A Magyar Tüdőgyógyász Társaság 54. Nagygyűlése, Szeged, 2006.06.08-10.

Máthéné Köteles É; Varga J: A funkcionális állapot felmérési lehetőségei a pulmonológiai rehabilitáció hatásának nyomon követesére. *MEDICINA THORACALIS*, 2012; 65:3 p.A63, 1p.

Varga J; Pogány B; **Máthéné Köteles É**; Somfay A: Oxigén vagy sűrített levegő szupplementációval végzett intervallum tréning hatása a dinamikus hyperinflációra a nem hypoxias krónikus obstruktív légzőszervi betegek rehabilitációjában. Orvosi Rehabilitáció és Fizikális Medicina Magyarországi Társasága XXXI. Vándorgyűlése, Szombathely, 2012.09.06-09.08.

Varga J; Pogány B; **Máthéné Köteles É**; Somfay A: A dinamikus hiperinfláció csökkenése oxigénnel végzett intervallum tréning hatására COPD-ben, *MEDICINA THORACALIS*, 2012; 65 pp. 198-199.

Varga J; Pogany B; **Máthéné Köteles É**; Somfay A: Exercise induced reduction in dynamic hyperinflation after interval training with oxygen breathing. *EUROPEAN RESPIRATORY JOURNAL*, 2012;40 Suppl 56 Paper: P1901

Aranyász K; Varga J; **Máthéné Köteles É**; Kozma Á; Kuklis Á; Somfay A: Erőfejlesztő és folyamatos légzőizom tréning szerepe a COPD-s betegek rehabilitációjában. In: MTT Onkopulmonológiai és a Légzésrehabilitációs Szekciójának konferenciája, 2011; p. 11

Kozma Á; **Máthéné Köteles É**: A gyógytornász szerepe a pulmonológiai betegek ambuláns rehabilitációjában In: MTT Epidemiológiai és Gondozási Szekció Konferenciája; 2011; p. 1

Máthéné Köteles É; Varga J: Circuit training in the rehabilitation of patients with COPD. In: Croatian - Slovenian - Hungarian Pulmonologist Meeting, 2011; p. 1

Máthéné Köteles É; Mára A; Varga J; Somfay A: The effects of the circuit training and the dynamic cycle ergometric conditioning in the outpatient rehabilitation of COPD patients In: Croatian – Slovenian - Hungarian Pulmonologist Meeting; 2011; p. 2

Máthéné Köteles É; Mára A; Varga J; Somfay A: A körtréning és dinamikus alsó végtagi kerékpáros tréning hatása a COPD-s betegek ambuláns rehabilitációjában
In: MTT Allergológiai és Légzéspathológiai Szekció Tudományos Ülése, 2011; pp. 31-32., 2p.

Aranyász K; Varga J; **Máthéné Köteles É;** Molnár E; Kozma Á; Somfay A: Állóképességi légzőizom tréning COPD-ben. *MEDICINA THORACALIS* 2010; 63:3 p. 226.

Máthéné Köteles É; Szilágyi L; Somfay A: Videó a pulmonológiai rehabilitációról. A Magyar Tüdőgyógyász Társaság 54. Nagygyűlése, Szeged, 2006.06.08-10.

Máthéné Köteles É; Szilágyi L; Varga J; Somfay A: Gyógytornászok által kontrollált kerékpár kondicionálás hatása COPD-s betegek terhelhetőségére. In: A Magyar Tüdőgyógyász Társaság Kardiopulmonális Fóruma; 2004. p. 1

LIST OF ABBREVIATIONS

AIS:	Athens Insomnia Scale
ATS:	American Thoracic Society
BDI:	Beck Depression Inventory
BMI:	Body Mass Index
CHD:	Coronary Heart Disease
CR:	Cardiac Rehabilitation
CVD:	Cardiovascular Disease
ECG:	Electrocardiogram
eHealth:	electronic Health
EHR:	Electronic Health Record
FPG:	Fasting Plasma Glucose
HbA1c:	Glycated Hemoglobin A1c
HC:	Hip Circumference
HDL-C:	High Density Lipoprotein Cholesterol
ICT:	Information and Communication Technology
IDF:	International Diabetes Federation
IoT:	Internet of Things

LDL-C: Low Density Lipoprotein Cholesterol

MetS: Metabolic Syndrome

mHealth: mobile Health

MI: Myocardial Infarction

PTCA: Percutaneous Transluminal Coronary Angioplasty

QoL: Quality of Life

RPM: Remote Patient Monitoring

SD: Standard Deviation

6MWD: Six-minute walk distance

6MWT: Six-minute walk test

T2DM: Type 2 Diabetes Mellitus

TG: Triglyceride

TR: Telerehabilitation

VO_{2max}: Maximum oxygen consumption

WC: Waist Circumference

WHO: World Health Organization

WHO-WBS: World Health Organization Well-Being Scale

W_{max}: Maximum workload

1. Background

The last few decades' fast and spectacular development in the field of Information and Communication Technology (ICT) makes it possible to apply intelligent technologies and "smart" (IOT- Internet of Things) devices during everyday medical practice of healthcare professionals. High speed and broadband internet connectivity, wireless networks, cloud-based data storage systems, high resolution cameras, laptops, tablets, mobile phones and applications are more easily accessible and can be financially afforded by the general public in most parts of the world. As the 2015 World Health Organization (WHO) global survey report on eHealth (electronic health) points out, there are approximately 124 countries in the world where they have some available form of telemedical facilities[1]. In Europe according to the WHO Regional Office for Europe Report on the implementation of eHealth in the WHO European Region, 12 Member States (27% of respondents) have a dedicated policy or strategy for telehealth and 36% (16 Member States) refer to telehealth in their national eHealth strategies. Teleradiology has been found the most developed telehealth service program, 83% (38 Member States) report its usage but there are other frequently used services such as Teledermatology or Telepathology[2]. Doctors can even diagnose an acute heart attack from a distance through telemedical electrocardiogram (ECG) systems. With the outbreak of the Covid-19 pandemic the utilization of this field has speeded up and spread over, has become more widely used and legally approved. During the pandemic the different telehealth facilities were used mainly for the purpose of evaluating the actual state of the patients, using consultations with the doctors (teleconsultations) via telephone or video platforms. Main focus was the therapy management utilizing e-prescribing, in fewer cases establishing of diagnosis (telediagnosing). Telemonitoring of the status and physical activity level of patients with cardiovascular diseases (CVD) or other chronic non-communicable diseases such as Type 2 Diabetes Mellitus (T2DM) or Metabolic Syndrome (MetS) are not a common practice in Hungary. International studies suggest, however, that home-based, telemonitored physical training programs can be equally effective as hospital or centre-based programs for CVD patients requiring cardiac rehabilitation[3-9]. Some of these telemonitored programs were also characterized by better patient satisfaction, training adherence and cost-effectiveness than the conventional inpatient or outpatient solutions[3-9].

Cardiac rehabilitation all over the world tends to turn from the direction of secondary prevention (management of people with already established CVD) to primary prevention's (management of patients without clinically manifest disease but being at risk of developing CVD) direction[10-11]. As in the phase of secondary prevention, so in the phase of primary prevention the construction of a physical training regimen is crucial. E-health services with extended interventions can be utilized effectively. Monitoring the physical activities can happen in several ways, from the simplest step-counters to the complicated accelerometer-based activity monitoring. Non-invasive heart rate monitoring can also happen by different techniques. It could be measured and followed by multi-channel or just single-channel ECG monitoring, electric, but not ECG visualized dedicated monitors or by optical sensors[12]. Telemonitoring the intensity of physical activities of patients who have cardiometabolic risk factors but not dependent on close medical supervision, is a viable alternative of outpatient-controlled training by saving human and financial resources. Several types of heart rate monitors and lifestyle coaching mobile applications exist on the market with the help of which we can remotely and closely monitor the physical activity level and/or dietary habits of our patients however these solutions are not integrated in the system of healthcare.

1.1 Definitions of Telehealth, Telemedicine

The terms *Telehealth* and *Telemedicine* are usually interchanged and used as synonyms, but they refer to slightly different concepts. *Telehealth* is the broader concept, it includes remote but not just clinical care and services using telecommunication technologies, while *Telemedicine* is a subgroup of Telehealth, specifically referring to remote clinical or medical services. Telemedicine literally means „healing at a distance" and according to a WHO adapted definition it is "The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities"[13] (*WHO*, 2010. page 9.). In other words, it is a medical facility that uses ICT to allow interaction between the Health Service providers and the patients physically located in different places. Interpersonal connections are managed through some kind of an online electronic system. As a wider definition it functionally involves *Teleconsultation*, *Telemanipulation*, *Telediagnosing* and *Telemonitoring* and other functions dealing with education, health promotion, prevention and treatment[2].

eHealth (electronic Health) by definition is a group of activities that use electronic ways to deliver health-related data, resources and services. These include the EHR systems and can be used for providing some treatment options to the patients from a distance (e-prescriptions), for delivering online training for the health professional staff, for the educating patients (e-learning) or for the registering and follow-up of infectious diseases or epidemics[2].

mHealth (mobile Health) is a subsystem of eHealth using different mobile technologies to provide support for medical practices, reaching out patients from distant geographical locations, using wearable and portable equipment thus providing more independence for the users. It also applies mobile phone applications related to lifestyle management, health status, well-being and cardiorespiratory fitness and uses body-contact wearable devices or sensors[2].

1.2 Different classifications, forms and features of Telemedicine

We should differentiate between a *Telemedical care/Telecare* and a *Teleconsultation*. A *Telecare* facility is a direct patient care that happens *between a health care professional and a patient* (e.g. between a general practitioner and a patient) while *Teleconsultation* happens *between two health care professionals (*e.g. a general practitioner and a specialist consultant), aiming for a second opinion helping a diagnosis or treatment. A Telecare session can be either via telephone call or video-consultation, based on simply the EHR data or specifically on the data from the given-out monitoring devices/sensors. Similarly, Teleconsultation can be based on personal data from text, imaging or specifically given out monitoring devices/sensors and the consultation can happen by phone or video calls. Written feedback e.g., creating an EHR document is a common requirement in both cases[13,14].

According to the timing of the information transmitted, the delivering of telehealth can be synchronous or asynchronous. In the first case information is transferred in „real-time" requiring continuous investment of time from the site of health professionals. In the case of asynchronous or offline service, the information is pre-recorded, and the stored data are forwarded and assessed later by health care specialist typically with shorter time utilization as in the case of synchronous service. *Remote Patient Monitoring (RPM)* is realized typically as asynchronous service by the monitoring of the different medical or vital bioparameters of the patients from a distance (e.g., at home). The most often telemetrically monitored parameters are the blood pressure, the blood glucose level, the oxygen saturation, the body weight, or the heart rate[13]. The WHO European Report on telehealth implementation states RPM the second most frequently used telehealth facility (used by 72% - 33 Member States) which has the highest number of pilots and new solutions in the member countries[2]. The advantage of asynchronous service is that the supervising healthcare staff can schedule the monitoring in his/her work time while the patients can do the measurements, the activities whenever they are available, e.g., in their free time or on weekends. Asynchronous monitoring relies typically upon the appropriately chosen aggregated data (e.g., average values, standard deviations, tendencies, or duration of time in the preferred heart-rate zone, total time expenditure or the pulse curve in the case of training monitoring). The drawback of offline monitoring is that the healthcare professionals cannot interfere at once in case any problem arises, but with the appropriate selection of patient populations' this limitation can be accepted. The added value of offline monitoring is the minimalization of emergency situation by better patient management, not the handling of emergencies.

Another important aspect is when someone self-monitors certain bioparameters, that it would help in their decision-making based on the gained data thus enhancing self-management on a long-term. In case of hesitation, external support in decision making can be gained by the quick overview of the recorded parameters.

The areas where we can benefit from using telehealth facilities can be pictured on a very wide range. There has been an increasing need for these services in remote areas (geographical locations and physical obstacles), in developing countries, for the physically disabled populations, for huge patient populations of chronic non-communicable diseases (CVD, obesity, T2DM, MetS), for highly vulnerable patients, for isolated population (e.g., prisoners, in natural disaster areas or where the human resources are overloaded and have long clinical waiting lists. Therefore, we point out the following advantages of telemedical services:

- time-and cost-effectiveness from both the patients' and the healthcare provider's side,
- immediate lowering of the burden from the healthcare professional staff,
- decreasing the clinical waiting lists,
- elimination of direct contact and risk of infection between the patients and the health professionals or between a group of patients,
- reducing hospitalization and the number of days spent in hospital,
- increasing patient satisfaction,
- enhancing self-monitoring and self-management,
- accessing the facilities/services from the comfortable home environment,
- fitting in the after-work schedule of the active, working-age populations by using the store-and-forward monitoring,
- reaching out to the patients with limited mobility or living distantly without traveling time and cost [15-18].

There are some disadvantages of telemedicine which we must be aware of when planning to use these facilities:

- the provider must possess the appropriate technical support, ICT systems, “smart” equipment and must be able to operate them,
- purchasing and maintaining the needed equipment or technologies are not everywhere supported financially, these facilities may not be available for every layer of the society (e.g., broadband internet),
- the elderly population might not be able to use the intelligent technologies without help (poor digital literacy),
- the online diagnosis might not be proper thus leaving the patient in a state of fault security that everything is right and do not need further assessments or face-to face personal appointments,
- the provided measuring devices at home sometimes can work imprecise (e.g., in case of arrhythmias like atrial fibrillation) thus needing a personal face-to-face visit for checking,
- documentation, data protection and legal issues[15-18].

1.3 Evidence supporting home-based programs, telemedicine and remote patient monitoring in the field of physiotherapy and cardiac rehabilitation

Using telemonitoring in the practice of physiotherapy worldwide is not unknown, it has become more and more popular and can be delivered in many ways. Guided online therapy sessions can be applied through real-time videoconferencing, when the physiotherapists instruct different exercises to the patient one-to-one or for a group of patients. We have seen many examples for this during the Covid-19 pandemic. In this situation the patients might need to have some therapy equipment at home (elastic bands, balls, dumbbells etc.) or need to have somebody to help them[19] and although the way and intensity of the exercises can be controlled by the therapist this way at once in real-time but the possibilities for correction or to interfere in case of a problem are very limited. During the inpatient rehabilitation (e.g., in a hospital) therapy adherence is usually better as the patients are under direct supervision and visual monitoring by the healthcare professionals, although lacking continuous heart-rate monitoring, as measurements are usually performed only before and after the trainings with manual self-counting of the pulse. However, maintaining the adherence during the outpatient services or until the follow-ups has always been a challenge for the therapists. There are other barriers occurring in the outpatient care system from both the patients' and the providers' side. Unfortunately, physiotherapy outpatient services are not available everywhere, but where present there are usually long waiting lists for these services, there is a shortage of staff, the therapists are usually overloaded with work and the patients, who are usually from the workers' population, must adapt to the available working hours if they want a supervised session of exercise.

In the last decade in many countries a very intensive research activity has started in this field, investigating the justification and effectiveness of telemedicine supported exercise-based cardiac rehabilitation programs. Research suggests that exercise telemonitoring and telerehabilitation (TR) programs can be equally effective (regarding the outcomes, time and cost) as hospital-based conventional programs for CVD or respiratory patients requiring cardiac or pulmonary rehabilitation[3-9].

Huang and colleges (2015) conducted a systematic review and meta-analysis of 9 randomized controlled trials, researching the effects of telehealth supported exercise CR programs compared with the traditional inpatient rehabilitation. Altogether in the 9 studies 1546 patients participated [after myocardial infarction (MI), revascularization, coronary artery disease and patients with low-moderate risk of future cardiac events]. 781 patients were in the telehealth intervention groups and 765 in the centre-based CR programs with a mean age of 60.9 years. Although the way of delivering the cardiac rehabilitation programs was different in the compared studies (by telephone, Internet, telephone plus computerized patient-managing system, recording-transmitting ECG device by telephone and e-mail) and there were some differences in the duration of the programs (6 weeks–6 months), in the frequency of the trainings (1-6 sessions weekly), in the length of the sessions (25-60 min) and the measurement of the training intensity [maximum oxygen consumption (VO_{2max}), maximum heart rate, Borg-scale] but the results are quite homogenous. They found no significant differences in the observed main outcomes [mortality, exercise capacity, modifiable cardiac risk factors such as blood lipids, blood pressure, smoking and weight, adherence, health-related quality of life (QoL) and psychosocial state] between the centre-based and the tele-rehabilitation groups, thus concluding that telehealth supported delivery of exercise-based cardiac rehabilitation should be a non-inferior alternative to the centre-based CR programs, offering a chance of participation for those who have limited access or time to the conventional inpatient facilities[3].

Buckingham and colleges (2016) performed a Cochrane systematic review and meta-analysis, including 17 studies and 2172 patients altogether. They compared the effects of home-based versus supervised centre-based CR programs on different outcomes such as mortality, exercise capacity, QoL, and modifiable cardiac risk factors (blood pressure, blood lipid levels and smoking) in heart disease patients (MI, angina pectoris, heart failure or patients after coronary revascularization). In terms of mortality and exercise capacity on short- and long-term they found no difference between the home-based and centre-based CR groups. In one study they found that the mean maximum oxygen consumption (VO_{2max}) at the 6-year follow-up was significantly higher in the home-based group than in the centre-based group. They have observed lower high-density lipoprotein cholesterol (HDL-C) levels, lower diastolic blood pressure in centre-based participants. The home-based CR was associated with slightly higher training adherence[4].

The meta-analysis by *Rawstorn and colleges* (2016) included 11 trials altogether 1189 coronary heart disease (CHD) patients with a mean age of 58 years. They also assessed the potential benefits of telemedically controlled exercise-based CR versus conventional centre-based CR training programs considering the exercise capacity (VO_{2max} or MET) and modifiable CVD risk factors. The delivery of telehealth facilities (telephone, biosensors, accelerometry, heart rate monitoring, computers, mobile or smartphones and mobile applications) varied among the studies as well as the training duration (1.5-12 months). Two included studies did long-term follow up (1.5 and 7.2 years). The telemedically supported exercise programs contained 2-5 sessions per week on average, lasting 30–60 min/session with an intensity level progressing from moderate to vigorous (from 40–60% to 70–85% of peak capacity) intensity. Results show that compared with centre-based programs, the telemedically supported exercise CR programs were more effective in improving physical activity level, therapy adherence, diastolic blood pressure and blood lipid concentrations. Telehealth and centre-based CR were equally effective for improving the exercise capacity and the modifiable CVD risk factors and physical activity level was higher following telehealth CR than after the usual care[5].

Chan and colleges (2016) in their literature review and meta-analysis, included 8 studies in cardiac rehabilitation and 1 study in pulmonary rehabilitation, with an overall of 782 participants (patients with MI, coronary artery bypass grafting, coronary angioplasty, other catheter interventions, heart transplantation or post-valve surgery). They compared the effects of telemedicine supported rehabilitation programs with traditional, centre-based training programs regarding the measured outcomes such as the VO_{2max}, the maximum workload (W_{max}), the six-minute walk distance (6MWD), the exercise duration, the energy expenditure and the QoL. Although in the studies different telemonitoring techniques (transtelephonic ECG monitoring, heart-rate monitoring, video cameras or smartphones with applications) and different exercise protocols were applied, the results were again quite homogenous. In 4 studies they found significant improvements in the VO_{2max} for both groups, in 3 studies they found similar improvements in W_{max} in both groups, while in 1 study they found greater improvements in W_{max} in the telemonitored group, the results of 2 studies showed statistically significant increase in 6MWD in both groups with no significant between group difference. No adverse events, hospitalization or mortality were reported (investigated in 8 out of 9 studies) during the telemonitored interventions. They concluded that the cardiac and pulmonary telerehabilitation programs resulted in similar therapy adherence, quality of life and exercise outcomes compared to the conventional programs except for exercise duration, which resulted slightly better in favor of the centre-based interventions[6].

The FIT@Home study by *Kraal and colleges'* (2017) compared the effects of telemonitored home-based and conventional centre-based trainings regarding physical fitness, physical activity, training adherence and healthcare costs. They involved 78 low-to-moderate cardiac risk patients (acute coronary syndrome or after revascularization), in the home-based telemonitored or the centre-based training groups. Their intervention was for 12 weeks, at least two training sessions (45–60 min/session) per week, with an intensity of 70–85% of the maximal heart rate assessed by a cardiopulmonary exercise test. In the telemonitored group they used a heart rate monitor with a chest strap. Data was uploaded to a web application and the patients received weekly feedbacks on their performance by healthcare professionals. They found no differences in the physical fitness parameters, in the physical activity levels at the one year follow up. While the health-related QoL and psychological status were similar in both groups, the home-based and telemonitored program was associated with a higher patient satisfaction and ended up more cost-effective than the centre-based training. They concluded that home-based training with telemonitoring guidance can be used as an alternative to centre-based training for low-to-moderate cardiac risk patients in cardiac rehabilitation[7].

In their non-inferiority study, *Maddison and colleges (*2019) compared the physiological effects and cost-effectiveness of the 12 weeks, real-time telemonitored exercise-based versus centre-based CR programs in 162 coronary heart disease patients. At baseline, at the 12^{th} and the 24^{th} week follow-up, they assessed different outcome measures such as the $\dot{V}O_{2max}$, modifiable CV risk factors, adherence, motivation, health-related QoL and financial costs. In the TR group the patients received individualized exercise, they were provided the telemonitoring equipment for free, including a smartphone, a web application and a software designed by the research group, a chest-wearable sensor measuring the heart rate, the respiratory rate, ECG and an accelerometer (Figure 1.). Their platform allowed the remote exercise monitoring and the audio coaching to happen synchronously by transferring the measured bioparameters via internet to the web server. The patients were able to follow and self-monitor their actual parameters on the smartphone app. The exercise was also recorded thus letting a retrospective performance review, goal setting and patient education. Their results showed that home-based and telemedically supported CR was non-inferior to the conventional centre-based CR in regarding the measured functional, risk factor and behavioral outcomes[8].

Figure 1: Remotely monitored exercise-based cardiac telerehabilitation platform schematic

Source: Maddison et al (2019). Effects and costs of real-time cardiac telerehabilitation: randomized controlled noninferiority trial. Heart. 105:122–129. Page 123.

They found that the telemonitored group participants were less sedentary at the 24th weeks, the centre-based group patients had slightly smaller waist and hip circumferences at the 12th week. The program delivery and medication costs were far lower for the telemonitored group (70%) but other than these they did not find any significant differences between the two groups. Finally, they concluded to recommend the home-based and remotely telemonitored CR as an efficient and cost-effective alternative to the traditional centre-based CR[8].

In their recent review, *Batalik and colleges* (2020) included 12 studies, 545 patients (after MI, coronary revascularization, low or medium cardiovascular risk and heart failure) altogether in the different TR groups, reviewing the efficiency and utilization of TR compared with centre-based CR and usual care. Commonly all TR programs contained some forms of physical exercise, but they differed in the duration of the intervention period (6-24 weeks), in the number of sessions per week (1-5), in the duration (30-300 minutes per week) and the intensity of the trainings (40-80% of heart rate reserve) and in the type of physical activity (walking, Nordic walking, jogging, cycling). Telemonitoring included ECG telemetry, wearable monitors or heart rate sensors with a chest strap either real-time or asynchronous, with telephone call, email or SMS feedbacking on the home-based trainings (Figure 2). Regarding their primary outcomes, in 6 studies they found similar improvements in exercise capacity (measured by the VO_{2max}, by the 6MWD or by exercise stress test with peak MET) in the TR and the centre-based CR programs but in 6 studies the improvements in exercise capacity were significantly better in the TR groups compared to the usual care groups. The average percentage of completion rate in the TR groups was almost as high as in the control groups (86% vs 89%) and no severe complications, adverse events or deaths were reported. According to their findings home-based telerehabilitation programs were found to be at least as effective as traditional centre-based cardiac rehabilitation programs in improving CVD risk factors and exercise capacity for cardiac patients and they also found TR to be an effective and suitable alternative to inpatient cardiac rehabilitation[9].

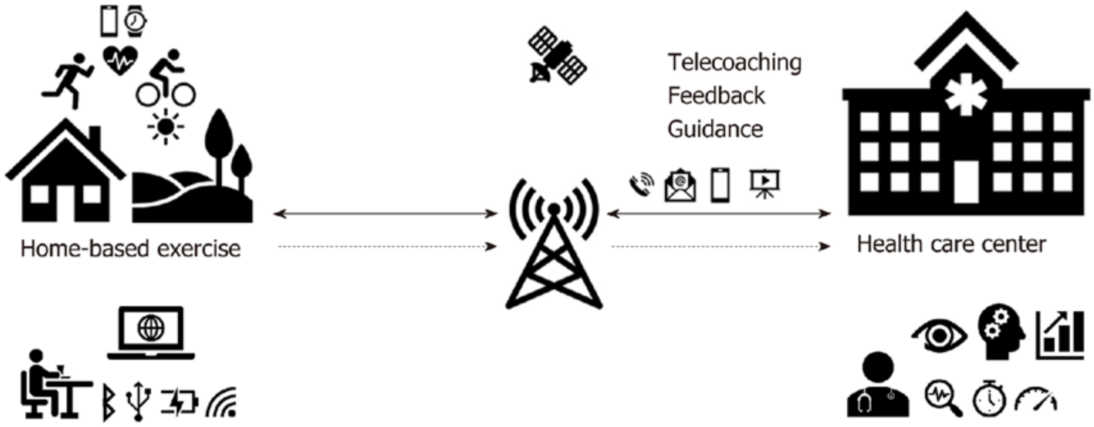

Figure 2: Scheme of remotely monitored telerehabilitation

Source: Batalik et al (2020). Remotely monitored telerehabilitation for cardiac patients: A review of the current situation. World J Clin Cases. 8(10): 1818-1831. Page 1821

1.4 Metabolic syndrome: definition, risk factors, diagnostic criteria and non-pharmacological treatment

Metabolic Syndrome is characterized by the concomitant presence of cardiometabolic risk factors such as central (abdominal) obesity (defined by increased waist circumference), high blood pressure, elevated fasting plasma glucose and triglyceride levels and decreased HDL-C level[20]. This condition increases 2-5 times the risk of developing CVD and T2DM in the next 5 to 10 years[20] and the occurrence of cardiovascular death by 1.8 times in the next 15 years[21]. The aggregation of MetS risk factors or components at the same time, increases CVD risk further. According to the Framingham Offspring Study, which analyzed the data from 3708 participants, the prevalence of MetS almost doubled after the 10 years follow-up, high plasma glucose level and central obesity experienced the highest increase. Participants who had MetS with a combination of central obesity, hypertonia and hyperglycemia had a 236% increase in cardiovascular event incidents and a 309% increase in the risk of mortality[22].

As considered a syndrome, MetS is defined slightly differently by the various international organizations, the WHO, the EGIR (the European Group for the Study of Insulin Resistance), the IDF (International Diabetes Federation) and the NCEP (National Cholesterol Education Program) ATP III. (Adult Treatment Panel III.). According to the different definitions, the absolutely required components also differ e.g. in the WHO categories, insulin resistance or diabetes, in the EGIR categories the hyperinsulinemia, by the IDF, the central obesity (waist circumference less than 94 cm in men and less than 80 cm in women) are need to be present, plus usually two other components out of the four or five other criteria (dyslipidemia, decreased HDL-cholesterol level, hypertension or microalbuminuria). According to the NCEP ATP III, there is no compulsory component, any three of the five core components if present concomitantly that is considered a MetS. Clinically this diagnostic criteria system is the easiest to apply and therefore the most widely used in practice[23].

The prevalence of MetS obviously depends on the used diagnostic criteria. In developed countries MetS affects around one fourth (20-30%) of the adult population, this ratio is increasing especially amongst the elderly (23.5% to 40.6%)[22, 24]. In Hungary the prevalence of MetS according to *Szigethy and colleges'* study was 38% among men and 30% among women in the 20-69 years population tending to develop even earlier, during childhood[25]. *Kékes and colleges* within the frameworks of their study "Nationwide Comprehensive Health protection Screening Program in Hungary 2010-2020" („Magyarország Átfogó Egészségvédelmi Szűrőprogramja 2010–2020") have assessed 65 267 participants and investigated the occurrence of MetS among them. The results showed that the prevalence of MetS was 30-37% and was higher among men until the age of 45, but between the age of 45-65 (menopausal age), the prevalence was significantly higher among women[26].

According to the IDF guideline and other international recommendations, the changing of the lifestyle, regular, proper physical activity and calorie restricted healthy diet are inevitable to lose bodyweight, to treat the MetS and play a key role in the prevention as well[27, 28]. Providing personal supervision in out/inpatient care settings for a bigger target population of Metabolic syndrome patients would challenge the National Healthcare System but based on the literature, using telemedicinal facilities for the home performed trainings could be a promising and available option.

Sequi-Domingez and colleges (2020) in their systematic review and meta-analysis, analyzed 9 studies (total of 992 patients, mean age 38.4-59.7 years) and investigated the effects of telemedically supported lifestyle interventions for reducing cardiometabolic risk in Metabolic syndrome patients. They assessed the following outcomes: body composition, WC, BMI, blood pressure, FPG, glycated hemoglobin A1c (HbA1c), total cholesterol, low-density lipoprotein cholesterol (LDL-C), HDL-C and triglycerides. Their findings showed that mHealth interventions caused great improvements in the body composition, blood pressure, FPG, and HDL-C levels but no relevant changes were detected in HbA1c, total cholesterol, LDL-C and triglyceride levels. Although according to their results, mHealth supported interventions of physical activities or lifestyle interventions were not superior to traditional care but were found to be effective and could serve as an alternative solution being time-, and cost-effective, tailored to the individual's needs and enhancing self-management [29].

Haufe and colleges' (2019) study involved 314 MetS participants (mean age 48±8 years), who were workers in a German car factory. They aimed to investigate the effects of a 6-month mHealth supported physical activity and lifestyle intervention on the severity of MetS (measured by the Z score) and the work ability of the included workers. In the intervention group they were provided a GPS running watch with heart rate and activity monitoring functions wearable on the wrist, plus they had to install an application to their mobile phone. Participants were asked to perform minimum 150 min of moderate intensity physical activity per week for 6 months. The following parameters were monitored: wearing time, number of steps, preset or self-defined activities, recording activity time, distance, and heart rate as assessed by an optical heart-rate sensor. Training data were saved and forwarded through an interface to a server at Hannover Medical School, where the supervisor monitors could see the type of activity, duration, heart rate, distance, and number of steps. The type of physical activity or training was according to the patients' preferences, but they were asked to keep their heart rates in a target heart rate zone (65–75% of the maximum heart rate, previously measured during the incremental exercise test) during the activities. The control group were those participants who were put on the waiting list for future participation in the intervention group, but until that they were asked to continue their current lifestyles. According to their results the mean bodyweight was reduced more in the exercise group than in the control group, the mean percentage of body fat significantly decreased in the exercise group but not in the control group. The MetS Z score significantly decreased for the exercise group compared with the control group, all MetS components showed a significant between-group difference (except HDL-C) in favor of the telemonitored exercise group. The physical and mental component scores of the QoL questionnaire and the exercise capacity also increased in the exercise group significantly greater than in the control group. Both groups scored less in the HADS (Hospital Anxiety and Depression Scale) questionnaire for anxiety and depression but with a greater improvement in the exercise group. Duration of physical activity was positively associated with changes in total work ability, but not with metabolic syndrome severity. Their findings highlight that a 6-month telemedically monitored and exercise-focused intervention, with distant supervision and feedback from monitoring professionals, can decrease the risk factors of MetS, reduce the severity of the disease and improve the work ability of the assessed working-age population of employees with MetS. They also recommend offering these types of interventions to other working-age populations in need, to reduce individual disease risks, healthcare related and economical burdens which are associated with Metabolic syndrome[30].

There is evidence that home-based and mHealth supported training programs can be equally effective as hospital or centre-based programs[3-9] and that these types of programs were positively affecting cardiometabolic parameters, MetS risk factors, QoL and workability[29, 30]. Reforming the lifestyle is a very cumbersome process; only a very small proportion of the population is able to cope with this alone and change the ingrained lifestyle habits. The majority of patients require strong external support, coaching and supervision. This will challenge the Public Health Services, depleting structural, financial and human resources. There is another, predetermined conflict pertaining to the patient: a great proportion of the affected patients are in the active age group, where their occupational activities prohibit the regular visits to outpatient facilities offering therapeutic physical training programs. A further barrier is the time consumption and cost of regular commuting to and from the nearest outpatient clinic. Since the outbreak of the Covid-19 pandemic we should also consider the potential infection hazards related to institutional group training. Services provided through telemedicine technology are preferred in this situation to minimize interpersonal contacts between health care workers and patients as well as between patients. Providing the treatment by telemonitoring and coaching the home-based exercise trainings of patients who have cardiometabolic risk factors like in MetS, but not yet dependent on close medical supervision, is a forward-looking and viable option as reducing some burden of the institutional healthcare staff and saving time and money for the patients.

Review of the evidence also shows that MetS is comorbid with different psychological disorders; obesity (central adiposity) and diabetes (insulin resistance) increase the risk of depression and anxiety but on the other hand after successful weight loss programs the improvement of depression was reported. Furthermore depression, anxiety and MetS all have environmental and behavioral factors in common, increasing their risk of prevalence, such as unhealthy diet, smoking, chronic stress and physical inactivity[31,32]. It is also supported by evidence that vital exhaustion (excessive fatigue, loss of energy and demoralization) is an independent risk factor of cardiovascular diseases[33]. Based on the findings of two meta-analyses, the relative risks for cardiovascular events are between 1.50 and 2.03[34, 35]. Few studies have analyzed the psychological effects of home-based telemonitored training in cardiac rehabilitation and most of them only measured changes in the QoL and the results are mixed. Some studies have found an improvement in quality of life [36-38], while other studies have found no significant difference in the increase in quality of life of those treated remotely by using telemedical support compared with the conventional treatment[3, 39].

2. Aims of the Thesis

Although evidence supports that mHealth supported interventions are effective strategies in the non-pharmacological treatment of the Metabolic syndrome[29, 30], to date there has been no unitary and exact protocol, good practice or consensus for the implementation and integration of telemedically supported home-based telemonitored physical training programs in the therapy of MetS patients in Hungary. Therefore, our purpose was to investigate the physiological and psychological effects of a 12 week, home-based and telemonitored physical training program of MetS patients, to see the changes of different risk factors and parameters of the Metabolic syndrome with using heart rate monitoring, online supervision of the trainings, individual coaching by physiotherapists, and weekly feedbacking to the patients. Additionally, we intended to try out the usage of different types of monitoring devices (heart-rate monitoring watch and chest strap paired with a “smart” phone) during the telerehabilitation. We also kept in the focus of our interest that in case of finding the results positive how to implement and integrate our pilot program into the National Healthcare System, in the physiotherapy practice and spread it over to a greater population in need.

2.1 Hypothesis I.

In our study we sought to investigate the **physiological effects** of a 12-week home-based and telemonitored training program **on the anthropometric** [waist circumference (WC), hip circumference (HC), weight and body mass index (BMI)] **and body composition parameters** [the total body fat mass (BFM), its ratio referred to the body weight (BFM%), the muscle mass (MM), the fat free mass (FFM), the visceral fat (VF) level in the abdomen, the trunk fat percentage (TF%) and the average basal metabolic rate (BMR)] of Metabolic syndrome patients. We assumed that these parameters will positively change.

2.2 Hypothesis II.

We intended to assess **the effects** of a 12-week home-based and telemonitored training program **on the maximal exercise and functional capacity** (stress ECG duration time, maximum MET and 6MWD) **and laboratory parameters** [fasting plasma glucose (FPG) level, HbA1c level, HDL-C level, total cholesterol (TC) level and triglyceride (TG) level] of Metabolic syndrome patients. We hypothesized that these parameters will positively change and the cardiorespiratory fitness of the MetS patients will improve.

2.3 Hypothesis III.

We aimed to evaluate **the psychological effects** of our 12-week home-based and telemonitored training program **on the level of depression, insomnia, vital exhaustion, and well-being** of Metabolic syndrome patients by assessing and evaluating the Shortened Beck Depression Inventory (BDI), the Athens Insomnia Scale (AIS), the shortened Maastricht Vital Exhaustion Questionnaire (MQ) and the WHO Well-Being Scale (WHO-WBS). We assumed that these parameters will positively change, thus the quality of life of the patients will improve.

2.4 Hypothesis IV.

During the 12-weeks telemonitoring we intended **to try and compare the usage of two different types of heart-rate monitoring devices** ("smart" watch and chest strap paired with a "smart" phone). We hypothesized that both devices will be equally suitable for their purpose (monitoring the heart rate) and the two subgroups, Group SM (smart watch) and Group CS+P (chest strap + phone) will have similar results regarding the outcomes, therefore the type of monitoring device used will not have a significant effect on the results.

3. Materials and methods

3.1 Participants

Altogether 59 participants with a confirmed diagnosis of Metabolic syndrome were enrolled in the study. MetS was defined according to NCEP ATP III. MetS criteria system[20,23,40]. All participants were volunteers and gave their written informed consent to participate in the study.

3.2 Study design and patient recruitment

This study was a prospective, non-randomized intervention evaluation study among Metabolic Syndrome patients, who were involved in the study between the 1st of September 2018 and the 31st of January 2020. They were recruited from the city of Szeged (Hungary) and surrounding villages within a 40 km distance. The recruitment was running in General Practitioners (GP) offices, occupational physician offices as well as in cardiological inpatients and outpatient facilities. Participants were recruited by the physician's referral. All subjects were informed about the study protocol and provided a written informed consent before the enrollment in the study. The study was done in accordance with the Declaration of Helsinki and the study protocol was approved by the Hungarian Medical Research Council (ETT TUKEB), the Ethical Trial Number is 50780-2/2017EKU, the Clinical Trial Registration number is NCT05146076.

3.3 Inclusion criteria

Participants (men and women), aged between 25 and 70 years were involved in the study, who practiced only very low level of regular physical activity (self-reported, less than 30 minutes a week), and had at least three risk factors concomitantly present from the followings to qualify for the diagnosis of the MetS:[20,23,40]

(a) waist circumference above 102 cm in men and above 88 cm in women,

(b) proved T2DM or FPG level above 5.6 mmol/L,

(c) treated hypertension or spontaneous blood pressure ≥ 130/85 Hgmm,

(d) treated hypertriglyceridemia (HTG) or serum TG level above 1.7 mmol/L,

(e) serum HDL-C level under 1.03 mmol/L in men, under 1.3 mmol/L in women

To manage the telemonitoring devices and data transfer the participants had to have basic informatics skills and digital literacy to be able to use a smartphone or transfer data from the smart watch to the phone, laptop or personal computer through a wired or wireless (Bluetooth) connection.

3.4 Exclusion criteria

The participants were excluded with: any upcoming planned invasive cardiological intervention [Percutaneous Transluminal Coronary Angioplasty (PTCA), coronary artery bypass, valve repair or replacement], uncontrolled hypertension (blood pressure >160/100 Hgmm), type 1 diabetes mellitus (T1DM), T2DM which needed more than one dose of insulin per day, chronic heart failure (CHF), chronic renal failure where the estimated Glomerular Filtration Rate (eGFR) < 60 ml/min), oncological diseases, serious cognitive dysfunction, lack of cooperation, any known disease or condition that seriously affected the mental and legal capacity, any other conditions preventing regular physical trainings.

3.5 Primary and secondary outcome measures

When planning our study, we set two primary outcome measures. One of them was the waist circumference (WC) as it is a basic anthropometric measure to assess abdominal obesity and its increased proportion serves as one of the risk factors in the MetS by definition[20,23,40]. Our second primary outcome measure was the six-minute walk distance (6MWD), the patients' best achievable walked distance in six minutes performed during the six-minute walk test (6MWT), which is a simple field test commonly used to assess the functional capacity[41,42]. We considered all other measured parameters (a series of anthropometric, fitness, body composition, metabolic parameters: the hip circumference, the body weight, the body mass index, the stress-ECG duration time, laboratory parameters such as fasting plasma glucose, glycated hemoglobin, triglyceride, high-density lipoprotein and total cholesterol levels and quality of life) as secondary outcome measures.

3.6 Baseline and follow-up patient assessments

The baseline and follow-up medical assessments and the data collection took place in the Department of Medicine, Albert Szent-Györgyi Medical School, University of Szeged, (Szeged, Hungary), while the physiotherapy assessments and the relevant data collection were performed in the Department of Physiotherapy, Faculty of Health Sciences and Social Studies, University of Szeged (Szeged, Hungary). Baseline assessments were performed maximum 1 week before starting the training program, while follow-up evaluation was performed within 1 week of completing the 12-week training program.

3.6.1 Anthropometric measurements

The following anthropometric parameters were assessed in all participants at the initial and the final visits: waist and hip circumferences, body weight and height by the standardized way. Exact body weight was measured by the body composition analyzer device (Tanita BC-418, Japan), standing on its scale part, without shoes and heavy clothing. Height was measured in centimeters (cm) using a metric stadiometer attached to a wall. The patients stood erect without shoes, with the back of the head, the shoulder blades, the buttocks and the heels touching the wall and the patient looking directly forward[43]. All circumferences were measured in centimeters (cm) using a stretch-resistant tape that provides a constant 100 g tension. Hip circumference (HC) was measured at the level of the greater trochanter (around the widest portion of the buttocks), with the tape parallel to the floor. Waist circumference was measured at two levels: at navel level (WC_{navel}) and at the narrowest part of the midriff ($WC_{midriff}$) thus at the smallest circumference between the lower margin of the last palpable rib and the top of the iliac crest (Figure 3.). For each measurement, the subjects stood erect, with feet close together, arms at the sides and body weight evenly distributed across the two feet. The subjects were relaxed, and the measurements were taken at the end of the normal expiration phase of the breathing[44].

Figure 3. Measuring $WC_{midriff}$ with a tape measure

Source: own photo

3.6.2 Functional capacity

The functional capacity was measured during the 6MWT, in accordance with the American Thoracic Society (ATS) guideline, outside on a 30-meter-long marked track. The distance reached in six minutes (in meters) was measured and documented[41, 42].

3.6.3 Maximal exercise capacity

Under cardiologist’s supervision a twelve channel ECG (CardioSys, MDE Diagnostic, Walldorf, Germany) was performed at rest and during exercise using an incremental loading in accordance with the Modified Bruce Protocol until the age predicted maximal heart rate or the maximal tolerated capacity of the patient. The age predicted maximal heart rate was calculated based on the 220-age formula. The maximal capacity in Metabolic Equivalent of Task (MET; ml/kg/min), the maximal heart rate (bpm), systolic and diastolic blood pressure (Hgmm) and the duration of the Stress-ECG test (min) were measured and documented.

3.6.4 Body composition analysis

The body composition was measured by a Bioelectrical Impedance Analysis (BIA) method using a segmental body composition analyzer device (Tanita BC-418, Japan, Figure 4). The device measures body composition by measuring bioelectrical impedance in the body using eight electrodes and constant current source with a high frequency current (50kHz, 500µA). The degree of difficulty with which electricity passes through a substance is known as the electrical resistance. Electricity passes through water rather easily but fat within the body allows almost no electricity to pass through. The percentage of fat and other body constituents can be inferred from the measurements of this resistance. Electric current is supplied from the electrodes on the tips of the toes of both feet and the fingertips of both hands, and voltage is measured on the heel of both feet and the thenar side of both hands. The current flows into the upper limbs or lower limbs, depending on the body part(s) to be measured, five different impedance measurements to be made – whole body, right leg, left leg, right arm and left arm. During the measurement the exact bodyweight (kg), the total body fat mass (BFM) in kilograms (kg), its ratio referred to the body weight (BFM%), the muscle mass (MM) in kilograms (kg), the fat free mass (FFM) in kilograms (kg) were estimated (calculated). The visceral fat level (VF) in the abdomen and the trunk fat percentage (TF%) were measured by an abdominal fat analyzer device (Tanita ViScan AB-140, Japan), shown on Figure 5. The Body Mass Index (BMI; kg/m2) and the average basal metabolic rate (BMR) in Joule (J) were calculated by the device and were documented.

Figure 4. Tanita BC-418 Body composition analyzer device

Source: https://www.tanita.com/en/bc-418/

Figure 5. Measurement of abdominal visceral fat with the Tanita ViScan AB-140 device

Source: own photo

3.6.5 Medical evaluation and laboratory parameters

Anamnesis, detailed medical history, available laboratory data, current drug treatment were reviewed by the physicians and documented at the time of the initial medical evaluation. Based on these data and the assessment of the physical status of the patients, the inclusion and exclusion criteria were checked. Routine echocardiographic evaluation was also performed using a Vivid-e (Boston, Massachusetts, US) cardiac ultrasound machine. Blood samples from 1 month prior the starting date were accepted and documented at the initial and the final visit.

3.6.6 Psychological questionnaires

During the initial and the final visits, the participants were asked to fill in (self-report) the following standardized psychological questionnaires:

1. Shortened Beck Depression Inventory (BDI): this self-report instrument contains 9 items from the original 21-item version of BDI, and it is highly correlated with the total score (r = 0.92, p<0.001), see in Appendix. It is used to determine the intensity and severity of depression. 0-9 points: normal score; 10-18 points: mild depressive mood; 19-25 points: moderate depressive mood; over 26 points: severe depressive mood[45, 46].

2. Athens Insomnia Scale (AIS): the scale consists of 8 items which measure sleep complaints, see the scale in the Appendix. The first five pertains to night-time problems, and the other three items assess the negative consequences of disturbed sleep during the day. Respondents are required to rate positively if they have experienced sleep difficulties at least thrice per week during the last month. Each item is rated on a 4-point numerical rating scale (where 0= no problem at all and 3= very serious problem). Total scores range from 0 to 24. Higher scores in these AIS measures indicate that responders have severe insomnia symptoms[47].

3. Shortened Maastricht Vital Exhaustion Questionnaire (MQ): This is the 9-item form of the original 21-item questionnaire which was used to measure feelings of exhaustion[48], see in the Appendix. This shortened version was applied in a Hungarian representative health survey, Hungarostudy 1995[49]. Higher scores indicate that responders have severe vital exhaustion symptoms. The correlation between the shortened Hungarian version and the original Dutch 21-item scale is high (r = 0.94, p<0.001)[50].

4. WHO Well-Being Scale (WHO-WBS): It is the most common measure which is used to assess self-reported well-being in clinical or follow-up studies (see in the Appendix). Validation of this questionnaire is based on data from Hungarostudy 2002. The Hungarian version of this scale is a reliable and valid measure of positive quality of life. The Cronbach alfa rate of the scale is 0.84, which refers to a high internal consistency. It is a five-item questionnaire which assesses well-being during a period of two weeks. The raw score ranges from 0 to 25. A score of 0 represents the worst quality of life and 25 the best. a questionnaire to examine health-related quality of life either relying on subjective experience, self-report or using a multidimensional approach which combines psychological, physical and social aspects. The Well-Being Scale is the most common measure which is used to assess self-reported well-being in clinical or follow-up studies[51].

3.6.7 Intervention: Home-based telemonitored physical trainings

After all the assessments were completed, the physiotherapists informed the participants about the details and features of the trainings and the monitorings. They were given an information sheet and each participant received a 15–30-minute individual patient education on the usage of the given training monitor device and the procedures of the data transfer. The participants were asked to perform 3-5 trainings (minimum 30 minutes per session) individually at home, aiming to a minimum of 150 minutes per week for 12 weeks. There were no restrictions regarding what type of trainings they performed at home (walking, running, cycling, swimming etc.) but they were informed about the recommended and beneficial training types and intensity (aerobic endurance training combined with resistance training, minimum 150 minutes per week) suitable for Metabolic Syndrome patients[52,53]. The target heart rate zone for the home-based training was calculated individually, based on the exercise capacity of the patients and the perceived level of exhaustion in the 60-80% range of the age dependent maximal heart rate. Patients were asked to keep their heart rate within this target zone during the physical activities they performed at home.

3.6.8 Heart rate and training monitoring

During the home-based physical activities and trainings, the heart rate was monitored by two different types of devices that were allocated to the patients at the initial visit. Both devices were available in the commercial market for reasonable price. One of them was an electric heart rate sensor with a chest strap (Polar H10, Kempele, Finland,) and a wirelessly connected android smartphone (Meizu M5c, China), shown on Figure 6. For patients using this type of device data collection was initiated and stopped through the free to download fitness application (Polar Beat) on the paired smartphone. Training duration, distance, intensity and heart rate zones could be reviewed by the patient on the smartphone online as well as after completing the training. At the end of the training the data were also synchronized automatically to a cloud based integrated system for reviewing and coaching [54,55]. The data were uploaded using study ID-s, that were only identifiable by the research staff and sensitive personal data were not synchronized.

Figure 6. Heart rate sensor (electric) with a chest strap paired with a smartphone and a mobile application

Source: own photo

The other type of heart rate monitor we used was a "smart" watch with an optical heart rate sensor (Polar M430 GPS running watch, Kempele, Finland, Figure 7.) that could start and end the trainings by itself, but the synchronization of training data was not automatic. Patients using this type of sensor had to upload the training data by manually building up a wired connection to a PC running the Polar Flow website, or through initiating a wireless connection to a patient owned smartphone running the Polar Flow application by pressing a button on the smartwatch. The browser-based review process was identical for the two groups. The assignment of devices to individual patients was planned in a random manner, however during the inclusion procedure we should realize that we need to consider patient's preferences to complete the study within the planed timeframe (a series of patients would refuse the participation in the study, if the use of chest strap or smart watch was randomly assigned).

Figure 7. "Smart" watch with an optical heart rate sensor

Source: https://wibi.com.kw/products/polar-m430-is-a-gps-running-watch-with-heart-rate

The patients were exercising at home at least on three days of the week. The remote training monitoring was asynchronous (not in real-time). The physiotherapists reviewed the training activities of every patient weekly and contacted them individually via phone or email giving feedback and trying to motivate them. Average time expenditure for an individual consultation was about 10-20 minutes. Figure 8. shows a diary view of the trainings performed by a participant. Figure 9. indicates some features of a monitored training that were visible on the website for the monitoring person.

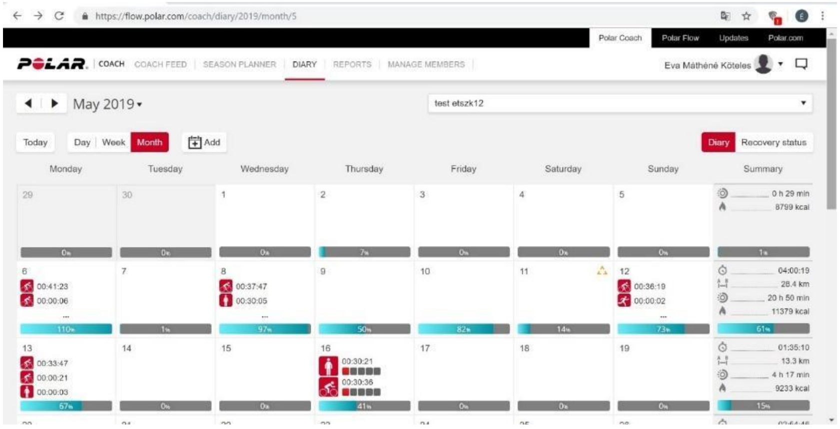

Figure 8. Printscreen picture of the weekly performed trainings from the Polar Flow coaching website[55]

Source: own photo

Figure 9. Printscreen picture of a monitored training session from the Polar Flow coaching website[55]

Source: own photo

3.6.9 Data collection and statistical analysis

Power analysis for the study was performed using the software G* Power (Version 3.1.9.2) for power-and-sample size calculation (University of Düsseldorf, Germany). The calculated sample size was 51 based on waist circumferences, working with an effect size d=0.45, alpha as Type I error of 0.05, and a power value of 0.9. Statistical data were reported as the mean±standard deviation (SD). Paired t-test was used to analyze the effect of the training on several parameters, whereas we used correlation analysis to measure the strength of connection between two continuous variables. For the subgroup analysis, repeated measures variance analysis (RM-ANOVA) was applied for the measured parameters before and after physical training where the grouped variables were the CSP+P and SW subgroups. For pairwise comparisons, Bonferroni correction was used. Statistical tests were performed using R statistical software and the diagrams were made also using R statistical software (R version 3.6.2)[56]. Values of $p<0.05$ were considered significant.

4. Results

4.1 Subject population

Altogether 59 MetS patients (37 men and 22 women, mean age 49.35±8.51 years) were enrolled in the study. 4 participants (2 men and 2 women) dropped out from the program, although they have started and had been allocated a heart rate monitor device but did not finish the program and refused to take part in the final medical and physiotherapy assessments. The dropout rate was 6.8%. Finally, 55 patients (35 men and 20 women, mean age 49.19±7.93 years, Table 1. shows further demographic data) completed the 12-week home-based telemonitored program. Metabolic syndrome risk factors at baseline and after training program are shown on Table 2. Out of those patients who completed the program, in 4 cases the final exercise ECG test and in 1 case the final 6MWT could not be performed even because of health-related issues (acute knee injury and pain that limited the walking and cycling ability) or technical problems.

Table 1. Demographic characteristics of the participants

		Number of patients
Gender	male	35
	female	20
Qualification	primary school	4
	vocational training	4
	high school	29
	university / college	18
Economic activity	homemaker	1
	employed	19
	public servant	14
	self employed	14
	unemployed	1
	retired	6
Family status	single	4
	civil partnership	8
	married	36
	divorced	7

Table 2. Metabolic syndrome risk factors at baseline and after training program

	Number of cases at baseline	Number of cases after 12-week training (percentage of baseline numbers)	
		Improved	Worsened
Treated T2DM	10		
Treated Hypertonia	37		
Treated Hyperlipidemia	16		
Abnormal FPG	35	23 (66%)	3 (9%)
Abnormal Blood Pressure	48	9 (19%)	1 (2%)
Abnormal TG	28	5 (18%)	10 (36%)
Abnormal HDL-C	12	12 (100%)	1(8%)
Abnormal WC	50	7 (14%)	2(4%)
Minimum 3 Risk factors	55	6 (11%)	0 (0%)

Abbreviations: T2DM: Type 2 Diabetes Mellitus; FPG: Fasting Plasma Glucose; TG: Triglyceride; HDL-C: High-Density Lipoprotein Cholesterol; WC: Waist Circumference

The weekly average heart rate monitored training time was 152±116.2 minutes for the whole selected population. Out of the 55 participants who completed the program, 22 patients (40%) performed the recommended 150 minutes or more physical activity time during a week.

None of the assessors (physicians and physiotherapists) reported any adverse events during the initial and final assessments and none of the patients and monitors reported any adverse events during the 12-week home-based training program.

4.2 Results supporting Hypothesis I.

In this part the changes in the measured anthropometric and body composition parameters are presented that support Hypothesis I.

4.2.1 Waist circumferences

After the 12-week telemonitored training program the average WC measured at the narrowest part of the midriff ($WC_{midriff}$, 106.17±14 cm to 103.88±13.5 cm, $p<0.001$) and the average WC measured at navel level (WC_{navel}, 112.8±14.8 cm to 110.6±15.5 cm, p=0.001) significantly reduced, indicated on Figure 10.

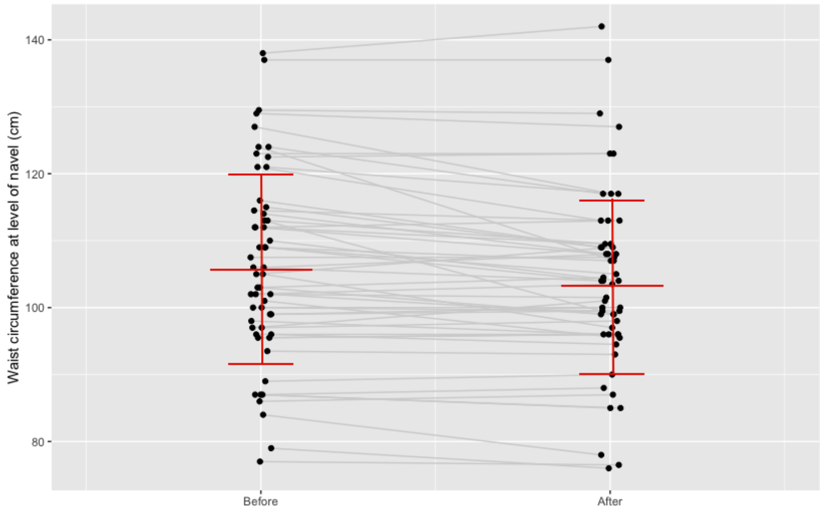

Figure 10. Changes in the waist circumference (cm) measured at navel level before and after the intervention

4.2.2 Hip circumference

Post intervention the average HC decreased from 114.73±13.75 cm to 112.15±13.2 cm ($p<0.001$).

4.2.3 Body weight and BMI

Both the average body weight and the BMI of the participants decreased slightly but statistically significant. The body weight decreased from 98.72±21.7 kg to 97.45±21.76 kg ($p<0.01$) and the calculated BMI decreased from 32.98±6.69 to 32.58±6.73 ($p<0.01$). Table 3. summarizes all the measured anthropometric parameters at baseline and post intervention.

Table 3. Anthropometric parameters at baseline and after the training program

	n	At baseline (mean±SD)	After 12-week training (mean±SD)	Diff (95% CI)
WC_{navel} (cm)	55	112.82±14.82	110.61±15.53	-2.21 (-3.47;-0.95)**
$WC_{midriff}$ (cm)	55	106.17±14.03	103.88±13.5	-2.29(-3.40;-1.18)**
HC (cm)	55	114.73±13.75	112.15±13.2	-2.58(-3.50;-1.66)**
Body Height (cm)	55	172.9±9.29	n.a.	n.a.
Body Weight (kg)	55	98.72±21.7	97.45± 21.76	-1.27(-2.12; -0.41)*
BMI (kg/m^2)	55	32.98±6.69	32.58±6.73	-0.41(-0.68; -0.13) *

Abbreviations: SD: Standard Deviation of the mean; WC_{navel}: Waist Circumference measured at navel level; $WC_{midriff}$: Waist Circumference measured at the narrowest part of the midriff; HC: Hip Circumference; BMI: Body Mass Index; CI: Confidence Interval; n.a.: not applicable. Paired T-test was used. Level of significance: * <0.01, **<0.001

4.2.4 Body composition parameters

We have found some parameters showing improving tendencies but have not found any changes that were statistically significant in the measured body composition parameters except the muscle mass (MM), which decreased instead of increasing. The overall average body fat mass (BFM) showed a decreasing tendency from 33.22±13.9 kg to 32.61±14.46 kg (p=0.087), the average body fat mass relative to the body weight (BFM%) has decreased, from 33.01±8.26 to 32.74±8.73 (p=0.372) but not changed significantly. Surprisingly, the average fat free mass (FFM) has also showed a decreasing tendency, from 65.51±13.17 kg to 64.97±12.99 kg (p=0.146) and the average muscle mass has decreased significantly from 62.4±12.6 kg to 61.8±12.5 kg (p=0.049). The average basal metabolic rate (BMR) calculated by the device has decreased significantly from 8239.56±1694.38 J to 8150.02±1653.45 J (p=0.037). We have managed to measure the visceral fat (VF) level in the abdomen and the trunk fat percentage (TF%) in 47 participants, in the case of 8 participants, their increased waist circumference limited their fitting under the measuring device. We could not detect any significant change in the VF level after the 12-week training, although the average trunk fat percentage has shown a declining trend, but the change did not reach significant level. Table 4. summarizes the data of the measured and calculated body composition parameters at baseline and after the training program.

Table 4. Body composition parameters at baseline and after the training program

	n	At baseline (mean±SD)	After 12-week training (mean±SD)	Diff (95% CI)
BFM (kg)	55	33.22±13.9	32.61±14.46	-0.61(-1.31;0.09)
BFM (%)	55	33.01±8.26	32.74±8.73	-0.27(-0.87; 0.33)
FFM (kg)	55	65.51±13.17	64.97±12.99	-0.54(1.28;0.19)
MM (kg)	55	62.4±12.6	61.8±12.5	-0.64 (-1.27;-0.004)*
BMR (J)	55	8239.56±1694.38	8150.02±1653.45	-89.55(-173.53; -5.56)*
VF	47	18.1± 5.89	18.23±6.59	0.14(-0.68;0.96)
TF (%)	47	41.4±6.67	41.15±7.51	-0.25(-1.29;0.79)

Abbreviations: SD: Standard Deviation of the mean; BFM: Body Fat Mass; FFM: Fat Free Mass; MM: Muscle Mass. BMR: Basal Metabolic Rate; VF: Visceral Fat; TF: Trunk Fat, CI: Confidence Interval. Paired T-test was used. Level of significance: * <0.05

4.3 Results supporting Hypothesis II.

In this part the changes in the maximal exercise capacity, in the functional capacity and in the laboratory parameters are presented that support Hypothesis II.

4.3.1 Stress-ECG duration time

The average stress-ECG duration time significantly increased after the exercise program (n=51), from 13.74±3.29 minutes to 15.66±2.64 minutes ($p<0.001$).

4.3.2 Maximum exercise capacity in METs

The average maximal exercise capacity improved significantly post intervention (n=51), from 11.02±2.6 MET to 12.14±2 MET ($p<0.001$).

4.3.3 Six Minute Walk Distance

We have found statistically significant change in the average six-minute walk distance (n=54), the 6MWD increased from 539.69±78.62 m to 569.72±79.96 m ($p<0.001$), indicated on Figure 11. A positive correlation was found between the average weekly training time and the increase of 6MWD (r=0.3; p=0.029).

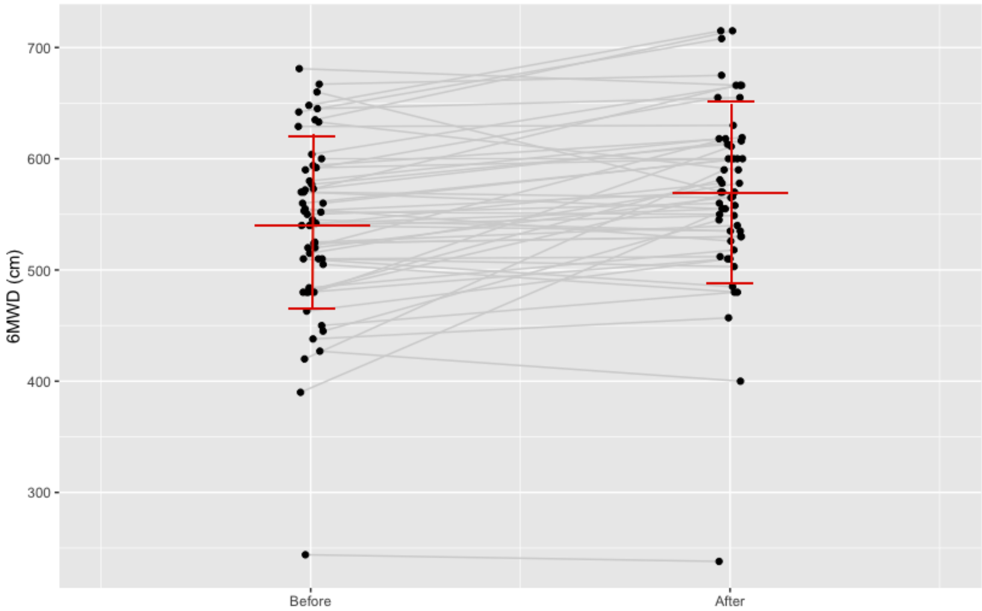

Figure 11. Changes in the 6MWD before and after the training program

4.3.4 Laboratory parameters

We have documented statistically significant changes in the average HDL-C level (n=45), it decreased from 1.28±0.31 mmol/L to 1.68±0.36 mmol/L ($p<0.001$), as indicated on Figure 12.; and in the FPG level (n=47), it decreased from 6.16±1.26 mmol/L to 5.44±1.31 mmol/L (p=0.001). We have found a weak correlation tendency between the average weekly training time and the HDL-C level increase (r=0.23; p=0.137). In 41 patients we have managed to document the HbA1c level and its level significantly decreased from 6.22±0.68% to

5.87±0.78 % (p=0.01), as indicated on Figure 13. There was a declining trend in the triglyceride (TG) level (n=47), from 2.19±1.45 mmol/L to 1.89±0.55 mmol/L (p=0.181), but the change did not reach significant level. The total cholesterol (TC) level change was not significant (5.66±1.38 mmol/L to 5.83±0.94 mmol/L; n=47). Table 5. shows the documented laboratory parameters at baseline and after the training program.

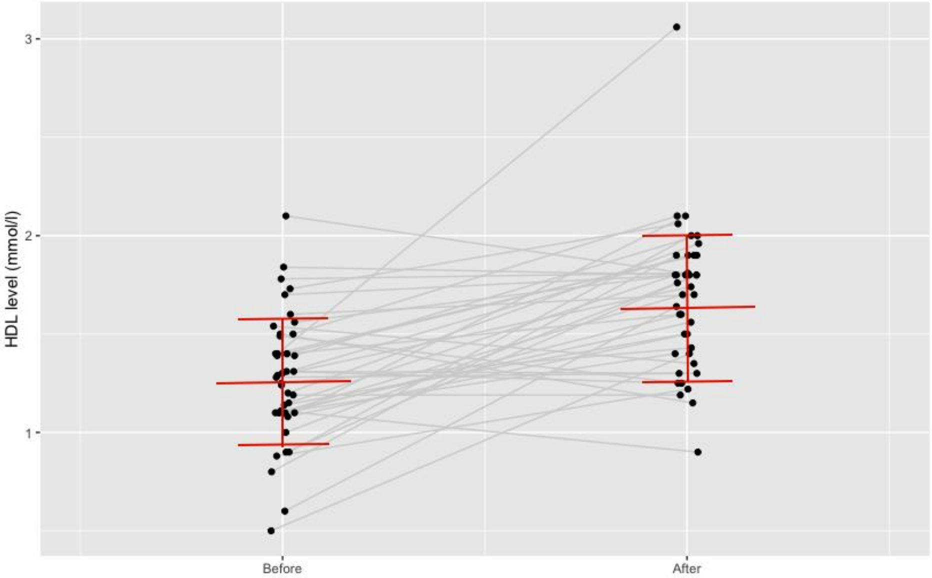

Figure 12. Changes in the HDL-C level before and after the training program

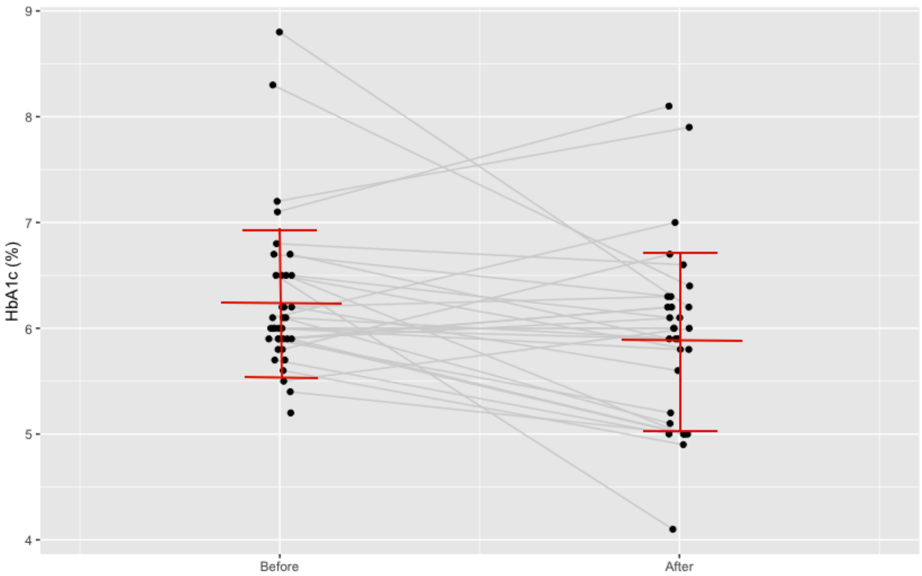

Figure 13. Changes in the HbA1c level before and after the training program

Table 5. Laboratory parameters at baseline and after the training program

	n	At baseline (mean±SD)	After 12-week training (mean±SD)	Diff(95% CI)
HDL-C (mmol/L)	45	1.28±0.31	1.68±0.36	0.40(-0.27;-0.53)**
FPG (mmol/L)	47	6.16±1.26	5.44±1.31	-0.72(-1.11;-0.32)**
HbA1c (%)	41	6.22±0.68	5.87±0.78	-0.35(-0.61;-0.09)*
TG (mmol/L)	47	2.19±1.45	1.89±0.55	-0.29(-0.73;0.14)
TC (mmol/L)	47	5.66±1.38	5.83±0.94	0.18(-0.14;0.49)

Abbreviations: SD: Standard Deviation of the mean; HDL-C: High-Density Lipoprotein-Cholesterol; FPG: Fasting Plasma Glucose; HbA1c: Glycated Hemoglobin A1c; TG: Triglyceride; TC: Total Cholesterol; CI: Confidence Interval. Paired T-test was used. Level of significance: * <0.01, ** <0.001

4.4 Results supporting Hypothesis III.

Out of the 55 patients who finished the monitored training program we managed to collect the completed, self-reported psychological questionnaires from 38 patients (roughly 70%). These 38 cases were included in the statistics. In this part the changes in the psychological state, level of depression, insomnia, vital exhaustion and well-being are presented that support Hypothesis III.

4.4.1 Level of depression

We have not found any statistically significant changes in the scores of the BDI questionnaire. The overall scores decreased from 2.32±2.78 points to 2.18±3.52 points (p=0.709).

4.4.2 Insomnia

We have not found any statistically significant changes in the scores of the AIS questionnaire. The overall scores increased from 2.47±3.20 points to 2.61±4.07 points (p=0.695).

4.4.3 Level of vital exhaustion

We have found statistically significant decrease of the overall scores of the MQ scale (n=38), from 3.37±2.97 points to 2.63±2.70 points (p<0.05).

4.4.4 Well-being

Post intervention there was a significant increase of the overall scores of the WHO-WBS scale (n=38) from 9.92±2.59 points to 10.61±2.76 points (p<0.05). Table 6. shows the scores of the used four psychological questionnaires at baseline and after the training program.

Table 6. Psychological Questionnaire's scores at baseline and after training program

	n	At baseline (mean±SD)	After 12-week training (mean±SD)	Diff (95% CI)
BDI (points)	38	2.32±2.78	2.18±3.52	-0.13(-0.84;0.58)
AIS (points)	38	2.47±3.20	2.61±4.07	0.13(-0.54;0.81)
MQ (points)	38	3.37±2.97	2.63±2.70	-0.74 (-1.44;-0.03)*
WHO-WBS (points)	38	9.92±2.59	10.61±2.76	0.68(0.04;1.32)*

Abbreviations: SD: Standard Deviation of the mean; BDI: Beck Depression Inventory; AIS: Athens Insomnia Scale; MQ: Maastricht Vital Exhaustion Questionnaire; WHO-WBS: WHO-Well Being Scale; CI: Confidence Interval. Paired T-test was used. Level of significance: * <0.05

4.5 Results supporting Hypothesis IV.

We performed a subgroup analysis in the statistics comparing the patients' results in the two different type heart-rate monitoring groups despite the fact that the two groups cannot be considered randomly classified. Group SM (smart watch) included 23 participants [mean age 49.78±6.65 years, 15 men (65.22%) /8 women (33.78%). Group CS+P (chest strap+phone) included 31 patients [mean age 48.48±8.77 years, 20 men (64.52%) /11 women (35.48%)]. There was no significant difference between the groups regarding the age (p=0.555), and the sex (p=0.999). One patient led a training diary because she was not able to use neither the smart watch nor the smartphone properly, therefore we had to exclude her data from the subgroup analysis, but not from the whole population's statistics.

4.5.1 Anthropometric parameters

At baseline, the body height, the body weight, the BMI, the HC and the $WC_{midriff}$ were without significant difference between the subgroups. WC_{navel} was significantly bigger in the smart watch group (Group SW baseline vs Group CS+P baseline, 117.28±17.55 cm vs 108.66±10.65 cm, p=0.044).

After the training program the waist- and hip circumferences, the body weight and BMI have decreased significantly in Group CS+P (baseline vs after training), whereas in Group SW only the HC decreased significantly (baseline vs after training). Table 7. shows the comparison of the two groups.

Table 7. Anthropometric parameters in the two groups before and after the training program

	Baseline (mean±SD)			After training (mean±SD)		Baseline vs after training	
	Group CS+P (n=31)	Group SW (n=23)	P value between groups	Group CS+P (n=31)	Group SW (n=23)	P value Group CS+P	P value Group SW
WC_{navel} (cm)	108.66 ±10.65	117.28 ±17.55	0.044	105.54 ±10.02	116.23 ±18.74	<0.001	0.296
$WC_{midriff}$ (cm)	102.72 ±12.50	110.08 ±14.96	0.062	99.32± 10.78	109.19 ±14.60	<0.001	0.207
HC (cm)	111.51 ±9.35	118.26 ±17.38	0.101	108.56 ±8.78	116.15 ±16.46	<0.001	0.031
Body Height (cm)	172.33 ±9.46	174.39 ±8.53	0.415	Not changed	Not changed	-	-
Body Weight (kg)	94.087 ±18.77	104.75 ±25.22	0.093	91.86± 16.99	104.76 ±25.83	0.001	0.988
BMI (kg/m^2)	31.44± 4.25	34.60± 8.63	0.117	30.748 ±3.95	34.60± 8.73	0.001	0.982

Abbreviations: SD: Standard Deviation of the mean; Group CS+P: chest strap+phone group; Group SW: smart watch group; WC_{navel}: Waist Circumference measured at navel level; $WC_{midriff}$: Waist Circumference measured at the narrowest part of the midriff; HC: Hip Circumference; BMI: Body Mass Index

4.5.2 Body composition parameters

At baseline, the BFM, BFM%, FFM, MM, BMR, VF level and BF% body composition parameters were without significant difference between the groups.

After the training program, there were no significant between group differences regarding most of the body composition parameters, but the BFM has decreased significantly in Group CS+P (baseline vs after training). Table 8. shows the comparison of the two groups.

Table 8. Body composition parameters in the two groups before and after the training program

	Baseline (mean±SD)			After training (mean±SD)		Baseline vs after training	
	Group CS+P (n=31)	Group SW (n=23)	P value between groups	Group CS+P (n=31)	Group SW (n=23)	P value Group CS+P	P value Group SW
BFM (kg)	30.12± 9.19	36.73± 17.94	0.116	28.68± 8.86	37.11± 18.65	0.005	0.417
BFM (%)	32.03± 6.96	33.75± 9.55	0.469	31.23± 7.04	34.04± 10.10	0.076	0.442
FFM (kg)	63.97± 13.98	68.02± 12.00	0.258	63.38± 13.30	67.67± 12.41	0.298	0.442
MM (kg)	60.96± 13.43	64.77± 11.51	0.267	60.18± 12.75	64.45± 11.91	0.096	0.46
BMR (J)	8013.2± 1749.60	8592.2± 1617.41	0.215	7893.3± 1628.45	8555.0± 1657.10	0.058	0.517
VF	n=26 18.6± 6.62	n=17; 17.06± 5.17	0.399	n=28 19± 6.82	n=18 17.25± 6.69	0.964	0.999
TF (%)	n=26 41.72± 5.66	n=17 41.05± 8.81	0.657	n=28 40.69± 6.46	n=18 42.48± 9.14	0.467	0.758

Abbreviations: SD: Standard Deviation of the mean; Group CS+P: chest strap+phone group; Group SW: smart watch group; BFM: Body Fat Mass; FFM: Fat Free Mass; MM: Muscle Mass. BMR: Basal Metabolic Rate; VF: Visceral Fat; TF: Trunk Fat

4.5.3 Exercise tolerance and functional capacity parameters

At baseline, the average Stress-ECG duration time was significantly lower in Group SW (14.84±1.93 min vs 12.33±4.04 min, p=0.01), the maximal exercise tolerance was without significant between group difference.

Stress-ECG duration time and maximal exercise capacity increased significantly only in Group SW (before vs after training), while the 6MWD has increased significantly in both groups.

The average weekly training time achieved tended to be higher in Group SW, but due to considerable dispersal of individual data this difference was statistically not significant. Table 9. shows the comparison between the two groups.

Table 9. Exercise and functional capacity parameters in the two groups before and after the training program

	Baseline (mean±SD)			After training (mean±SD)		Baseline vs after training	
	Group CS+P (n=31)	Group SW (n=23)	P value between groups	Group CS+P (n=31)	Group SW (n=23)	P value Group CS+P	P value Group SW
Stress ECG duration time (min)	14.84± 1.93	12.33± 4.04	0.01	15.03± 4.60	14.81± 4.14	0.814	0.008
Max. exercise tolerance (MET, ml/kg/min)	11.28± 2.38	n=20 11.08± 2.66	0.784	11.8± 2.82	n=20 12.51± 1.36	0.306	0.003
6MWD (m)	537.13 ±58.25	n=22 556.73 ±79.23	0.33	566.87 ±63.09	n=22 588.82 ±69.4	0.003	0.007
Weekly training time (min)	-	-	-	n=29 130.10 ±97.82	170.51 ±111.5	-	-

Abbreviations: SD: Standard Deviation of the mean; Group CS+P: chest strap+phone group; Group SW: smart watch group; ECG: Electrocardiogram; MET: Metabolic Equivalent of Task; 6MWD: 6-minute walk distance

4.5.4 Laboratory parameters

At baseline, the FPG, HbA1c and TG values were not significantly different between the groups.

After the training program HDL-C increased significantly in both groups (before vs after training) while the FPG decrease in Group SW and the HbA1c decrease in Group CS+P was significant. Table 10. shows the comparison of the two groups.

4.5.5 Psychological questionnaires

There was no statistically significant difference between the two groups regarding the average scores of the used psychological questionnaires at baseline. After the training program the MQ scale has decreased significantly in Group SW, but not in Group CS+P. Table 11. shows the comparison between the groups.

Table 10. Laboratory parameters in the two groups before and after the training

	Baseline (mean±SD)			After training (mean±SD)		Baseline vs after training	
	Group CS+P (n=31)	Group SW (n=23)	P value between groups	Group CS+P (n=31)	Group SW (n=23)	P value Group CS+P	P value Group SW
HDL-C (mmol/L)	n=22 1.26± 0.3	n=17 1.26± 0.37	0.999	n=24 1.55± 0.34	n=17 1.8± 0.42	0.001	0.001
FPG (mmol/L)	n=26 6.24± 1.51	n=18 6.18± 0.84	0.857	n=27 5.73± 1.15	n=18 5.35± 0.97	0.07	0.002
HbA1c (%)	n=20 6.36± 0.7	n=14 6.25± 0.73	0.664	n=21 5.9± 0.73	n=14 5.99± 0.92	0.031	0.264
TG (mmol/L)	2.35± 1.76	1.86± 0.76	0.209	n=25 1.9± 0.57	n=22 2.03± 0.52	0.243	0.298
TC (mmol/L)	5.21± 1.46	6.28± 1.03	0.006	5.58± 0.93	6.17± 0.93	0.074	0.635

Abbreviations: SD: Standard Deviation of the mean; Group CS+P: chest strap+phone group; Group SW: smart watch group; HDL-C: High-Density Lipoprotein-Cholesterol; FPG: Fasting Plasma Glucose; HbA1c: Glycated Hemoglobin A1c; TG: Triglyceride; TC: Total Cholesterol

Table 11. Psychological Questionnaire's scores in the two groups before and after program

	Baseline (mean±SD)			After training (mean±SD)		Baseline vs after training	
	Group CS+P (n=31)	Group SW (n=23)	P value between groups	Group CS+P (n=31)	Group SW (n=23)	P value Group CS+P	P value Group SW
BDI (points)	n=21 2.14± 2.57	n=13 1.46± 1.66	0.356	n=21 1.9± 4.01	n=13 1.54± 1.56	0.7	0.794
AIS (points)	n=21 1.48± 1.97	n=13 2.77± 3.75	0.267	n=21 1.24± 2.23	n=13 2.85± 4.47	0.497	0.911
MQ (points)	n=21 2.71± 2.26	n=13 3.08± 2.66	0.687	n=21 2.33± 2.2	n=13 1.77± 1.96	0.442	0.02
WHO-WBS (points)	n=21 10.43± 2.44	n=13 10.15± 2.38	0.748	n=21 11.29± 2.41	n=13 10.62± 2.63	0.098	0.337

Abbreviations: SD: Standard Deviation of the mean; Group CS+P: chest strap+phone group; Group SW: smart watch group; BDI: Beck Depression Inventory; AIS: Athens Insomnia Scale; MQ: Maastricht Vital Exhaustion Questionnaire; WHO-WBS: WHO-Well Being Scale

5. Discussion

Main findings of our study are that a 12-week home-based and telemedically supported training program had a positive effect on many core parameters and components of the Metabolic syndrome. We demonstrated in our study, that the home-based physical exercise training monitored by widely available heart rate monitors and open access software application can produce significant changes in a series of anthropometric, exercise capacity and laboratory parameters, and in the quality of life of cardiometabolic patients within 12 weeks. Therefore, we can say that our study was successful and we were able to establish an interventional architecture which can be integrated in the health care system and can effectively influence central obesity, exercise capacity and psychological state of MetS patients.

The weekly average heart rate monitored training time for the total measured population was 152±116.2 minutes. Out of the 55 participants who completed the program, 22 patients (40%) performed the recommended 150 minutes or more physical activity time during a week. This average weekly training time reached by our patients meets the physical activity guidelines according to which a minimum of 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity per week is recommended to achieve medical benefits[52,53]. However, only 40% of the participants achieved the recommended 150 minutes or more weekly activity time. This ratio indicates that in the case of the majority of our patients (60%) more efforts should have been applied to motivation during the coaching, e.g., with more frequent feedbacks, automatic motivational text messages etc., to develop and improve self-motivation. Promotion of exercise, maintaining interest in physical trainings and enhancing self-motivation on the long-term are key tasks. With the help of online coach systems, the type, the duration, the intensity and other parameters of physical activities performed at home could be continuously followed from a distance by the supervising physiotherapists. Using a fitness device available to the public for telemonitoring, with online feedback from a professional, can also lead to a better adherence to the training program, but the feedback should be regular and motivating. Out of the enrolled 59 patients we only lost 4 patients, who have not finished the program. The drop-out rate was 6.8%. We can find meta-analysis which states that in home-based telemonitored rehabilitation environment the adherence level of participants is higher than in the centre-based environment[57]. Other meta-analysis was not able to document this relationship[58]. Our opinion is therefore that our online training monitoring worked well for this purpose, but all possible efforts should be taken to try to increase the activity time and the adherence to the program.

5.1 Effects of the 12-week, home-based and telemonitored exercise program on the anthropometric and body composition parameters of MetS patients

After the telemonitored training program, we observed statistically significant improvements in the level of all measured anthropometric parameters. The hip circumference (HC) decreased approximately by 3 cm in average; the waist circumferences ($WC_{midriff}$, WC_{navel}) decreased approximately by 2.5 cm in average; patients lost an average of 1.27 kg from their body weight and the BMI also decreased slightly but significantly over the 12 weeks period. Key component of the MetS is abdominal or central obesity that can be defined by the increased waist circumference[20]. Achieving a decrease in the waist circumference is a significant result as this component itself is considered an independent risk factor of the MetS. Furthermore, lowering the waist circumferences and decreasing the body weight positively affect abdominal obesity and are proven to decrease further risk factors of MetS, like the elevated plasma glucose level and T2DM as well[59]. After evaluation of the results in the anthropometric parameters we can say that their positive and significant changes support our Hypothesis I.

In our study we have found parameters of the body composition showing improving tendencies (total body fat mass alone and relative to the body weight, trunk fat percentage) but have not found any statistically significant changes except the muscle mass (MM), which unfortunately decreased instead of increasing. One possible explanation for this could be that body composition measurements do not reproduce as well as anthropometric or bodyweight measurements. They can be affected by many factors, therefore detecting significant changes is more difficult. The muscle mass decrease means that they lost some proportion of their muscles. We must be aware that in this measurement, muscle mass is an estimated parameter, thus we cannot exclude the deviation of the estimation with the change of other parameters. But we cannot exclude that this estimation was correct, so the muscle mass of the participants really decreased. This could partly be explained by the type of training/physical activities they performed at home. We did not set a strict regime for exercising at home, only advised the types of trainings that are recommended for MetS patients (aerobic endurance training combined with resistance training, min. 150 minutes a week) and individually set the intensity (60-80% of the measured maximum heart rate, keeping the pulse in the target zone) but they had their own choice regarding the types of activities. Our sensor system mainly focused on the endurance type trainings. After evaluating these results and for preventing the loss of muscle mass, an exact and stricter exercise protocol (combination of aerobic endurance and resistance training), a sensor system documenting both endurance and resistance trainings and a longer training period (time for adaptation) should be considered and focused on in the future. In our study we have observed no significant changes in the proportion of visceral fat. The importance of visceral fat (deposits between the abdominal organs) is that these are associated with systemic inflammation which is thought to be responsible for the risk of CVD associated with obesity, and insulin resistance that play a key role in the development of the MetS[60, 61]. According to evidence of previous studies summarized in a recent review, it would have been more important to observe reductions in the amount of visceral fat than to see reductions in the body weight or the BMI[62]. On the other hand, it is also supported by evidence that physical activity combined with a healthy diet will result in better improvements regarding many parameters, including the body composition as well, than applying only physical trainings[63, 64]. Evaluating the results of our study on the body composition parameters, their changes do not support Hypothesis I. Therefore, to see more relevant changes in the body composition parameters of MetS patients we should consider adding dietary counseling, combining the telemonitoring of physical exercise and diet and set stricter exercise training regime with a combination of endurance and resistance trainings.

5.2 Effects of the 12-week home-based and telemonitored training program on the maximal exercise capacity and laboratory parameters of MetS patients

After the telemonitored training program, we observed statistically significant improvements in the exercise tolerance (maximal exercise capacity, stress-ECG duration time) and in the functional capacity measured by the 6MWD. The average maximal exercise capacity increased by 1.12 MET and the average stress ECG duration time by roughly 2 minutes. The 6MWD improved by an average of 30 meters. This change, according to *Bohannon and Crouch,* is within the range of the minimal clinically important difference (MCID) for change in the 6MWD for adults with pathology[65]. It has been previously proved by numerous studies on the MetS that increasing the cardiorespiratory fitness (CRF) level of these patients plays a key role in decreasing the risk factors and the actual prevalence of the disease[66]. Moreover, this could positively affect the work ability of these patients, according to *Haufe and college's* study, which concluded that regular and telemonitoring-supported physical activity increases work ability, and this effect is independent of sex and occupation[30]. Although their telemonitored intervention took 6 months, they reported bigger weight loss and exercise capacity improvement than we did in our study, but they could not detect significant HDL-C increase that we could in our study.

One of our most important findings was that after a 12-week home-based telemonitored training we could observe a significant increase in the average HDL-C level of our MetS participants. According to evidence from previous large prospective studies, including the well-known Framingham Heart Study, every 1 mg/dL or 0.026 mmol/L increase in the HDL-C level is associated with a 2-3% decrease in the risk of developing cardiovascular diseases[67]. Referring this finding to our recent study and calculating with a 0.4 mmol/L HDL cholesterol level increase, this could mean an approximately 30% decrease of cardiovascular risks. This improvement, according to some studies, is even better than the improvements that were achieved by using statins or fibrate therapy[68-72]. In addition to effectively reducing LDL-C (low-density lipoprotein cholesterol) levels, statins are also able to increase HDL-C level by 6-14.7%[68-72]. The hallmarks of fibrate therapy are a substantial decrease of plasma TG levels ranging from 30-50% and a moderate increase of HDL-C levels ranging from 5-15%[73]. *Kodama and colleges* in 2007 conducted a meta-analysis on 25 studies assessing the effects of exercise training on HDL-C level. They found a modest but significant HDL-C level increase (0.065 mmol/L) as a result of regular aerobic exercise. According to their work, the minimal amount of exercise volume at which HDL-C level increase occurred was 120 minutes per week[74]. In our study we have obtained bigger average HDL-C increase (0.4 mmol/L) with higher average weekly training time (152±116.2 minutes).

Regarding the glucose metabolism, the average FPG level of our MetS patients decreased significantly after the telemonitored exercise intervention. High level of FPG is by evidence, strongly associated with the risk of developing T2DM. According to the Diabetes Prevention Program (DPP) results 50% of the participants in the lifestyle intervention group had achieved the targeted weight loss (7%) or more by the end of the curriculum (24th week) and 38% had a weight loss of at least 7% at the time of the most recent visit. With an average follow up of 2.8 years, their results showed that lifestyle intervention reduced the incidence of T2DM by 58% compared with placebo[75]. Our study was not as effective as the DPP study in regards of body weight reduction as we put the emphasis on the training activity increase, only a few minutes of general dietary education was applied during the initial visit. After evaluating the results of our study on the exercise tolerance, functional capacity and the laboratory parameters, we can state that their positive changes support our Hypothesis II.

The latest WHO guideline[76] for physical activity and sedentary behavior recommends physical activity specified for people living with selective chronic conditions (such as T2DM or hypertension). They have found strong evidence that physical activity is associated with decreased risk of CVD mortality and decreased levels of HbA1c, blood pressure, BMI and lipids amongst adults with T2DM. For adults with hypertension, there is high-certainty evidence that physical activity decreases risk of progression of cardiovascular disease and reduces blood pressure, while there is moderate-certainty evidence that physical activity reduces the risk of CVD mortality[76]. According to the 2021 European Society of Cardiology Guidelines on cardiovascular disease prevention in clinical practice, consumer-based wearable activity monitors/trackers and home-based and telehealth (mHealth) interventions are now recommended for cardiovascular patients to increase patient participation and long-term adherence to exercise training programs[77].

5.3 Effects of the 12-week home-based and telemonitored training program on the level of depression, insomnia, vital exhaustion, and well-being of MetS patients

After the telemonitored training program, we observed statistically significant improvements in some of the psychological questionnaires' scores (MQ, WHO-WBS), indicating that the vital exhaustion and the well-being state of our patients have improved.

Regarding the changes in the patients' psychological state, we must emphasize that the level of vital exhaustion - one of the most important indicators of chronic stress - decreased significantly after the 12 weeks home-based physical training program. *Pedersen and colleges* in their cohort study investigated the connection between vital exhaustion and MetS, including 3621 participants who did not have MetS at the baseline of their study. During the ten years of follow-up, 186 women (9%) and 120 men (8%) developed MetS and they found that vital exhaustion was associated with a higher risk of MetS, most strongly in men[78]. Therefore, decreasing the level of vital exhaustion, would mean decreasing one potential psychological risk factor of the MetS.

We found a significant increase in the level of well-being as well. *Boylan and Ryff's* 2015 study examined the association between well-being or their components and MetS in 1205 participants in their survey of the Midlife in the US (MIDUS). At their 9-10 years of follow-up, they found a 36.6% MetS prevalence; and life satisfaction, positive affect and personal growth predicted fewer MetS components. They concluded that several dimensions of well-being predicted lower risk of MetS[79]. Therefore, increasing the level of well-being of the participants will result in decreasing the prevalence of MetS. After evaluating the results of our program on the psychological state of MetS patients, we can say that regarding the vital exhaustion and the well-being state, it resulted in positive changes that support Hypothesis III.

The level of depression and the level of insomnia did not change after the telemonitored physical training program. It is important to emphasize that these values were considered normal prior to our telemonitored program. As they did not change, their results do not support Hypothesis III.

5.4 Effects of the usage of different types of heart rate monitoring devices on the measured anthropometric, body composition, exercise tolerance, laboratory and psychological parameters

In Hypothesis IV. we assumed that the usage of two different types of monitoring devices will produce similar results in the two user groups, therefore the type of heart rate monitoring device used will not have a significant effect on the results. The evidence we found just partly supports this hypothesis, as we have detected significant after training differences between the two different device user groups in some of the parameters. The majority of the measured anthropometric parameters and the body fat mass significantly changed in the chest strap plus phone group (except HC, as it changed significantly in both groups), while the exercise tolerance parameters mainly changed in the “smart” watch group (except the 6MWD, as it changed significantly in both subgroups). HDL-C changed significantly in both groups, while the FPG change in the “smart” watch group and the HbA1c change in the chest strap group was significant. Vital exhaustion changed significantly in the “smart” watch group.

Scientific evidence shows that if compared with surface ECG, chest strap is more accurate for monitoring the heart rate then the wrist watches in athletes during endurance training and in cardiac patients as well[80, 81]. In our study, 31 patients were allocated a chest strap plus mobile phone, and 24 patients got a “smart” watch. The distribution of the given-out measuring devices was not random, in some cases we took the patients’ preferences into consideration and the actual device availability also limited us. Patients reported a dislike towards the chest strap because they felt it caused discomfort and tightness on the chest. This corresponds with the results of *Kraal and colleges’* work, in the FIT@Home study, who reported the same problem [7]. Many of the patients preferred using the chest strap with their own mobile phones and did not used the given-out phone, therefore we had to pair their own mobiles with the given-out devices but that not caused any problem.

The "smart" watch tended to record more weekly training time (around 40 minutes more in average) then the chest strap + phone combination. This tendency maybe related with the simplicity of usage of this device worn on the wrist for days. On the other side, the wearing of chest strap was uncomfortable for days, and its application under the underclothes before the training required dressing facility. On the other hand chest strap has a greater accuracy for heart rate determination, which can result in more effective coaching. We cannot exclude, however, the option, that more determined persons were more accepting the discomfort of the chest strap, and the depicted more favorable body weight response is simply a sampling bias.

For preventing the inconvenience of chest straps, *Batalik and colleges* also used the "smart" watches as we did for monitoring the heart rate of cardiac patients (n=56). They compared the effectiveness of 12-week home-based and the regular outpatient rehabilitation programs. They found that the exercise capacity and the QoL improved in both groups without significant between group difference and the "smart" watch provided a proper heart rate monitoring function and successful alternative to outpatient facilities and would recommend the "smart" watch for MetS patients as well[82]. Although we did not compare our telemonitored program with the regular outpatient rehabilitation, but their results still correspond with our study, furthermore we provide more detailed information and results of the telemonitored program. Based on our experience we should support the utilization of chest strap instead of smart watches in patients tolerating both type of devices, however smart watches are viable alternative for patients not tolerating chest strap. Further studies are required to evaluate arm worn optical heart rate monitors promising better patient comfort as well as accuracy higher than that of wrist worn optical devices.

5.5 Limitations

We had several limitations in this present study.

1. We used two different devices for heart rate monitoring to gain monitoring experience with the two different types of devices, although we were not able to allocate these devices randomly. The comparison of the two devices is consequently limited, but the arrangement was first of all suitable for testing the effectiveness of the global telemedical service.

2. We only monitored the physical exercise activities. Dietary counseling and food intake monitoring were not part of our program, although besides regular physical trainings a healthy diet is the other key element in the complex lifestyle interventions of the MetS. In a

currently running study we are assessing the combined effects of exercise telemonitoring and diet logging.

3. Our home-based and telemonitored program lasted for 12 weeks, which is a relatively short period of time. To see results and changes on the long-term, we should increase the duration of the training program to at least 6 months and perform the late follow-up of the patients.

4. Our study ran partially during the two years of the worldwide Covid-19 pandemic. During this time, we were limited in many necessary activities connected to the study protocol, like patient assessments, collecting back some necessary data on time, like the psychological questionnaires from some of our patients.

6. Conclusion and clinical implication

Despite the low sample size and the limited intervention period, our 12-week home-based telemonitored training supported by an affordable, publicly available device system produced positive, statistically significant changes in many core components of the Metabolic syndrome in patients suffering from MetS. Distant patient monitoring is now an available option for following the patients' activities, coaching and feedbacking the home-based interventions. There is an increasing need for these types of facilities in the overloaded healthcare services and during pandemic times, although the exact modes of the procedures should be standardized. Telehealth facilities, including the telemonitoring of certain human parameters or complete exercise trainings with professional support, will extend the possibility for rehabilitation/lifestyle intervention activities beyond in-clinical service centres or inpatient frames to a great number of MetS patients with distant geographical locations. It could also provide a chance for those patients with time restrictions for participating in a regular daytime outpatient service. Since the outbreak of the Covid-19 pandemic we all experienced an increased demand for these kinds of telemedical solutions to provide a service without much human interaction but with healthcare professionals' distant supervision. In conclusion, we can say that our telemonitored program worked well and could work in pandemic situations providing an alternative service in a home-based environment and would be a new therapeutic approach for the increasing number of MetS patients. Therefore, based on our results we suggest these types of interventions to be extended, used and integrated in the national healthcare system in Hungary, as part of the non-pharmacological treatment option in the physiotherapy of MetS patients.

Besides regular physical activities, calorie restricted and healthy diet is another key element in the prevention and the complex lifestyle changing therapy of the MetS. Dietary counseling and food intake monitoring were not part of our program, but as supported by evidence, we suggest combining exercise telemonitoring with diet logging and monitoring through a web- or mobile-based application to see further improvements in the physiological parameters of MetS patients.

The long-lasting effect of lifestyle intervention is crucial. Project type intervention typically documents favorable short-term results, but the prompt withdrawal of telecoaching may abolish the effects. However, decline will never be so prompt as in the case of drug treatment withdrawal. To moderate withdrawal effects more and more studies use patient-owned devices for the intervention, which can be used in the framework of self-care, also after the completion of the telecoached intervention phase. Intermittent late follow-up of the patient can promote the long-term effects of the intervention, allowing detection of patient adherence failures, where repeated coaching phases could be helpful. The assessment of late follow-up episodes could be automated, where algorithms evaluate the data and process the feedback for patients, saving costly human effort.

Regarding the choice of devices, we should recommend the use of chest strap instead of “smart” watches for patients accepting both type of devices. Nevertheless, this preference is not absolute, because in some parameters patients utilizing smart watches performed better, than patients using chest strap and smartphone system. Due to continuous development of devices, we should evaluate in the future also recently marketed arm worn optical sensors.

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8. References

1. World Health Organization (2015): Atlas of eHealth country profiles 2015: the use of eHealth in support of universal health coverage based on the findings of the 2015 global survey on eHealth. ISBN 978 92 4 156521 9, https://www.who.int/goe/publications/atlas_2015/en/
2. World Health Organization. Regional Office for Europe (2016): From innovation to implementation: eHealth in the WHO European Region. World Health Organization. Regional Office for Europe. ISBN 978 92 890 5137 8, https://apps.who.int/iris/handle/10665/326317
3. Huang K., Liu W., He D., Huang B., Xiao D., Peng Y., He Y., Hu H., Chen M., Huang D. (2015). Telehealth interventions versus center-based cardiac rehabilitation of coronary artery disease: a systematic review and meta-analysis. *Eur J Prev Cardiol*. 22:959–71
4. Buckingham S. A., Taylor R. S., Jolly K., Zawada A., Dean S. G., Cowie A., Norton R. J., Dalal H. M. (2016). Home-based versus centre-based cardiac rehabilitation: abridged Cochrane systematic review and meta-analysis. *Open Heart*. 3:e000463. doi:10.1136/openhrt-2016-000463
5. Rawstorn J. C., Gant N., Direito A., Beckmann C., Maddison R. (2016). Telehealth exercise-based cardiac rehabilitation: a systematic review and meta-analysis. *Heart*. 102:1183–1192. doi:10.1136/heartjnl-2015-308966
6. Chan C., Yamabayashi C., Syed N., Kirkham A., Camp P.G. (2016). Exercise Telemonitoring and Telerehabilitation Compared with Traditional Cardiac and Pulmonary Rehabilitation: A Systematic Review and Meta-Analysis. *Physiotherapy Canada*. 68(3);242–251.
7. Kraal J.J., Van den Akker-Van Marle M.E., Abu-Hanna A., Stut W., Peek N., MC Kemps H. (2017). Clinical and cost-effectiveness of home-based cardiac rehabilitation compared to conventional, centre-based cardiac rehabilitation: Results of the FIT@Home study. *European Journal of Preventive Cardiology*. 24(12):1260–1273.
8. Maddison R., Rawstorn J.C., Stewart R.A.H., Benatar J., Whittaker R., Rolleston A., Jiang Y., Gao L., Moodie M., Warren I., Meads A., Gant N. (2019). Effects and costs of real-time cardiac telerehabilitation: randomized controlled noninferiority trial. *Heart*. 105:122–129.

9. Batalik L., Filakova K., Batalikova K., Dosbaba F. (2020). Remotely monitored telerehabilitation for cardiac patients: A review of the current situation. *World J. Clin. Cases*. 8(10): 1818-1831. doi: https://dx.doi.org/10.12998/wjcc.v8.i10.1818
10. Wilhelm M., Abreu A., Adami PE, Ambrosetti M., Antonopoulou M, Biffi A., Cavarretta E., D'Ascenzi F. Gibson I., Grobbee D.E., Iliou M-C., Koskinas K., Marques-Vidal P. Nixdorff U., Papadakis M., Piepoli M.F., Vassiliou V., Wood D., Dendale P., Halle M. (2022). EAPC Core Curriculum for Preventive Cardiology. *Eur J Prev Cardiol* 29:251–274.
11. German C.A., Baum S.J., Ferdinand K.C., Gulati M., Polonsky T.S., Toth P.P., Shapiro M.D. (2022) Defining preventive cardiology: A clinical practice statement from the American Society for Preventive Cardiology. *Am J Prev Cardiol* 12:100432
12. Kósa I. (2023). Az életmódorvosi állapotfelmérés, kockázatelemzés, terápia, követés in Babai L. (2023) Életmódorvostan. ISBN:9789632268712 pp. 71-82.
13. WHO Global Observatory for eHealth (2010). Telemedicine: opportunities and developments in Member States: report on the second global survey on eHealth. World Health Organization. ISBN 978 92 4 156414 https://apps.who.int/iris/handle/10665/44497
14. Latifi R., C.R. Doarn, R.C. Merrell (2021). Telemedicine, Telehealth and Telepresence. Principles, Strategies, Applications and New Directions. ISBN: 978-3-030-56916-7
15. Daragó L., Jung Zs., Ispán F., Bendes R., Dinya E: A telemedicina előnyei és hátrányai. *Orv Hetil*, 2013;154:1167–1171.
16. Győrffy Zs., Békási S., Szathmári-Mészáros N., Németh O (2020): A telemedicina lehetőségei a COVID–19-pandémia kapcsán a nemzetközi és a magyarországi tapasztalatok és ajánlások tükrében. *Orv Hetil*, 161(24): 983–992.
17. Julesz M. (2020): A telemedicina és a COVID–19-világjárvány. *Információs Társadalom* XX;*3*: 27–38. https://dx.doi.org/10.22503/inftars.XX.2020.3.2
18. Máthéné Köteles É., Korom A., Vágvölgyi A., Ábrahám J. E., Szűcs M., Domján A., Barnai M., Kósa I. (2021): Telemedicina használata a fizioterápiában: Metabolikus szindrómás betegek 12 hetes otthoni fizikai tréningjének monitorizálása, kutatásunk és részeredmények bemutatása. *FIZIOTERÁPIA.* 30(4):3-10.

19. Mahmoud I.A.M. Sr.: Usability of Telemedicine in Physical Therapy Rehabilitation: Systematic review. *JMIR Rehabil Assist Technol*. 2021. doi: 10.2196/25250. Epub ahead of print. PMID: 34287208.

20. Alberti K.G.M.M., Eckel R.H., Grundy S.M., Zimmet P.Z., Cleeman J.I., Donato K.A., Fruchart J-C., James W.P.T., Loria C.M., Smith S.C. (2009). Harmonizing the Metabolic Syndrome. A Joint Interim Statement of the International Diabetes Federation Task Force on Epidemiology and Prevention. National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation.* 120(16):1640–1645.

21. Church T.S., Thompson A.M., Katzmarzyk P.T., Sui X, Johannsen N, Earnest C.P., Blair S.N. (2009). Metabolic syndrome and diabetes, alone and in combination, as predictors of cardiovascular disease mortality among men. *Diabetes Care.* 32(7):1289–94.

22. Franco O.H., Massaro J.M., Civil J., Cobain M.R., O'Malley B., D'Agostino R.B. (2009). Trajectories of entering the metabolic syndrome: the Framingham Heart Study. *Circulation.* 120(20):1943–50.

23. Huang P. L. (2009). A comprehensive definition for metabolic syndrome. *Dis Model Mech.* 2(5-6): 231–237.

24. Grundy S.M. (2008). Metabolic Syndrome Pandemic. *Arterioscler. Thromb. Vasc. Biol*. 28:629-636.

25. Szigethy E., Széles Gy., Horváth A., Hidvégi T., Jermendy Gy., Paragh Gy., Blaskó Gy., Ádány R., Vokó Z. (2012): Epidemiology of the metabolic syndrome in Hungary. *Public Health*. 126:143-149.

26. Kékes E., Barna I., Daiki T., Dankovics G., Kiss I. (2013): A metabolikus szindróma „Magyarország Átfogó Egészségvédelmi Szűrőprogramja 2010–2020" 2010–2012. évi tevékenységének tükrében. *Hypertonia és Nephrologia*. 17(2):75-81.

27. Alberti K.G.M.M., Zimmet P., Shaw J. (2006). Metabolic syndrome – a new world-wide definition. A Consensus Statement from the International Diabetes Federation. *Diabet. Med.* 23(5):469-80.

28. Eckel R.H., Jakicic J.M., Ard J.D., de Jesus J.M., Houston Miller N., Hubbard V.S., Lee I-M., Lichtenstein A.H., Loria C.M., Millen B.E., Nonas C.A., Sacks F.M., Smith S.C. Jr, Svetkey L.P., Wadden T.A., Yanovski S.Z. (2014): 2013 AHA/ACC guideline on lifestyle management to reduce cardiovascular risk: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol.* 63:2960–84.

29. Sequi-Dominguez I., Alvarez-Bueno C., Martinez-Vizcaino V., Fernandez-Rodriguez R., del Saz Lara A., Cavero-Redondo I. (2020). Effectiveness of Mobile Health Interventions Promoting Physical Activity and Lifestyle Interventions to Reduce Cardiovascular Risk Among Individuals With Metabolic Syndrome: Systematic Review and Meta-Analysis. *J Med Internet Res* 2022(8):e17790, doi: 10.2196/17790, https://www.jmir.org/2020/8/e17790/

30. Haufe S., Kerling A., Protte G., Bayerle P., Stenner H.T., Rolff S., Sundermeier T., Kück M., Ensslen R., Nachbar L., Lauenstein D., Böthig D., Bara C., Hanke A.A., Terkamp C., Stiesch M., Hilfiker-Kleiner D., Haverich A., Tegtbur U. (2019). Telemonitoring-supported exercise training, metabolic syndrome severity, and work ability in company employees: a randomised controlled trial. *Lancet Public Health*. 4:343–352.

31. Goldbacher E.M., Matthews K.A. (2007). Are Psychological Characteristics Related to Risk of the Metabolic Syndrome? A Review of the Literature. *Ann. Behav. Med.* 34(3):240–252.

32. Nousen E.K., Franco J.G., Sullivan E.L. (2013). Unraveling the mechanisms responsible for the comorbidity between metabolic syndrome and mental health disorders. *Neuroendocrinology*. 98(4):254–266.

33. Noser E., Fischer S., Ruppen J., Ehlert U. (2018). Psychobiological stress in vital exhaustion. Findings from the Men Stress 40+ study. *Journal of Psychosomatic Research*. 105:14–20.

34. Cohen R., Bavishi C., Haider S., Thankachen J., Rozanski A. (2017). Meta-analysis of relation of vital exhaustion to cardiovascular disease events. *Am. J. Cardiol*. 119 (8):1211–1216.

35. Frestad D., Prescott E. (2017). Vital exhaustion and coronary heart disease risk: a systematic review and meta-analysis. *Psychosom. Med.* 79(3):260–272.

36. Nicolucci A., Cercone S., Chiriatti A., Muscas F., Gensini G. and on behalf of the REMOTE Study Group. (2015). A Randomized Trial on Home Telemonitoring for the Management of Metabolic and Cardiovascular Risk in Patients with Type 2 Diabetes. *Diabetes Technology & Therapeutics.* 17(8):563-570.

37. Laustsen S., Oestergaard L.G., van Tulder M., Hjortdal V.E., Petersen A.K. (2020). Telemonitored exercise-based cardiac rehabilitation improves physical capacity and health-related quality of life. *Journal of Telemedicine and Telecare*. 26(1–2) 36–44.

38. Ramachandran H.J., Jiang Y., Tam W.W.S., Yeo T.J., Wang W. (2022). Effectiveness of home-based cardiac telerehabilitation as an alternative to Phase 2 cardiac rehabilitation of coronary heart disease: a systematic review and meta-analysis. *European Journal of Preventive Cardiology.* 29(7):1017–1043.

39. Avila A., Claes J., Gottschalk K., Buys R., Azzawi M., Vanhees L., Cornelissen V. (2018). Home-based rehabilitation with telemonitoring guidance for patients with coronary artery disease (Short-term results of the TRiCH Study): Randomized Controlled Trial. *Journal of Medical Internet Research.* 20(6):e225.

40. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults: Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *JAMA* (2001). 285: 2486–2497.

41. American Thoracic Society (ATS) Statement: Guidelines for the Six-Minute Walk Test. *Am. J. Respir. Crit. Care. Med.* 2002;166:111–117.

42. Fletcher G.F., Balady G.J., Amsterdam E.A., Chaitman B., Eckel R., Fleg J., Froelicher V.F., Leon A.S., Pin˜a I.L., Rodney R., Simons-Morton D.G., Williams M.A., Bazzarre T. (2001). Exercise Standards for Testing and Training, A Statement for Healthcare Professionals From the American Heart Association. *Circulation.* 104:1694-1740.

43. World Health Organization (WHO): Physical Status: the use and interpretation of anthropometry: report of a WHO Expert Committee, Geneva, 1995. ISBN 92 41208546

44. World Health Organization (WHO): Waist circumference and waist–hip ratio: report of a WHO Expert Consultation, Geneva, 2008. ISBN 978 92 4 1501491

45. Beck A.T., Beck R.W. (1972). Shortened version of BDI. *Postgraduate Medicine.* 52: 81–85.

46. Rózsa S., Szadoczky E., Füredi J. (2001). A Beck Depresszió Kérdőív rövidített változatának jellemzői hazai mintán [Psychometric properties of the Hungarian version of the shortened Beck Depression Inventory]. *Psychiatria Hungarica. [The Journal of the Hungarian Psychiatric Association]* 16:384–402.

47. Novak M., Mucsi I., Shapiro C.M., Rethelyi J., Kopp M.S. (2004). Increased utilization of health services by insomniacs- an epidemiological perspective. *Journal of Psychosomatic Research.* 56: 527–536.

48. Appels A., Mulder P. (1989). Fatigue and heart disease. The association between vital exhaustion and past, present and future coronary heart disease. *Journal of Psychosomatic Research.* 33(6):727-738.

49. Kopp M.S., Skrabski A., Szedmak S. (1998). Depressive symptomatology and vital exhaustion are differently related to behavioural risk factors for coronary artery disease. *Psychosomatic Medicine.* 60:752–758.

50. Kopp M.S., Konkoly-Thege B., Balog P., Stauder A., Salavecz G., Rozsa S., Purebl G., Adam S. (2010). Measures of stress in epidemiological research. *Journal of Psychosomatic Research.* 69:211–225.

51. Susanszky E., Konkoly-Thege B., Stauder A., Kopp M. (2006). A WHO Jól-lét Kérdőív rövidített (WBI-5) magyar változatának validálása a Hungarostudy 2002 országos lakossági egészségfelmérés alapján [Validation of the short (5-item) version of the WHO Well-Being Scale based on a Hungarian representative health survey, Hungarostudy 2002]. *Mentalhigiene & Pszichoszomatika [Journal of Mental Health and Psychosomatics]* 7:247–255.

52. Thompson P.D., Buchner D., Pina I.L., Balady G.J., Williams M.A., Marcus B.H., Berra K., Blair S.N., Costa F., Franklin B., Fletcher G.F., Gordon N.F., Pate R.R., Rodriguez B.L., Yancey A.K., Wenger N.K. (2003). Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). *Circulation.* 107:3109–3116.

53. Arnett D.K., Blumenthal R.S., Albert M.A., Buroker A.B., Goldberger Z.D., Hahn E.J., Himmelfarb C.D., Khera A., Lloyd-Jones D., McEvoy J.W., Michos E.D., Miedema M.D., Munoz D., Smith S.C. Jr., Virani S.S., Williams K.A. Sr., Yeboah J., Ziaeian B. (2019). 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation.* 140:596–646.

54. https://flow.polar.com

55. https://flow.polar.com/coach

56. https://www.r-project.org

57. Taheri S., Zaghloul H., Chagoury O. et al (2020). Effect of intensive lifestyle intervention on bodyweight and glycaemia in early type 2 diabetes (DIADEM-I): an open-label, parallel-group, randomised controlled trial. *Lancet Diabetes Endocrinol.* 8:477–489.

58. Chong M.S., Sit J.W.H., Karthikesu K., Chair S.Y. (2021). Effectiveness of technology-assisted cardiac rehabilitation: A systematic review and meta-analysis. *Int. J. Nurs. Stud.* 124:104087.

59. Rothberg A.E., McEwen L.N., Kraftson A.T., Ajluni N., Fowler C.E., Nay C.K., Miller N.M., Burant C.F., Herman W.H. (2017). Impact of weight loss on waist circumference and the components of the metabolic syndrome. *BMJ Open Diabetes Research and Care.* 5 (1):e000341.

60. Engström G., Hedblad B., Stavenow L., Jonsson S., Lind P., Janzon L., Lindgärde F. (2004). Incidence of obesity associated cardiovascular disease is related to inflammation sensitive plasma proteins: a population-based cohort study. *Arterioscler Thromb Vasc Biol.* 24:1498–1502.

61. Strasser B., Arvandi M., Siebert U. (2012). Resistance training, visceral obesity and inflammatory response: a review of the evidence. *Obesity reviews*. 13:578–591.

62. Paley C.A., Johnson M.I. (2018). Abdominal obesity and metabolic syndrome: exercise as medicine? *BMC Sports Sci. Med. Rehabil.* 10:7.

63. Bouchonville M., Armamento-Villareal R., Shah K., Napoli N., Sinacore D.R., Qualls C., Villareal D.T. (2014): Weight Loss, Exercise, or Both and Cardiometabolic Risk

Factors in Obese Older Adults: Results of a Randomized Controlled Trial. *Int J Obes (Lond)*, 38(3): 423–431.

64. Pedersen L.R., Olsen R.H., Anholm C., Astrup A., Eugen-Olsen J., Fenger M., Simonsen L., Walzem R.L., Haugaard S.B., Prescott E. (2019). Effects of 1 year of exercise training versus combined exercise training and weight loss on body composition, low-grade inflammation and lipids in overweight patients with coronary artery disease: a randomized trial. *Cardiovasc Diabetol*. 18(1):127. doi: 10.1186/s12933-019-0934-x.

65. Bohannon R.W., Crouch R. (2017). Minimal clinically important difference for change in 6-minute walk test distance of adults with pathology: a systematic review. *J. Eval. Clin. Pract.* 23:377–381.

66. Myers J., Kokkinos P., Nyelin E. (2019). Physical Activity, Cardiorespiratory Fitness, and the Metabolic Syndrome. Nutrients. 11(7):1652.

67. Gordon D.J., Probstfield J.L., Garrison R.J., Neaton J.D., Castelli W.P., Knoke J.D., Jacobs D.R. Jr., Bangdiwala S., Tyroler H.A. (1989). High density lipoprotein cholesterol and cardiovascular disease: four prospective American studies. *Circulation.* 79:8-15.

68. Downs J.R., Clearfield M., Weis S., Whitney E., Shapiro D.R., Beere P.A., Langendorfer A., Stein E.A., Kruyer W., Gotto A.M. Jr. (1998). Primary prevention of acute coronary events with lovastatin in men and women with average cholesterol levels: results of AFCAPS/TexCAPS. Air Force/Texas Coronary Atherosclerosis Prevention Study. *JAMA.* 279:1615–1622.

69. Simes R.J., Marschner I.C., Hunt D., Colquhoun D., Sullivan D., Stewart R.A., Hague W., Keech A., Thompson P., White H., Shaw J., Tonkin A. (2002). Relationship between lipid levels and clinical outcomes in the Long-term Intervention with Pravastatin in Ischemic Disease (LIPID) Trial: to what extent is the reduction in coronary events with pravastatin explained by on-study lipid levels? *Circulation.* 105:1162–1169.

70. Streja L., Packard C.J., Shephard J., Cobbe S., Ford I. (2002). Factors affecting low-density lipoprotein and high-density lipoprotein cholesterol response to pravastatin in the West of Scotland Primary Prevention Study (WOSCOPS). *Am. J. Cardiol.* 90:731–736.

71. Athyros V.G., Mikhailidis D.P., Papageorgiou A.A., Symeonidis A.N., Mercouris B.R., Pehlivanidis A., Bouloukos V.I., Elisaf M., GREACE Collaborative Group. (2004). Effect of atorvastatin on high density lipoprotein cholesterol and its relationship with coronary events: a subgroup analysis of the GREek Atorvastatin and Coronary-heart-disease Evaluation (GREACE) Study. *Curr. Med. Res. Opin.* 20:627–637.

72. Nissen S.E., Nicholls S.J., Sipahi I., Libby P., Raichlen J.S., Ballantyne C.M., Davignon J., Erbel R., Fruchart J.C., Tardif J.C., Schoenhagen P., Crowe T., Cain V., Wolski K., Goormastic M., Tuzcu E.M., ASTEROID Investigators. (2006). Effect of very high-intensity statin therapy on regression of coronary atherosclerosis: the ASTEROID trial. *JAMA.* 295:1556–1565.

73. Goldenberg I., Benderly M., Goldbourt U. (2008). Update on the use of fibrates: focus on bezafibrate. *Vasc. Health Risk Manag*. 4:131–141.

74. Kodama S., Tanaka S., Saito K., Shu M., Sone Y., Onitake F., Suzuki E., Shimano H., Yamamoto S., Kondo K., Ohashi Y., Yamada N., M.D., Sone H. (2007). Effect of Aerobic Exercise Training on Serum Levels of High-Density Lipoprotein Cholesterol. *Arch. Intern. Med.* 167:999-1008.

75. The Diabetes Prevention Program Research Group (2002). Reduction in the incidence of Type 2 Diabetes with lifestyle intervention or Metformin. *N. Engl. J. Med.* 346(6):393-403.

76. Bull F.C., Al-Ansari S.S., Biddle S., Borodulin K., Buman M.P., Cardon G., Carty C., Chaput J-P., Chastin S., Chou R., Dempsey P.C., DiPietro L., Ekelund U., Firth J., Friedenreich C.M., Garcia L., Gichu M., Jago R., Katzmarzyk P.T., Lambert E., Leitzmann M., Milton K., Ortega F.B., Ranasinghe C., Stamatakis E., Tiedemann A., Troiano R.P., van der Ploeg H.P., Wari V., Willumsen J.F. et al. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br. J. Sports Med*. 54:1451–1462.

77. Visseren F.L.J., Mach F., Smulders Y.M., Carballo D., Koskinas K.C., Bäck M., Benetos A., Biffi A., Boavida J-M., Capodanno D., Cosyns B., Crawford C., Davos C.H., Desormais I., Di Angelantonio E., Franco O.H., Halvorsen S., Hobbs F.D.R., Hollander M., Jankowska E.A., Michal M., Sacco S., Sattar N., Tokgozoglu L., Tonstad S., Tsioufis K.P., van Dis I., van Gelder I.C., Wanner C., Williams B., ESC Scientific Document

Group. (2021). 2021 ESC Guidelines on cardiovascular disease prevention in clinical practice: Developed by the Task Force for cardiovascular disease prevention in clinical practice with representatives of the European Society of Cardiology and 12 medical societies with the special contribution of the European Association of Preventive Cardiology (EAPC). *European Heart Journal.* 42(34), 3227–3337.

78. Pedersen J.M., Lund R., Andersen I., Clark A.J., Prescott E., Rod N.H. (2016). Psychosocial risk factors for the metabolic syndrome: A prospective cohort study. *International Journal of Cardiology*. 215:41–46.

79. Boylan J.M., Ryff C.D. (2015). Psychological Well-being and Metabolic Syndrome: Findings from the MIDUS National Sample. *Psychosom. Med.* 77(5): 548–558.

80. Gillinov S., Etiwy M., Wang R., Blackburn G., Phelan D., Gillinov A.M., Houghtaling P., Javadikasgari H., Desai M.Y. (2017). Variable Accuracy of Wearable Heart Rate Monitors during Aerobic Exercise. *Med Sci Sports Exerc.* 49(8):1697-1703. doi: 10.1249/MSS.0000000000001284.

81. Pasadyn S.R, Soudan M., Gillinov M., Houghtaling P., Phelan D., Gillinov N., Bittel B., Desai M.Y. (2019). Accuracy of commercially available heart rate monitors in athletes: a prospective study. *Cardiovasc Diagn Ther.* 9(4):379-385. doi: 10.21037/cdt.2019.06.05.

82. Batalik L., Dosbaba F., Hartman M., Batalikova K., Spinar J. (2020). Benefits and effectiveness of using a wrist heart rate monitor as a telerehabilitation device in cardiac patients: a randomized controlled trial. *Medicine*. 99:11(e19556). http://dx.doi.org/10.1097/MD.0000000000019556

9. Appendix

9.1 Psychological Questionnaires

9.1.1 Shortened Beck Depression Inventory (Hungarian version)

		egyáltalán nem jellemző	alig jellemző	jellemző	teljesen jellemző
1.	Minden érdeklődésemet elveszítettem mások iránt.				
2.	Semmiben nem tudok dönteni többé.				
3.	Több órával korábban ébredek, mint szoktam, és nem tudok újra elaludni.				
4.	Túlságosan fáradt vagyok, hogy bármit is csináljak.				
5.	Annyira aggódom a testi-fizikai panaszok miatt, hogy másra nem tudok gondolni.				
6.	Semmiféle munkát nem vagyok képes ellátni.				
7.	Úgy látom, hogy a jövőm reménytelen, és a helyzetem nem fog változni.				
8.	Mindennel elégedetlen vagy közömbös vagyok.				
9.	Állandóan hibáztatom magam.				

9.1.2 Shortened Maastricht Vital Exhaustion Questionnaire (Hungarian version)

	nem	**néha**	**gyakran**
1. Gyakran érzi fáradtnak magát?	0	1	2
2. Gyengének érzi magát?	0	1	2
3. Kedvetlenebbnek érzi magát, mint régebben volt?	0	1	2
4. Jobban irritálják apróbb dolgok, mint régen?	0	1	2
5. Érzi úgy néha, hogy a teste olyan, mint egy kimerülő elem?	0	1	2
6. Gyakran érzem boldogtalannak magam.	0	1	2
7. Gyakran vagyok ingerült.	0	1	2

9.1.3 Athens Insomnia Scale (Hungarian version)

Vannak-e alvással kapcsolatos problémái, amelyek az elmúlt hónap során hetente legalább három alkalommal előfordultak?

	NEM OKOZ PROBLÉMÁT	ENYHE PROBLÉMÁT OKOZ	JELENTŐS PROBLÉMÁT OKOZ	SÚLYOS PROBLÉMÁT OKOZ
1. Problémát okoz az elalvás?	0	1	2	3
2. Problémát okoz az éjszakai felébredés?	0	1	2	3
3. Problémát okoz a túl korai ébredés?	0	1	2	3
4. Problémát okoz az alvás teljes időtartama?	0	1	2	3
5. Problémát okoz az alvás minősége (függetlenül attól, hogy mennyit aludt)?	0	1	2	3
6. Befolyásolja nappali közérzetét alvási problémája?	0	1	2	3
7. Befolyásolja nappali (testi, szellemi) teljesítményét alvási problémája?	0	1	2	3

9.1.4 WHO Well-Being Scale (Hungarian version)

Az elmúlt két hét során érezte-e magát	nem jellemző	alig-jellemző	jellemző	teljesen jellemző
1. vidámnak és jókedvűnek?	0	1	2	3
2. nyugodtnak és ellazultnak?	0	1	2	3
3. aktívnak és élénknek?	0	1	2	3
4. ébredéskor frissnek és kipihentnek?	0	1	2	3
5. a napjai tele voltak számára érdekes dolgokkal?	0	1	2	3

9.2 Publications

I.

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Physiological and psychological effects of a 12-week home-based telemonitored training in metabolic syndrome

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Background: Metabolic Syndrome (MetS) increases the risk of cardiovascular diseases (CVD) and affects around one fourth of the population worldwide. In the prevention and treatment regular exercise trainings are inevitable. Providing personal supervision in out/inpatient care settings for such a large target population challenges the healthcare systems, but using telemonitoring of the home-performed trainings could be a promising and widely available option.

Objectives: The aim of this study was to evaluate the physiological and psychological effects of a 12-week home-based physical training program, telemonitored by widely available fitness devices on parameters of MetS patients.

Methods: A total of 55 MetS patients (mean age 49.19 ± 7.93 years) were involved in the study. They were asked to perform 3–5 sessions of exercise activity (min. 150 min) each week for 12 weeks. Trainings were monitored off-line by heart rate sensors, a fitness application and a cloud-based data transfer system. Physiotherapists supervised, coached, and feedback the trainings through an online coach system. We investigated different anthropometric parameters, maximum exercise and functional capacity levels, laboratory parameters, the level of depression, insomnia, vital exhaustion, and wellbeing as well.

Results: The average weekly training time was 152.0 ± 116.2 min. Out of the 55 participants who completed the program, 22 patients (40%) performed the recommended 150 min or more weekly. Patients showed statistically significant changes in: all the measured waist and hip circumferences; 6-min walk distance (6MWD; from 539.69 ± 78.62 to 569.72 ± 79.96 m, $p < 0.001$);

maximal exercise capacity (11.02 ± 2.6 to 12.14 ± 2 MET, $p < 0.001$), stress-electrocardiogram duration time (13.74 ± 3.29 to 15.66 ± 2.64 min, $p < 0.001$); body weight (98.72 ± 21.7 to 97.45 ± 21.76 kg, $p = 0.004$); high-density lipoprotein cholesterol ($n = 45$, 1.28 ± 0.31 to 1.68 ± 0.36 mmol/L, $p < 0.001$); fasting plasma glucose (FPG; $n = 47$, 6.16 ± 1.26 to 5.44 ± 1.31 mmol/L, $p = 0.001$); glycated hemoglobin A1c (HbA1c; $n = 41$, 6.22 ± 0.68 to 5.87 ± 0.78%, $p = 0.01$). Out of the 55 patients who finished the program 38 patients (70%) completed all the psychological questionnaires. We found statistically significant decrease of the overall scores of the Maastricht Vital Exhaustion Questionnaire, from 3.37 ± 2.97 points to 2.63 ± 2.70 points ($p < 0.05$) and a significant increase of the overall scores of the WHO Wellbeing Scale from 9.92 ± 2.59 points to 10.61 ± 2.76 points ($p < 0.05$). We have not found any statistically significant changes in the scores of the Beck Depression Inventory and the Athens Insomnia Scale.

Conclusion: A 12-week home-based telemonitored training supported by an affordable, commonly available device system produces positive, statistically significant changes in many core components in MetS patients. Telemonitoring is a cheap method for coaching and feeding back the home-based interventions.

KEYWORDS

telerehabilitation, telemonitoring, metabolic syndrome, home-based, exercise training, psychological factors

Introduction

Metabolic Syndrome (MetS) is defined by the concomitant presence of cardiometabolic risk factors such as central (abdominal) obesity, high blood pressure, elevated fasting plasma glucose (FPG) and triglyceride levels, and decreased high-density lipoprotein cholesterol level (HDL-C) (1). This condition increases 2–5 times the risk of developing cardiovascular diseases (CVD) and type 2 diabetes mellitus (T2DM) in the next 5–10 years (1) and the occurrence of cardiovascular death by 1.8 times in the next 15 years (2). In developed countries MetS affects around one fourth (20–30%) of the adult population. This ratio is increasing especially amongst the elderly (23.5–40.6%) (3, 4). According to the guideline of the International Diabetes Federation lifestyle interventions, primarily regular physical activity and calorie-restricted healthy diet are essential in other to lose bodyweight and to treat the MetS (5).

Review of the evidence shows that MetS is comorbid with different psychological disorders; obesity (central adiposity) and diabetes (insulin resistance) increase the risk of depression and anxiety. Furthermore depression, anxiety, and MetS all have environmental and behavioral factors in common, increasing their risk of prevalence, such as unhealthy diet, smoking, chronic stress, and physical inactivity. On the other hand after successful weight loss programs the improvement of depression was reported (6, 7). It is also supported by evidence that vital exhaustion (excessive fatigue, loss of energy and demoralization) is an independent risk factor of CVD (8). Based on the findings of two meta-analyses, the relative risks for cardiovascular events are between 1.50 and 2.03 (9, 10).

Changing of the lifestyle is a very cumbersome process; only a very small proportion of the population is able to cope with this alone. The majority of patients require strong coaching, which challenges the Public Health Services, depleting of structural, financial, and human resources. There is another, predetermined conflict pertaining to the patient: a great proportion of the affected patients are in the active age group, where by their occupational activities prohibit the regular visits to outpatient facilities offering therapeutic physical training programs. A further barrier is the time consumption and cost of regular commuting to and from the nearest outpatient clinic. Since the outbreak of the COVID-19 pandemic we should also consider the potential infection hazards related to institutional group training. Services provided through telemedical technology are preferred in this situation to minimize interpersonal contacts between health care workers and patients as well as between patients.

Formal or informal telemedical services are used regularly by a considerable portion of patients. They are measuring their blood sugar and blood pressure in their home regularly and the data are used from a distance by the physician to adjust their drug therapy. Doctors can even diagnose an acute heart attack from a distance through telemedical electrocardiogram systems. Recent studies proved that online telemonitored trainings are as effective as hospital or center based programs in patients with cardiac abnormalities requiring cardiac rehabilitation. These telemonitored programs were characterized by higher patient satisfaction, improved adherence, and higher cost-effectiveness than inpatient or outpatient solutions (11–13).

Few studies have analyzed the psychological effects of home-based telemonitored training in cardiac rehabilitation and most of them only measured changes in quality of life. The results on the quality of life of telehealth intervention are mixed. Some studies have found an improvement in quality of life (14, 15), while other studies have found no significant difference in the increase in quality of life of those treated remotely (16, 17).

The usage of telemedicine for training monitoring of patients with cardiometabolic risk factors but not dependent on close medical supervision could be also a forward-looking decision. This could not only reduce the burden of healthcare facilities, but also save time and cost for the patients. Lots of lifestyle coaching apps are available on the market which make it possible to monitor the actual lifestyle—dietary habits and physical activities—of the patients from a distance. However these solutions are not integrated into the health care system, these are typically practiced only in the field of fitness.

Through the development of infocommunication technologies, “smart” devices are becoming more reliable while with decreasing cost these devices are becoming more broadly available for the general public in everyday life. This advanced technology makes it possible to supervise the home-based training of patients, depicting their heart rate during the training and also delivering information about daylong physical activity. Data are transferred through mobile units to a cloud based datastore, which provides web service for the overview of different aggregation of the home measured data.

Purposes

The primary purpose of our study was to evaluate the physiological and psychological effects of a 12-week home-based physical training program telemonitored by widely available fitness devices in MetS patients.

Materials and methods

Study design and patient recruitment

This study was a prospective non-randomized intervention evaluation study among MetS patients, who were involved in the study between 1st of September 2018 and 31st of January 2020. They were recruited from the city of Szeged (Hungary) and surrounding villages within a 40 km distance. The recruitment was performed in General Practitioners’ offices, occupational physicians’ offices as well as in cardiological inpatients and outpatient facilities. Participants were recruited through a physician’s referral. All subjects were informed about the study protocol and they provided a written informed consent before the enrollment in the study. The study was done in accordance with the Declaration of Helsinki and the study protocol was approved by the Hungarian Medical Research Council (ETT TUKEB), the Ethical Trial Number is 50780-2/2017EKU. Our Clinical trial registration number is NCT05146076.

Inclusion criteria

Voluntary patients, aged between 25 and 70 years, were involved in the study, who practiced only low level of regular physical activity (self-reported, less than 30 min a week), and had at least three risk factors concomitantly from the followings (1):

(a) waist circumference above 102 cm in men and above 88 cm in women,
(b) proved type 2 diabetes mellitus or FPG level above 5.6 mmol/L,
(c) treated hypertension or spontaneous blood pressure $\geq$ 130/85 mmHg,
(d) treated hypertriglyceridemia (HTG) or serum triglyceride (TG) level above 1.7 mmol/L,
(e) serum HDL-C level under 1.03 mmol/L in men, under 1.3 mmol/L in women

In order to manage the telemonitoring devices and data transfer the participants had to be able to use a smartphone and to transfer data from a smart watch to a phone, laptop or personal computer through a wired or wireless (Bluetooth) connection.

Exclusion criteria

Participants were excluded with: any upcoming planned invasive cardiological intervention (percutaneous transluminal coronary angioplasty, coronary artery bypass, valve repair or replacement), uncontrolled hypertension (blood pressure > 160/100 mmHg), type 1 diabetes mellitus (T1DM), T2DM which needed more than one dose of insulin per day, chronic heart failure, chronic renal failure where the estimated Glomerular Filtration Rate < 60 ml/min, oncological diseases, serious cognitive disfunction, lack of cooperation, any known disease or condition that seriously affected the mental and legal capacity, any other conditions preventing regular physical trainings.

Primary and secondary outcome measures

When planning our study, we set two primary outcome measures. One of them was the waist circumference (WC) as it is a basic anthropometric measure to assess abdominal obesity, and its increased proportion serves as one of the risk factors in the MetS by definition (1). Our second primary outcome measure was the 6-min walk distance, the patient's best achievable walked distance in 6 min performed during the 6-min walk test (6MWT), which is a simple field test commonly used to assess functional capacity (18, 19). We considered all other measured parameters (a series of anthropometric, fitness, body composition, metabolic parameters: the hip circumference, the body weight, the body mass index, the stress-ECG duration time, laboratory parameters such as FPG, glycated hemoglobin, triglyceride, high-density lipoprotein and total cholesterol levels, and quality of life) as secondary outcome measures.

Baseline and follow-up patient assessment

The baseline and follow-up medical assessments and the data collection took place in the Department of Medicine, Albert Szent-Györgyi Medical School, University of Szeged, (Szeged, Hungary), while the physiotherapy assessments and the relevant data collection were performed in the Department of Physiotherapy, Faculty of Health Sciences and Social Studies, University of Szeged (Szeged, Hungary). Baseline assessments were performed maximum 1 week before starting the training program, while follow-up evaluation was performed within 1 week of completing of the 12-week training program.

Anthropometric measurements

The following anthropometric measurements were taken by physiotherapists: Body weight measured by the body composition analyzer device (Tanita BC-418, Japan); height in centimeters using a metric staniometer attached to a wall (20); waist circumference measured in cm at navel level and the narrowest part of the midriff; and hip circumference at the level of the greater trochanter (21). Additional details about the procedures of the measurements are presented in **Supplementary material**.

Functional capacity

The functional capacity was measured during the 6MWT by the physiotherapists, in accordance with the American Thoracic Society guideline, on a 30 m long marked track. The distance reached in 6 min (in meters) was measured and documented (18, 19).

Maximal exercise capacity

Under a cardiologist's supervision a 12-channel electrocardiogram (CardioSys, MDE Diagnostic, Walldorf, Germany) was performed at rest and during exercise using an incremental loading in accordance with the Modified Bruce Protocol until the age-predicted maximal heart rate, where this target heart rate was calculated based on the 220-age formula. The maximal capacity in Metabolic Equivalent of Task (MET; ml/kg/min), the maximal heart rate (bpm) systolic and diastolic blood pressure (mmHg) and the time spent on the maximal exercise level in seconds (s) were measured and documented.

Body composition analysis

The body composition analysis was performed with a Bioelectrical Impedance Analysis using a segmental body composition analyzer device (Tanita BC-418, Japan) measuring the following parameters: bodyweight (kg), the total body fat mass (BFM) in kilograms (kg), its ratio referred to the body weight (BFM%), the muscle mass (MM) and, the fat-free mass (FFM) in kilograms (kg). The visceral fat level (VF) in the abdomen and the trunk fat percentage (TF%) were measured with an abdominal fat analyzer device (Tanita ViScan AB-140, Japan). The Body Mass Index (BMI; kg/m^2) and the average basal metabolic rate (BMR) in Joule (J) were calculated by the device and were documented. Additional details about the procedures of the measurements are presented in **Supplementary material**.

Medical evaluation and laboratory parameters

Anamnesis, detailed medical history, available laboratory data, current drug treatment were reviewed by the physicians and documented at the time of the initial medical evaluation. Based on these data and the assessment of the physical status of the patients, the inclusion, and exclusion criteria were checked. Routine echocardiographic evaluation was also performed using a Vivid-e (Boston, Massachusetts, US) cardiac ultrasound machine. Blood samples from 1 month prior to the starting date were accepted and documented at the initial and the final visit.

Psychological questionnaires

During the initial and the final visits the participants were asked to fill in (self-report) the following standardized psychological questionnaires:

1. Shortened Beck Depression Inventory: this self-report instrument contains 9 items from the original 21-item version of BDI, and it is highly correlated with the total score ($r = 0.92$, $p < 0.001$). It is used to determine the intensity and severity of depression. 0–9 points: normal score; 10–18 points: mild

depressive mood; 19–25 points: moderate depressive mood; over 25 points: severe depressive mood (22, 23).

2. Athens Insomnia Scale: the scale consists of eight items which measure sleep complaints. The first five pertains to night-time problems, and the other three items assess the negative consequences of disturbed sleep during the day. Respondents are required to rate positively if they have experienced sleep difficulties at least three times per week during the last month. Each item is rated on a 4-point numerical rating scale (where 0 = no problem at all and 3 = very serious problem). Total scores range from 0 to 24. Higher scores in these AIS measures indicate that responders have severe insomnia symptoms (24).

3. Shortened Maastricht Vital Exhaustion Questionnaire: This is the nine-item form of the original 21-item questionnaire which was used to measure feelings of exhaustion (25). This shortened version was applied in a Hungarian representative health survey, Hungarostudy 1995 (26). Higher scores indicate that responders have severe vital exhaustion symptoms. The correlation between the shortened Hungarian version and the original Dutch 21-item scale is high $r = 0.94$, $p < 0.001$ (27).

4. WHO Wellbeing Scale: It is the most common measure which is used to assess self-reported wellbeing in clinical or follow-up studies. Validation of this questionnaire is based on data from Hungarostudy 2002. The Hungarian version of this scale is a reliable and valid measure of positive quality of life. The Cronbach alpha rate of the scale is 0.84, which refers to a high internal consistency. It is a five-item questionnaire which assesses wellbeing during a period of 2 weeks. The raw score ranges from 0 to 25. A score of 0 represents the worst quality of life and 25 the best (28).

Intervention: Home-based telemonitored physical trainings

After all the assessments were completed, the physiotherapists informed the participants about the details and features of the trainings and the monitoring. They were given an information sheet and each participant received a 15–30 min individual patient education on the usage of the given training monitor device and the procedures of the data transfer. The participants were asked to perform 3–5 trainings (minimum 30 min per session) individually at home, aiming to a minimum of 150 min per week for 12 weeks. There were no restrictions regarding what type of trainings they performed at home (walking, running, cycling, swimming etc.) but they were informed about the recommended and beneficial training types and intensity suitable for MetS patients. The target heart rate zone for the home based training was calculated individually, based on the exercise capacity of the patients and the perceived level of exhaustion in the 60–80% range of the maximal predicted heart rate. Patients were asked to keep their heart rate within this target zone during the physical activities they performed at home.

Training monitoring

The home-based trainings were monitored by two different types of device—a chest strap (Polar H10, Kempele, Finland) wirelessly connected with an android smartphone (Meizu M5c, China) and a free to download fitness application (Polar Beat) or an optical heart rate sensor (Polar M430 GPS running watch, Kempele, Finland)—that were allocated to the patients at the initial visit (29, 30). Both were available in the commercial market for a reasonable price. Additional details about the measuring devices and the procedures of the measurements are presented in **Supplementary material**. The patients were exercising at home on at least 3 days of the week. The physiotherapists reviewed the training activity of every patient weekly and contacted them individually via phone or email giving feedback and trying to motivate the participants. Average time expenditure for an individual consultation was about 10–20 min. **Supplementary Figure 1** shows a diary view of the trainings performed by a participant, while **Supplementary Figure 2** indicates some features of a monitored training that were visible on the website for the monitoring person.

Statistical methods

Power analysis for the study was performed using the software G* Power (Version 3.1.9.2) for power-and-sample size calculation (University of Düsseldorf, Germany). The calculated sample size was 51 based on waist circumferences, working with an effect size $d = 0.45$, alpha as Type I error of 0.05, and a power value of 0.9. Statistical data were reported as the mean ± standard deviation (SD). Paired t-test was used to analyze the effect of the training on several parameters, whereas we used correlation analysis to measure the strength of connection between two continuous variables. Statistical tests were performed using R statistical software (R version 3.6.2) (31). Values of $p < 0.05$ were considered significant. Diagrams were made also using R statistical software.

Results

Subject population

Altogether 59 MetS patients (37 men and 22 women, mean age 49.35 ± 8.51 years) were enrolled in the study. Four participants (two men and two women) dropped out from the program, although they had started and had been allocated a heart rate monitor device but did not finish the program and refused to take part in the final medical and physiotherapy assessments. The dropout rate was 6.8%. Finally 55 patients (35 men and 20 women, mean age 49.19 ± 7.93 years) completed the 12 week home-based telemonitored program. **Table 1** shows the demographic characteristics of the participants. Out of those patients who completed the program, in 4 cases the final exercise

TABLE 1 Demographic characteristic of the participants.

		Number of patients
Gender	Male	35
	Female	20
Qualification	Primary school	4
	Vocational training	4
	High school	29
	University/Collage	18
Economic activity	Homemaker	1
	Employed	19
	Public servant	14
	Self employed	14
	Unemployed	1
	Retired	6
Family status	Single	4
	Civil partnership	8
	Married	36
	Divorced	7

electrocardiogram test and in 1 case the final 6MWT could not be performed either because of health related issues (acute knee injury and pain that limited the walking and cycling ability) or technical problems.

The average weekly heart rate monitored training time was 152 ± 116.2 min. Out of the 55 participants who completed the program, 22 patients (40%) performed the recommended 150 min or more activity time during a week.

None of the assessors (physicians and physiotherapists) reported any adverse events during the initial and final assessments and none of the patients reported any adverse events during the 12 week home-based training program.

Changes in waist circumference

Post intervention the average waist circumference measured at the narrowest part of the midriff ($WC_{midriff}$, 106.17 ± 14 to 103.88 ± 13.5 cm, $p < 0.001$) and the average waist circumference measured at navel level (WC_{navel}, 112.8 ± 14.8 to 110.6 ± 15.5 cm, $p = 0.001$) significantly reduced as indicated in **Figure 1**.

Other anthropometric parameters, such as the average hip circumference (HC, 114.73 ± 13.75 cm to 112.15 ± 13.2 cm, $p < 0.001$), the average body weight and the BMI that we considered secondary outcomes also showed statistically significant improvements. **Table 2** shows the measured anthropometric parameters at baseline and after the training program.

Changes in functional capacity

As can be seen in **Figure 2** the average 6 min walk distance increased ($n = 54$, 6MWD, 539.69 ± 78.62 to 569.72 ± 79.96 m, $p < 0.001$). A positive correlation was found between the average weekly training time and the increase of 6MWD ($r = 0.3$; $p = 0.029$).

Changes observed in the secondary outcome measures

The maximal exercise capacity ($n = 51$, from 11.02 ± 2.6 to 12.14 ± 2 MET, $p < 0.001$), and the time to the maximal exercise level (13.74 ± 3.29 to 15.66 ± 2.64 min, $p < 0.001$) also improved significantly.

Body composition parameters

Post intervention the body composition parameters had not changed significantly. The overall average body fat mass (BFM) showed a decreasing tendency from 33.22 ± 13.9 to 32.61 ± 14.46 kg ($p = 0.087$), but the average body fat mass relative to the body weight had not changed significantly. Surprisingly, the average fat-free mass (FFM) also showed a decreasing tendency. The average BMR calculated by the device had decreased from 8239.56 ± 1694.38 to 8150.02 ± 1653.45 J ($p = 0.037$). We managed to measure the visceral fat (VF) level in the abdomen and the trunk fat percentage (TF%) in 47 participants, in the case of 8 participants, their increased waist circumference limited their ability to fit under the measuring device. Post intervention the VF level did not change significantly, although the average TF% had shown a declining trend, but the change did not reach significant level. **Table 3** shows the measured body composition parameters at baseline and after the training program.

Laboratory parameters

Post intervention the average HDL-C level increased ($n = 45$, from 1.28 ± 0.31 to 1.68 ± 0.36 mmol/L, $p < 0.001$, as indicated in **Figure 3**) and the average FPG level decreased ($n = 47$, from 6.16 ± 1.26 to 5.44 ± 1.31 mmol/L, $p = 0{,}001$). In 41 patients we managed to document the glycated hemoglobin (HbA1c) level and it decreased from 6.22 ± 0.68 to 5.87 ± 0.78% ($p = 0.01$), as indicated in **Figure 4**. There was a declining trend in the triglyceride (TG) level ($n = 47$), but not significantly. The total cholesterol (TC) level did not change. **Table 4** shows the documented laboratory parameters at baseline and after the training program. A weak correlation tendency was found between the average weekly training time and the HDL-cholesterol level increase ($r = 0.23$; $p = 0.137$).

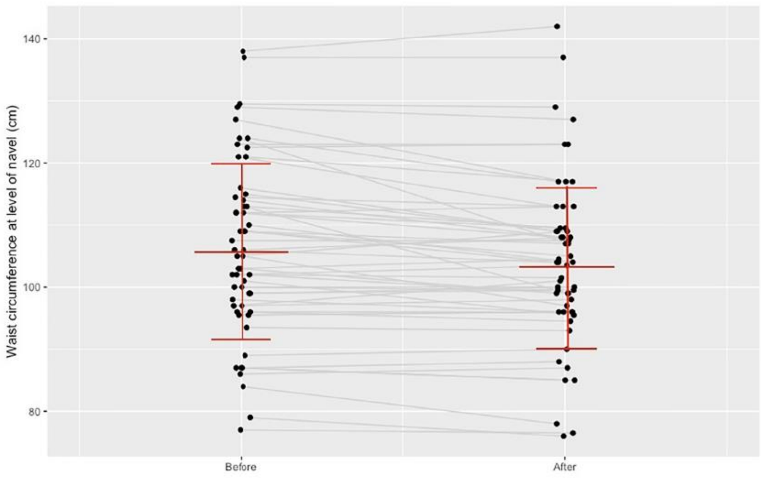

FIGURE 1
Change in the waist circumference measured at navel level before and after the training program.

TABLE 2 Anthropometric parameters at baseline and after the training program.

	n	At baseline (mean ± SD)	After 12-week training (mean ± SD)	Diff (95% CI)
WC_{navel} (cm)	55	112.82 ± 14.82	110.61 ± 15.53	−2.21 (−3.47; −0.95)**
$WC_{midriff}$ (cm)	55	106.17 ± 14.03	103.88 ± 13.5	−2.29 (−3.40; −1.18)**
HC (cm)	55	114.73 ± 13.75	112.15 ± 13.2	−2.58 (−3.50; −1.66)**
Body height (cm)	55	172.9 ± 9.29	n.a.	n.a.
Body weight (kg)	55	98.72 ± 21.7	97.45 ± 21.76	−1.27 (−2.12; −0.41)*
BMI (kg/m²)	55	32.98 ± 6.69	32.58 ± 6.73	−0.41 (−0.68; −0.13)*

SD, standard deviation of the mean; WC_{navel}, waist circumference measured at navel level; $WC_{midriff}$, waist circumference measured at the narrowest part of the midriff; HC, hip circumference; BMI, body mass index; n.a., not applicable. Paired *t*-test was used. Level of significance: $^{*}p < 0.01$, $^{**}p < 0.001$.

Psychological questionnaires

Out of the 55 patients who finished the monitored training program we managed to collect the completed, self-reported questionnaires from 38 patients (roughly 70%). These 38 cases were included in the statistics. The overall scores of the Vital Exhaustion Scale decreased ($n = 38$, from 3.37 ± 2.97 points to 2.63 ± 2.70 points, $p < 0.05$) and the overall scores of the WHO Wellbeing Scale increased ($n = 38$, from 9.92 ± 2.59 points to 10.61 ± 2.76 points, $p < 0.05$). The scores of the Beck Depression Inventory and the Athens Insomnia Scale did not change significantly. **Table 5** shows the scores of the four psychological questionnaires used at baseline and after the training program.

Discussion

A key component of the MetS is abdominal or central obesity that can be measured by the increase of waist circumference (1). In our study we have observed a significant decrease in the average WC, a minimal but statistically significant weight loss and BMI decrease over the 12 weeks period. Decrease in the body weight and lowering the waist circumference positively affects abdominal obesity and are proved to decrease other risk factors of MetS like elevated plasma glucose level and hypertension as well (32). Nowadays regular physical exercise is recommended for all diabetic patients, but the management of patients on intensive conservative insulin therapy is relatively complex (33). To

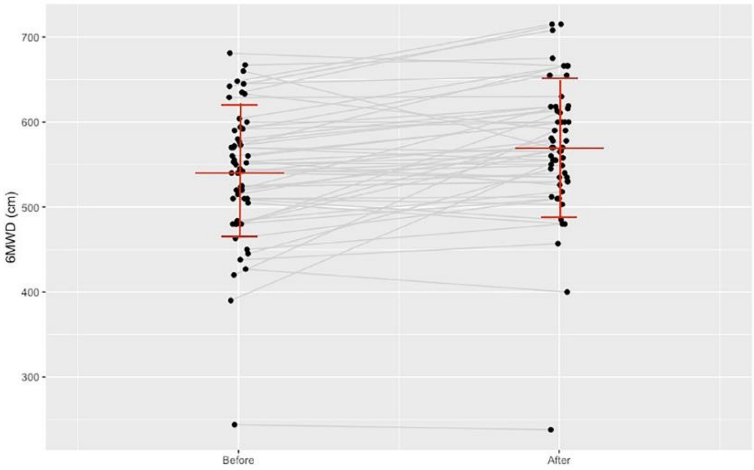

FIGURE 2
Change in the 6-min walk distance before and after the training program.

TABLE 3 Body composition parameters at baseline and after the training program.

	n	At baseline (mean ± SD)	After 12-week training (mean ± SD)	Diff (95% CI)
BFM (kg)	55	33.22 ± 13.9	32.61 ± 14.46	−0.61 (−1.31; 0.09)
BFM (%)	55	33.01 ± 8.26	32.74 ± 8.73	−0.27 (−0.87; 0.33)
FFM (kg)	55	65.51 ± 13.17	64.97 ± 12.99	−0.54 (1.28; 0.19)
MM (kg)		62.4 ± 12.6	61.8 ± 12.5	−0.64 (−1.27; −0.004)*
BMR (J)	55	8239.56 ± 1694.38	8150.02 ± 1653.45	−89.55 (−173.53; −5.56)*
VF	47	18.1 ± 5.89	18.23 ± 6.59	0.14 (−0.68; 0.96)
TF (%)	47	41.4 ± 6.67	41.15 ± 7.51	−0.25 (−1.29; 0.79)

SD, standard deviation of the mean; BFM, body fat mass; FFM, fat free mass; MM, muscle mass; BMR, basal metabolic rate; VF, visceral fat; TF, trunk fat. Paired *t*-test was used. Level of significance: * < 0.05.

avoid this complication in the current, developing phase of telerehabilitation we considered intensive insulin therapy as an exclusion criteria. With the maturation of monitoring tools, in subsequent studies we should also include such patients, because they form an important subgroup of the MetS population.

Our telemonitored MetS patients achieved significant increase in their exercise tolerance and functional capacity. The average maximal exercise capacity increased by 1.12 MET and the stress ECG duration time by roughly 2 min. The 6MWD improved by an average of 30 m. This is according to Bohannon and Crouch within the range of the minimal clinically important difference for change in the 6MWD for adults with pathology (34). It had been previously proved by numerous studies on the MetS that increasing the cardiorespiratory fitness level of these patients plays a key role in decreasing the risk factors and the prevalence of the disease (35). Moreover this will positively affect the workability of these patients. Haufe and colleagues in their recent study involving 314 MetS patients concluded that regular and telemonitoring-supported physical activity decreased MetS severity and increased workability, and this effect was independent of sex and occupation (36). Although their telemonitored intervention took 6 months, they reported bigger weight loss and exercise capacity improvement than in our study, but they could not detect significant HDL-C increase.

Because in the present study patients with MetS were undergoing intervention, we evaluated separately our data based on the cut-off values of individual MetS risk factors. Characteristics of the population regarding

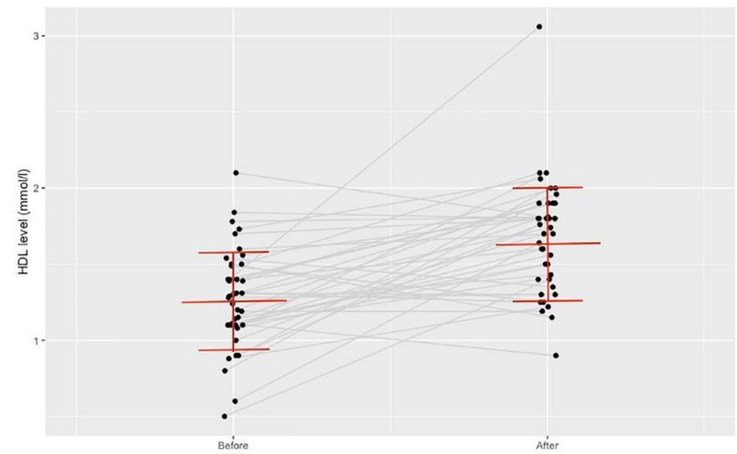

FIGURE 3
Change in high-density lipoprotein-cholesterol level before and after the training program.

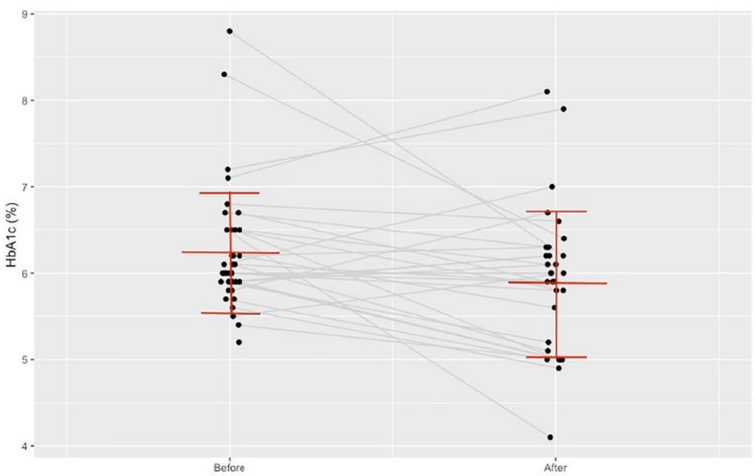

FIGURE 4
Change in glycated hemoglobin A1c level before and after the training program.

the presence of pharmacologically treated diseases (T2DM/Hypertension/Hyperlipidemia), as well as the proportion of abnormal individual MetS risk factors, are listed in Table 6. Drug treatment was unchanged during the intervention, so only changes of continuous variables were listed.

The average weekly training time reached by our patients meets the physical activity guidelines according to which a

TABLE 4 Laboratory parameters at baseline and after the training program.

	n	At baseline (mean ± SD)	After 12-week training (mean ± SD)	Diff (95% CI)
HDL-C (mmol/L)	45	1.28 ± 0.31	1.68 ± 0.36	0.40 (−0.27; −0.53)**
FPG (mmol/L)	47	6.16 ± 1.26	5.44 ± 1.31	−0.72 (−1.11; −0.32)**
HbA1c (%)	41	6.22 ± 0.68	5.87 ± 0.78	−0.35 (−0.61; −0.09)*
TG (mmol/L)	47	2.19 ± 1.45	1.89 ± 0.55	−0.29 (−0.73; 0.14)
TC (mmol/L)	47	5.66 ± 1.38	5.83 ± 0.94	0.18 (−0.14; 0.49)

SD, standard deviation of the mean; HDL-C, high-density lipoprotein-cholesterol; FPG, fasting plasma glucose; HbA1c, glycated hemoglobin A1c; TG, triglyceride; TC, total cholesterol. Paired *t*-test was used. Level of significance: *$p < 0.01$, **$p < 0.001$.

TABLE 5 Psychological Questionnaire's scores at baseline and after training program.

	n	At baseline (mean ± SD)	After 12-week training (mean ± SD)	Diff (95% CI)
BDI (points)	38	2.32 ± 2.78	2.18 ± 3.52	−0.13 (−0.84; 0.58)
AIS (points)	38	2.47 ± 3.20	2.61 ± 4.07	0.13 (−0.54; 0.81)
MQ (points)	38	3.37 ± 2.97	2.63 ± 2.70	−0.74 (−1.44; −0.03)*
WHO-WBS (points)	38	9.92 ± 2.59	10.61 ± 2.76	0.68 (0.04; 1.32)*

SD, standard deviation of the mean; BDI, Beck Depression Inventory; AIS, Athens Insomnia Scale; MQ, Maastricht Vital Exhaustion Questionnaire; WHO-WBS, WHO-Wellbeing Scale. Paired *t*-test was used. Level of significance: * < 0.05.

TABLE 6 Metabolic syndrome risk factors at baseline and after training program.

	Number of cases at baseline	Number of cases after 12-week training (Percentage of baseline numbers)	
		Improved	Worsened
Treated T2DM	10		
Treated hypertension	37		
Treated hyperlipidemia	16		
Abnormal FPG	35	23 (66%)	3 (9%)
Abnormal blood pressure	48	9 (19%)	1 (2%)
Abnormal TG	28	5 (18%)	10 (36%)
Abnormal HDL-C	12	12 (100%)	1 (8%)
Abnormal WC	50	7 (14%)	2 (4%)
Minimum 3 risk factors	55	6 (11%)	0 (0%)

T2DM, type 2 diabetes mellitus; FPG, fasting plasma glucose; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; WC, waist circumference.

minimum of 150 min of moderate-intensity or 75 min of vigorous-intensity physical activity per week is recommended to achieve medical benefits (37, 38). Forty percent of the participants achieved the recommended 150 min or more activity time during a week. This ratio indicates that in the case of the majority of our patients (60%) more efforts should have been applied to the issue of self-motivation.

Promotion of exercise, maintaining interest in physical trainings and enhancing self-motivation long-term are key tasks. With the help of online coach systems the type, the duration, the intensity and other parameters of physical activities performed at home could be continuously followed from a distance by the supervising physiotherapists. Using a fitness device available to the public for telemonitoring, with online feedback from a professional, can lead to a better adherence to the training programs, but the feedback should be regular and motivating. All efforts should be taken to try to increase the activity time. The effect of telemonitoring in the setting of cardiac rehabilitation has been evaluated in several studies. We can find meta-analysis which states that in home-based telemonitored rehabilitation environment the adherence level of participant is higher than in the center-based environment (39). Other meta-analysis was not able to document this relationship (40).

In our study we have found parameters of the body composition showing improving tendencies (total body fat mass alone and relative to the body weight, trunk fat percentage) but have not found any statistically significant changes. One possible explanation for this could be that body composition measurements do not reproduce as well as anthropometric or bodyweight measurements. They can be affected by many factors, therefore detecting significant changes is more difficult. Visceral fat (between the abdominal organs) deposits are associated with systemic inflammation and insulin resistance that play a key role in the development of the MetS. According to evidence of previous studies summarized in a recent review, it is more important to observe reductions in the amount of visceral fat than to see reductions in the body weight or the BMI (41), which we did in our study.

One of our most important findings was that after a 12 week home-based telemonitored training we could observe a significant increase in the HDL-C level of our MetS participants. According to evidence from previous large prospective studies, including the Framingham Heart Study (42), every 1 mg/dL or 0.026 mmol/L increase in the HDL-C level is associated with a 2–3% decrease in the risk of developing CVD. Referring this finding to our recent study, and calculating with a 0.4 mmol/L HDL cholesterol level increase, this could mean an approximately 30% decrease of cardiovascular risks. This improvement, according to some studies, is even better than the improvements that were achieved by using statins or fibrate therapy (43–47). In addition to effectively reducing LDL-C (low-density lipoprotein cholesterol) levels, statins are also able to increase HDL-C level by 6–14.7%. (43–47). The hallmarks of fibrate therapy are a substantial decrease of plasma TG levels ranging from 30 to 50% and a moderate increase of HDL-C levels ranging from 5 to 15% (48). Kodama et al. in 2007 conducted a meta-analysis on 25 studies assessing the effects of exercise training on HDL-C level. They found a modest but significant HDL-C level increase (0.065 mmol/L) as a result of regular aerobic exercise. The minimal amount of exercise volume at which HDL-C level increase occurred was 120 min per week (49). In our study we have obtained bigger HDL-C increase (0.4 mmol/L) with higher weekly training time (152.0 ± 116.2 min).

The FPG level of our MetS patients decreased significantly after the intervention. High level of FPG is by evidence, strongly associated with the risk of developing T2DM. According to the Diabetes Prevention Program (DPP) results 50% of the participants in the lifestyle intervention group had achieved the targeted weight loss (7%) or more by the end of the curriculum (24th week) and 38% had a weight loss of at least 7% at the time of the most recent visit. With an average follow up of 2.8 years, their results showed that lifestyle intervention reduced the incidence of T2DM by 58% compared with placebo (50). Our study was not as effective as the DPP study in regards of body weight reduction as we put the emphasis on the training activity increase, only a few minutes of dietary education were applied during the initial visit.

Regarding the changes in the patients' psychological state we have to emphasize that the level of vital exhaustion—one of the most important indicators of chronic stress—decreased significantly after the home-based physical training program. Pedersen and colleagues in their cohort study investigated the connection between vital exhaustion and MetS, including 3,621 participants who did not have MetS at the baseline of their study. During the 10 years of follow-up, 186 women (9%) and 120 men (8%) developed MetS and they found that vital exhaustion was associated with a higher risk of MetS, most strongly in men (51).

We found a significant increase in the level of wellbeing as well. Boylan and Ryff's (52) study examined the association between wellbeing or their components and MetS in 1205 participants in their survey of the Midlife in the US (MIDUS). At their 9–10 years of follow-up, they found a 36.6% MetS prevalence; and life satisfaction, positive affect and personal growth predicted fewer MetS components. They concluded that several dimensions of wellbeing predicted lower risk of MetS (52).

The level of depression and the level of insomnia did not change after the physical training program. It is important to stress that these values were considered normal prior to our telemonitored program.

The latest WHO guideline (53) for physical activity and sedentary behavior recommends physical activity specified for people living with selective chronic conditions (such as T2DM or hypertension). They have found strong evidence that physical activity is associated with decreased risk of CVD mortality and decreased levels of HbA1c, blood pressure, BMI and lipids amongst adults with T2DM. For adults with hypertension, there is high-certainty evidence that physical activity decreases risk of progression of cardiovascular disease and reduces blood pressure, while there is moderate-certainty evidence that physical activity reduces the risk of CVD mortality (53). According to the 2021 European Society of Cardiology Guidelines on cardiovascular disease prevention in clinical practice, consumer-based wearable activity monitors/trackers and home-based and telehealth (mHealth) interventions are now recommended for cardiovascular patients to increase patient participation and long-term adherence to exercise training programs (54).

The long lasting effect of life style intervention is crucial. Project type intervention typically documents favorable short term results, but the prompt withdrawal of telecoaching may abolish the effects. However, decline will never be so prompt as in the case of drug treatment withdrawal. To moderate withdrawal effects more and more studies use patient-owned devices for the intervention, which can be used in the framework of self-care, also after the completion of the telecoached intervention phase. Intermittent late follow-up of the patient can promote the long term effects of the intervention, allowing detection of patient adherence failures, where repeated coaching phases could be helpful. The assessment of late follow-up episodes could be automated, where algorithms evaluate the data and processed the feedback for patients, sparing costly human effort.

If we apply the special consideration of behavior economy by supplying the patients with the monitoring devices, we have the opportunity to utilize special incentives for late adherence to a life style change (55). It was earlier demonstrated that the effectiveness of life style intervention can be improved by appropriate financial contracting of the patients, where the patients undertake some financial burden at the initiation of the intervention with the promise of reimbursement after successful completion of the program. The appropriate fine tuning of such incentive requires detailed studies.

Limitations

1. We used two different devices that were available on the commercial market for a reasonable price, for monitoring the heart rate during the physical trainings. We intended to gain monitoring experience with the two different types. The comparison of the effectiveness and applicability of the different types of training monitors require further analyses, which exceeds the limits of this publication.
2. In our study we only monitored the home-based physical exercise. Dietary counseling and food intake monitoring were not part of our program, although besides regular physical trainings a healthy diet is the other key element in the complex lifestyle interventions of the MetS. In a running study we will assess the combined effects of exercise and diet.
3. Our home-based telemonitored program lasted for 12 weeks, which is a relatively short period of time. To see results and changes long-term, we should increase the duration of the training program and perform the late follow-up of our patients.
4. Our study ran partially during the 2 years of COVID-19 pandemic. In this time we were limited in gathering some necessary data like the psychological questionnaires from some of our patients.

Clinical implication

Telehealth facilities, including the telemonitoring of certain human parameters or complete exercise trainings with professional support, will extend the possibility for rehabilitation/lifestyle intervention activities beyond in-clinical service centers or inpatient frames to great a number of MetS patients with distant geographical locations. It could also provide a chance for those patients with time restrictions for participating in a regular daytime outpatient service. Since the outbreak of the COVID-19 pandemic we all experienced an increased demand for these kinds of telemedical solutions to provide a service without much human interaction but with healthcare professionals' distant supervision. Our program worked, and could work in pandemic situations providing an alternative service in a home-based environment for the increasing number of MetS patients.

Conclusion

A 12-week home-based telemonitored training supported by an affordable, widely available device system produces positive, statistically significant changes in many core components of the MetS in patients suffering from MetS. Telemonitoring is a cheap method for coaching and providing feedback on home-based interventions. This intervention approach is particularly useful for overloaded healthcare services and during pandemic times, but also has potential for use more broadly to improve the efficiency of healthcare delivery.

Data availability statement

The datasets presented in this article are not readily available due to local restrictions. Requests to access the datasets should be directed to corresponding author.

Ethics statement

The study was done in accordance with the Declaration of Helsinki and the study protocol was approved by the Hungarian Medical Research Council (ETT TUKEB), the Ethical Trial Number is 50780-2/2017EKU.

Author contributions

ÉM, MB, AD, CL, AN, BR, and IK given substantial contributions to the conception, the methodology, and the design of the manuscript. JÁ given substantial contribution in the patient recruitment, selection, and data collection. ÉM, AV, MB, AK, BR, and IK taken part in the investigation, data collection, and the interpretation of the results. MS did the statistical analysis. AD contributed to the project supervision. ÉM participated in writing and drafting the manuscript. MB, AN, BR, and IK revised the manuscript critically. All authors read and approved the final version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcvm.2022.1075361/full#supplementary-material

References

1. Alberti, KGMM, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, et al. Harmonizing the metabolic syndrome a joint interim statement of the international diabetes federation task force on epidemiology and prevention. national heart, lung, and blood institute; american heart association; world heart federation; international atherosclerosis society; and international association for the study of obesity. *Circulation.* (2009) 120:1640–5. doi: 10.1161/CIRCULATIONAHA.109.192644

2. Church TS, Thompson AM, Katzmarzyk PT, Sui X, Johannsen N, Earnest CP, et al. Metabolic syndrome and diabetes, alone and in combination, as predictors of cardiovascular disease mortality among men. *Diabetes Care.* (2009) 32:1289–94. doi: 10.2337/dc08-1871

3. Grundy SM. Metabolic Syndrome Pandemic. *Arterioscler Thromb Vasc Biol.* (2008) 28:629–36. doi: 10.1161/ATVBAHA.107.151092

4. Franco OH, Massaro JM, Civil J, Cobain MR, O'Malley B, D'Agostino RB. Trajectories of entering the metabolic syndrome: the Framingham Heart Study. *Circulation.* (2009) 120:1943–50. doi: 10.1161/CIRCULATIONAHA.109.855817

5. Alberti KGMM, Zimmet P, Shaw J. Metabolic syndrome – a new world-wide definition. A consensus statement from the international diabetes federation. *Diabet Med.* (2006) 23:469–80. doi: 10.1111/j.1464-5491.2006.01858.x

6. Nousen EK, Franco JG, Sullivan EL. Unraveling the mechanisms responsible for the comorbidity between metabolic syndrome and mental health disorders. *Neuroendocrinology.* (2013) 98:254–66. doi: 10.1159/000355632

7. Goldbacher EM, Matthews KA. Are psychological characteristics related to risk of the metabolic syndrome? A review of the literature. *Ann Behav Med.* (2007) 34:240–52. doi: 10.1007/BF02874549

8. Noser E, Fischer S, Ruppen J, Ehlert U. Psychobiological stress in vital exhaustion. Findings from the Men Stress 40+ study. *J Psychosom Res.* (2018) 105:14–20. doi: 10.1016/j.jpsychores.2017.11.019

9. Cohen R, Bavishi C, Haider S, Thankachen J, Rozanski A. Meta-analysis of relation of vital exhaustion to cardiovascular disease events. *Am J Cardiol.* (2017) 119:1211–6. doi: 10.1016/j.amjcard.2017.01.009

10. Frestad D, Prescott E. Vital exhaustion and coronary heart disease risk: a systematic review and meta-analysis. *Psychosom Med.* (2017) 79:260–72. doi: 10.1097/PSY.0000000000000423

11. Chan C, Yamabayashi C, Syed N, Kirkham A, Camp PG. Exercise telemonitoring and telerehabilitation compared with traditional cardiac and pulmonary rehabilitation: A systematic review and meta-analysis. *Physiother Canada.* (2016) 68:242–51. doi: 10.3138/ptc.2015-33

12. Kraal JJ, Van den Akker-Van Marle ME, Abu-Hanna A, Stut W, Peek N, Mc Kemps H. Clinical and cost-effectiveness of home-based cardiac rehabilitation compared to conventional, centre-based cardiac rehabilitation: Results of the FIT@Home study. *Eur J Prev Cardiol.* (2017) 24:1260–73. doi: 10.1177/2047487317710803

13. Maddison R, Rawstorn JC, Stewart RAH, Benatar J, Whittaker R, Rolleston A, et al. Effects and costs of real-time cardiac telerehabilitation: randomised controlled noninferiority trial. *Heart.* (2019) 105:122–9. doi: 10.1136/heartjnl-2018-313189

14. Nicolucci A, Cercone S, Chiriatti A, Muscas F, Gensini G. A randomized trial on home telemonitoring for the management of metabolic and cardiovascular risk in patients with type 2 diabetes. *Diabetes Technol Ther.* (2015) 17:563–70. doi: 10.1089/dia.2014.0355

15. Ramachandran HJ, Jiang Y, Tam WWS, Yeo TJ, Wang W. Effectiveness of home-based cardiac telerehabilitation as an alternative to Phase 2 cardiac rehabilitation of coronary heart disease: a systematic review and meta-analysis. *Eur J Prev Cardiol.* (2022) 29:1017–43. doi: 10.1093/eurjpc/zwab106

16. Avila A, Claes J, Goetschalckx K, Buys R, Azzawi M, Vanhees L, et al. Home-based rehabilitation with telemonitoring guidance for patients with coronary artery disease (Short-term results of the TRiCH Study): Randomized Controlled Trial. *J Med Internet Res.* (2018) 20:e225. doi: 10.2196/jmir.9943

17. Huang K, Liu W, He D, Huang B, Xiao D, Peng Y, et al. Telehealth interventions versus center-based cardiac rehabilitation of coronary artery disease: A systematic review and meta-analysis. *Eur J Prev Cardiol.* (2015) 22:959–71. doi: 10.1177/2047487314561168

18. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS Statement: Guidelines for the Six-Minute Walk Test. *Am J Respir Crit Care Med.* (2002) 166:111–7. doi: 10.1164/ajrccm.166.1.at1102

19. Fletcher GF, Balady GJ, Amsterdam EA, Chaitman B, Eckel R, Fleg J, et al. Exercise standards for testing and training, a statement for healthcare professionals from the american heart association. *Circulation.* (2001) 104:1694–740. doi: 10.1161/hc3901.095960

20. World Health Organization (WHO). *Physical Status: the use and interpretation of anthropometry: report of a WHO Expert Committee.* Geneva: World Health Organization (1995).

21. World Health Organization (WHO). *Waist circumference and waist–hip ratio: report of a WHO Expert Consultation.* Geneva: World Health Organization (2008).

22. Beck AT, Beck RW. Shortened version of BDI. *Postgrad Med.* (1972) 52:81–5. doi: 10.1080/00325481.1972.11713319

23. Rozsa S, Szadoczky E, Furedi J. A beck depresszió kérdőív rövidített változatának jellemzői hazai mintán [Psychometric properties of the Hungarian version of the shortened Beck Depression Inventory]. *Psychiatr Hung.* (2001) 16:384–402.

24. Novak M, Mucsi I, Shapiro CM, Rethelyi J, Kopp MS. Increased utilization of health services by insomniacs- an epidemiological perspective. *J Psychosom Res.* (2004) 56:527–36. doi: 10.1016/j.jpsychores.2004.02.007

25. Appels A, Mulder P. Fatigue and heart disease. The association between vital exhaustion and past, present and future coronary heart disease. *J Psychosom Res.* (1989) 33:727–38. doi: 10.1016/0022-3999(89)90088-3

26. Kopp MS, Skrabski A, Szedmak S. Depressive symptomatology and vital exhaustion are differently related to behavioural risk factors for coronary artery disease. *Psychosom Med.* (1998) 60:752–8. doi: 10.1097/00006842-199811000-00018

27. Kopp MS, Konkoly-Thege B, Balog P, Stauder A, Salavecz G, Rozsa S, et al. Measures of stress in epidemiological research. *J Psychosom Res.* (2010) 69:211–25. doi: 10.1016/j.jpsychores.2009.09.006

28. Susanszky E, Konkoly-Thege B, Stauder A, Kopp M. A WHO Jól-lét Kérdőív rövidített (WBI-5) magyar változatának validálása a Hungarostudy 2002 országos lakossági egészségfelmérés alapján [Validation of the short (5-item) version of the WHO Well-Being Scale based on a Hungarian representative health survey, Hungarostudy 2002]. *Ment Pszichoszomatik.* (2006) 7:247–55. doi: 10.1556/Mental.7.2006.3.8

29. Polar Flow. (2022). Available online at: https://flow.polar.com (accessed October 20, 2022).

30. Polar Flow. (2022). Available online at: https://flow.polar.com/coach (accessed October 20, 2022).

31. *The R Project for Statistical Computing*. (2022). Available online at: https://www.r-project.org (accessed October 20, 2022).

32. Rothberg AE, McEwen LN, Kraftson AT, Ajluni N, Fowler CE, Nay CK, et al. Impact of weight loss on waist circumference and the components of the metabolic syndrome. *BMJ Open Diabetes Res Care*. (2017) 5:e000341. doi: 10.1136/bmjdrc-2016-000341

33. Palermi S, Iacono O, Sirico F, Modestino M, Ruosi C, Spera R, et al. The complex relationship between physical activity and diabetes: an overview. *J Basic Clin Physiol Pharmacol*. (2021) 33:535–47. doi: 10.1515/jbcpp-2021-0279

34. Bohannon RW, Crouch R. Minimal clinically important difference for change in 6-minute walk test distance of adults with pathology: a systematic review. *J Eval Clin Pract*. (2017) 23:377–81. doi: 10.1111/jep.12629

35. Myers J, Kokkinos P, Nyelin E. Physical activity, cardiorespiratory fitness, and themetabolic syndrome. *Nutrients*. (2019) 11:1652. doi: 10.3390/nu11071652

36. Haufe S, Kerling A, Protte G, Bayerle P, Stenner HT, Rolff S, et al. Telemonitoring-supported exercise training, metabolic syndrome severity, and work ability in company employees: a randomised controlled trial. *Lancet Public Health*. (2019) 4:343–52. doi: 10.1016/S2468-2667(19)30075-1

37. Thompson PD, Buchner D, Pina IL, Balady GJ, Williams MA, Marcus BH, et al. Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). *Circulation*. (2003) 107:3109–16. doi: 10.1161/01.CIR.0000075572.40158.77

38. Arnett DK, Blumenthal RS, Albert MA, Buroker AB, Goldberger ZD, Hahn EJ, et al. 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation*. (2019) 140:596–646. doi: 10.1161/CIR.0000000000000725

39. Taheri S, Zaghloul H, Chagoury O, Elhadad S, Ahmed S, El KN, et al. Effect of intensive lifestyle intervention on bodyweight and glycaemia in early type 2 diabetes (DIADEM-I): an open-label, parallel-group, randomised controlled trial. *Lancet Diabetes Endocrinol*. (2020) 8:477–89. doi: 10.1016/S2213-8587(20)30117-0

40. Chong MS, Sit JWH, Karthikesu K, Chair SY. Effectiveness of technology-assisted cardiac rehabilitation: A systematic review and meta-analysis. *Int J Nurs. Stud*. (2021) 124:104087. doi: 10.1016/j.ijnurstu.2021.104087

41. Paley CA, Johnson MI. Abdominal obesity and metabolic syndrome: exercise as medicine? *BMC Sports Sci Med Rehabil*. (2018) 10:7. doi: 10.1186/s13102-018-0097-1

42. Gordon DJ, Probstfield JL, Garrison RJ, Neaton JD, Castelli WP, Knoke JD, et al. High density lipoprotein cholesterol and cardiovascular disease: four prospective American studies. *Circulation*. (1989) 79:8–15. doi: 10.1161/01.CIR.79.1.8

43. Downs JR, Clearfield M, Weis S, Whitney E, Shapiro DR, Beere PA, et al. Primary prevention of acute coronary events with lovastatin in men and women with average cholesterol levels: results of AFCAPS/TexCAPS. Air Force/Texas Coronary Atherosclerosis Prevention Study. *JAMA*. (1998) 279:1615–22. doi: 10.1001/jama.279.20.1615

44. Simes RJ, Marschner IC, Hunt D, Colquhoun D, Sullivan D, Stewart RA, et al. Relationship between lipid levels and clinical outcomes in the Long-term Intervention with Pravastatin in Ischemic Disease (LIPID) Trial: to what extent is the reduction in coronary events with pravastatin explained by on-study lipid levels? *Circulation*. (2002) 105:1162–9. doi: 10.1161/hc1002.105136

45. Streja L, Packard CJ, Shephard J, Cobbe S, Ford I. Factors affecting low-density lipoprotein and high-density lipoprotein cholesterol response to pravastatin in the West of Scotland Primary Prevention Study (WOSCOPS). *Am J Cardiol*. (2002) 90:731–6. doi: 10.1016/S0002-9149(02)02599-7

46. Athyros VG, Mikhailidis DP, Papageorgiou AA, Symeonidis AN, Mercouris BR, Pehlivanidis A, et al. Effect of atorvastatin on high density lipoprotein cholesterol and its relationship with coronary events: a subgroup analysis of the GREek Atorvastatin and Coronary-heart-disease Evaluation (GREACE) Study. *Curr Med Res Opin*. (2004) 20:627–37. doi: 10.1185/030079904125003421

47. Nissen SE, Nicholls SJ, Sipahi I, Libby P, Raichlen JS, Ballantyne CM, et al. Effect of very high-intensity statin therapy on regression of coronary atherosclerosis: the ASTEROID trial. *JAMA*. (2006) 295:1556–65. doi: 10.1001/jama.295.13.jpc60002

48. Goldenberg I, Benderly M, Goldbourt U. Update on the use of fibrates: focus on bezafibrate. *Vasc Health Risk Manag*. (2008) 4:131–41. doi: 10.2147/VHRM.S1434

49. Kodama S, Tanaka S, Saito K, Shu M, Sone Y, Onitake F, et al. Effect of aerobic exercise training on serum levels of high-density lipoprotein cholesterol. *Arch Intern Med*. (2007) 167:999–1008. doi: 10.1001/archinte.167.10.999

50. The Diabetes Prevention Program Research Group. Reduction in the incidence of Type 2 Diabetes with lifestyle intervention or Metformin. *N Engl J Med*. (2002) 346:393–403. doi: 10.1056/NEJMoa012512

51. Pedersen JM, Lund R, Andersen I, Clark AJ, Prescott E, Rod NH. Psychosocial risk factors for the metabolic syndrome: A prospective cohort study. *Int J Cardiol*. (2016) 215:41–6. doi: 10.1016/j.ijcard.2016.04.076

52. Boylan JM, Ryff CD. Psychological well-being and metabolic syndrome: Findings from the MIDUS National Sample. *Psychosom Med*. (2015) 77:548–58. doi: 10.1097/PSY.0000000000000192

53. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med*. (2020) 54:1451–62. doi: 10.1136/bjsports-2020-102955

54. Visseren FLJ, Mach F, Smulders YM, Carballo D, Koskinas KC, Bäck M, et al. 2021 ESC Guidelines on cardiovascular disease prevention in clinical practice: Developed by the Task Force for cardiovascular disease prevention in clinical practice with representatives of the European Society of Cardiology and 12 medical societies with the special contribution of the European Association of Preventive Cardiology (EAPC). *Eur Heart J*. (2021) 42:3227–337.

55. Husain SA, Diaz K, Schwartz JE, Parsons FE, Burg MM, Davidson KW, et al. Behavioral economics implementation: Regret lottery improves mHealth patient study adherence. *Contemp Clin Trials Commun*. (2019) 15:100387. doi: 10.1016/j.conctc.2019.100387

Telemedicina használata a fizioterápiában: Metabolikus szindrómás betegek 12 hetes otthoni fizikai tréningjének monitorizálása, kutatásunk és részeredmények bemutatása

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ABSZTRAKT

Bevezetés: Ismertetésre kerül a telemedicina fogalma, fajtái, előnyei, hátrányai, használati lehetőségei a fizioterápiában, a Metabolikus szindróma (MetS) definíciója, előfordulási gyakorisága, kritériumrendszerei, rizikófaktorai és nem gyógyszeres terápiája, valamint kutatási programunk, amelyben MetS páciensek otthoni fizikai tréningjét telemonitorizáltuk 12 hétig, majd vizsgáltuk a különböző felmért paraméterek változását.

Cél: a MetS betegek, telemedicinális eszközökkel monitorozott otthoni fizikai tréningjének hatására bekövetkező változások vizsgálata volt.

Anyag és módszer: A beválogatott MetS páciensek egyes paramétereit (anthropometriai, terheléses) felmértük, majd 12 hétig otthonukban tréningeztek, pulzusukat a tréningek során folyamatosan monitorozva az általunk biztosított „okos" eszközökkel (Polar M430 GPS Running watch vagy Polar H10 szívfrekvenciamérő mellpánt plusz Meizu M5c mobiltelefon, Polar Beat applikációval). A betegeknek minimum heti 150 percig kellett önállóan tréningezniük, majd a tréningadatokat a Polar rendszerbe szinkronizálniuk, hogy az őket a Polar internetes coach felületen folyamatosan monitorozó gyógytornászok áttekinthessék, felügyeljék a tréningeket és ez alapján folyamatos emailes vagy telefonos visszajelzést adjanak.

Eredmények: 55 MetS beteg (átlag életkoruk 49,19±7,93 év, 35 férfi, 20 nő) fejezte be az otthoni telemonitorizált tréningprogramot. Átlagos heti tréning idejük 152±116,2 perc volt, 40%-uk teljesítette az elvárt heti 150 perc önálló fizikai aktivitást vagy annál többet. Statisztikailag szignifikáns javulást tapasztaltunk a derék-, csípő- és haskörfogat, a maximális teljesítmény, a funkcionális kapacitás és a testtömeg esetében a kiindulási adatokhoz képest.

Limitációk: tréningprogram rövidsége, diétás tanácsadás, táplálkozás monitorozás hiánya, alanyok száma, többféle monitorozó eszköz összehasonlításának hiánya

Megbeszélés: Már 12 hetes telemonitorozott tréning után szignifikáns változások mutathatók ki az egyes anthropometriai és terheléses paraméterekben, kiemelendő a haskörfogat, mint önálló rizikófaktor csökkenése és a maximális teljesítmény javulása.

Kulcsszavak: telemedicina, távmonitorozás, Metabolikus szindróma, otthoni fizikai tréning

Telemedicine in physiotherapy practice: Telemonitoring the 12 week home-based physical trainings of Metabolic syndrome patients, presenting our research and parts of the results

ABSTRACT:

Introduction: *We will introduce the definition, types, advantages and disadvantages of telemedicine, its possible applications in the field of Physiotherapy, the definition, the prevalence, the criteria systems, the risk factors and non-pharmacological treatments of the a Metabolic syndrome (MetS) and we present our research project in which we telemonitored the home-based trainings of MetS patients for 12 weeks and observed the changes in the different measured parameters.*

Objective: *to investigate the changes after the 12 week, home-based and telemonitored physical training programme of the involved MetS patients.*

Material and methods: *Certain parameters (anthropometric, cardiopulmonary fitness) of the involved MetS patients were measured, then the patients individually performed physical trainings at home for 12 weeks, monitoring their heart rate with the provided „smart" devices (Polar M430 GPS Running watch or Polar H10 heart rate monitoring chest strap plus a Meizu M5c mobile phone with Polar Beat application). The patients were instructed to perform minimum 150 minutes of individual physical training weekly and to synchronize their training data to the Polar system, an internet-based coach platform, from which the monitoring Physiotherapists could follow and supervise the activities and sent continuos feedback to the patients via email or phone.*

Results: *55 MetS patients (average age 49.19±7.93 years, 35 men, 20 women) completed the home-based telemonitored training programme. Their average weekly training time was 152±116.2 minutes, 40% of the patients performed the required 150 minutes of physical training a week or more. We observed statistically significant changes in the measured waist and hip circumferences, the maximal exercise and the functional capacity and in the body weight relative to the baseline parameters.*

Limitations: *duration of the training program, lack of dietary counselling and food intake monitoring, number of patients enrolled, lack of comparison of the different training monitoring devices.*

Discussion: *We can observe significant changes in the anthropometry and the exercise tolerance even after a 12 week telemonitored home-based exercise training program, highlighting the decrease in the waist circumference, which is an independent risk factor and the improvement of the cardiorespiratory fitness.*

Keywords: *telemedicine, telemonitoring, metabolic syndrome, home-based physical training*

BEVEZETÉS

A telemedicina fogalma, fajtái

A telemedicina („távorvoslás") tulajdonképpen nem más, mint az információs és kommunikációs technológiák (ICT, Information and Communication Technology), rendszerek használata a medicinában, a gyógyító tevékenység és az egészségügyi szolgáltatások igénybevétele során, a fizikai távolságok leküzdése céljából (1). Az Állami Egészségügyi Ellátó Központ (ÁEEK) honlapján szereplő definíció szerint a telemedicina: „Olyan egészségügyi szolgáltatás, amelynek során az ellátásban részesülő és az ellátó személy közvetlenül nem találkozik, a kapcsolat valamilyen távoli adatátviteli rendszeren keresztül jön létre" (2). Ennek során történhet különféle diagnosztikus vagy terápiás távfelügyeleti eljárás, de a beteg és az egészségügyi szakszemélyzet egymástól földrajzilag távol van, személyesen nem találkoznak, a személyes kapcsolatot online, valamilyen elektronikus rendszeren keresztül oldják meg. Tágabb definíció szerint funkcionálisan ide sorolhatók azok az esetek is, amikor egymástól távoli helyszínen dolgozó egészségügyi szakemberek (pl. háziorvos - klinikai szakorvos) egészségügyi adatokat, információt cserélnek a páciens minőségibb, szakszerűbb ellátása érdekében (távkonzílium vagy szupervízió), amikor a vizsgálatot vagy beavatkozást végző személy távérzékelőkre támaszkodva távolról vezérli a beavatkozást igénylő vizsgálatot vagy intervenciót (táv-manipuláció), amikor a diagnózis alapját adó vizsgálat végzője és a diagnózis felállítója térben elválik egymástól, de interaktív kapcsolatban vannak (távdiagnosztika), illetve amikor az egészségügyi szakszemélyzet jelenlétét a betegnél/betegen levő, őt figyelő jelfogók (detektorok, szenzorok) és jeltovábbítók pótolják (távfelügyelet vagy telemonitoring) (2).

A telemedicinális ellátás várható előnyei közé sorolhatjuk

- az idő- és költséghatékonyságot mind a beteg, mind az egészségügyi személyzet és ellátó rendszer részéről,
- az egészségügyi személyzetre háruló nyomás azonnali csökkenését,
- a várólisták csökkenését,
- a kezelőszemélyzet és a páciens között a direkt fertőzésveszély elhárulását,
- a kórházban való tartózkodási napok csökkenését,
- a betegek fokozott elégedettségét,
- illetve, hogy a szolgáltatás eljuthat mozgásukban korlátozott és földrajzilag távol élő rászorultakhoz utazás nélkül.

A telemedicina hátrányai lehetnek azonban, hogy

- megfelelő technikai feltételekkel, infókommunikációs rendszerekkel, „okos eszközökkel" kell rendelkezni ennek működtetéséhez,
- a szükséges eszközök beszerzése nem mindenhol támogatott anyagilag,
- a társadalom egyes rétegei számára nem hozzáférhetőek ezek a szolgáltatások (pl. internet),
- az idősebb korosztály gyakran nem tudja a szükséges digitális eszközöket használni segítség nélkül,
- illetve az online felállított, esetlegesen helytelen diagnózis hamis biztonságérzetet adhat a pácienseknek, nem érezve szükségét egy további személyes konzultációnak (3, 4).

A telemedicina technikai alkalmazása (az adattovábbítás ideje és résztvevők közti interakciók alapján) alapvetően két módon történhet:

- Azonos (valós) időben (szinkron/„online"/"real-time") módon: jelentős költségekkel járó technika, videókonferencia formájában főleg az azonnali diagnózis felállításához használják, tréningezésnél az online beérkező adatok alapján azonnali visszajelzés adható a páciensnek a hibákról, teljesítményről, a tréningintenzitás valós időben szabályozható, viszont a monitorozást végző személy azonnali beavatkozási lehetőségei korlátozottak egy fellépő ritmuszavar vagy más probléma esetén. Jellemzően ezt alkalmazzák a tele-kardiológiában (tele-EKG), valós idejű kardiológiai rehabilitáció során.
- Időben eltolva (aszinkron/"store and forward") jelleggel: szélesebb körben alkalmazott technika (például a tele-radiológiában, tele-pathológiában), kisebb humánerő és technikai költséggel jár, tréning monitorozás esetén a páciens magának választhatja meg a tréning időpontját, így nagyobb önállósággal bír, nem kell alkalmazkodnia az őt monitorozó szakszemélyzet időbeosztásához, a monitorozó személy szokásos napi/heti munkarendjébe szabadon beilleszthető, az aggregált adatok alapján tréningről tréningre tud iránymutatást adni a vezetett beteg számára, viszont azonnali visszajelzés, feedback nem történik. Az ún. Remote patient monitoring módszerről ezen két technika együttes alkalmazásakor beszélhetünk, ezt jellemzően akut vagy krónikus betegek különböző paramétereinek otthonukban történő megfigyelésére és nyomonkövetésére használják, például a vércukorszint, pulzus, EKG vagy az otthoni dialízisek felügyelete kapcsán. (1, 4, 5).

A Covid-19 pandémia hatásai

A 2020. elején Kínában kitört Covid-19 járványt, az Egészségügyi Világszervezet (WHO, World Health Organization) 2020. márciusában hivatalosan is világjárványnak, pandémiának nyilvánította. Ez nagyban befolyásolta, meggyorsította a telemedicina alkalmazását, fejlesztését az egészségügyben a világon sok helyen, így Magyarországon is, hiszen hirtelen nagy tömegeket kellett ellátni, a fertőzés miatt veszélyt jelentettek és korlátozottá váltak a személyes kontaktusok. Például a háziorvosi praxisokban az online térben történő valós idejű orvos-beteg konzultációk, vizitek vagy az elektronikus recept felírás a felhőbe, a telekardiológiai vagy teleradiológiai ellátás mellett az addig szinte elképzelhetetlennek tűnő egészségügyi területeken is létrejöttek telemedicinális vizsgálatok, diagnózis felállítása, páciensek távmonitorozása, mint például a fogászat vagy a bőrgyógyászat. Bár ezen megoldásokat a járvány okozta kényszer szülte és alakította, nagyban hozzájárultak ahhoz, hogy meginduljon ennek az innovatív területnek a mindennapi gyakorlati alkalmazása, etikai és jogszabályi hátterének szabályozása. A módszer egyre szélesebb körű gyakorlati alkalmazása szükséges ahhoz is, hogy kiderüljenek az esetleges hiányosságok és buktatók, további fejlesztéseket ösztönözve. A telemedicina tehát egy olyan nyitott és folyamatosan változó terület, melybe az újabb és újabb technikai vívmányok, fejlesztések beintegrálhatók.

Telemedicina alkalmazása a fizioterápiában világszerte és Magyarországon

A világ több országában már régóta alkalmazzák a telemedicina típusú szolgáltatásokat számos egészségügyi területen, így a fizioterápia területén is. Természetesen a fizikai jelenléttel megvalósuló hagyományos gyógytornász-beteg találkozást, interakciót nem helyettesíthetik sok esetben, de kiegészíthetik azt, minőségét javíthatják és néhány esetben önállóan is alkalmazhatók. Ha az infókommunikációs technológiák fejlődését nézzük, akkor kezdetben csak telefonon történő konzultációra és előre felvett videós anyagok CD-n történő elküldésére volt lehetőség pl. betegoktatás vagy otthoni torna megtervezése céljából. Manapság viszont már rendelkezésre áll a megfelelő technikai háttér az online, valós idejű gyógytornász és beteg közötti videó-konzultációra, azonnali feedback küldésre, a virtuális valóság vagy különböző interaktív webes felületek és az okostelefonon lévő applikációk használatára is. Tanulmányok bizonyítják, hogy a telemedicinával felügyelt otthoni tréningeknél hasonlóan jó eredményeket lehet elérni, mint az intézeti vagy az ambuláns rehabilitációban, költséghatékonyabb így a terápia, a beteg elégedettség is javul és a terápiás adherencia is jobb lehet (6, 7, 8, 9, 10, 11).

A telemedicina a fizioterápiában mind a prevencióban, mind a rehabilitáció során a segítségünkre lehet. Az elesés prevencióban már régóta alkalmaznak az esés szempontjából nagy rizikójú betegcsoportoknál (idősek, Parkinson-betegek) különböző testen hordható helyzet- és mozgásérzékelő „okos" eszközöket, szenzorokat, melyeken keresztül ellenőrizhető és nyomonkövethető a betegek térbeli helyzete, mozgása, sebessége csökkentve az elesések kockázatát, illetve lehetővé téve a gyors segítségnyújtást riasztás esetén. Stroke rehabilitációban például az egyensúly, koordináció javítására használnak különféle virtuális valóság (VR, Virtual Reality) számítógépes programokhoz kapcsolt eszközöket, „játékokat", melyekkel intézeti bennfekvés alatt és később az otthonában is gyakorolhatja a páciens például a helyes súlyátvitelt, törzskontrollt és egyensúlyozást. A krónikus betegek (2-es típusú cukorbetegség, szívbetegek, krónikus légzőszervi betegek, stb.) hosszútávú gondozásában is jól alkalmazható a telemedicina az öngondoskodás támogatására, lehetővé téve például egyes vitális paraméterek (pl. vércukorszint, vérnyomás, pulzus, EKG), egyéb fontos állapot mutatók (pl. köpet mennyisége, színe, testsúly változás stb.) vagy a fizikai aktivitás (aktivitás monitorok, pulzusmérő óra, mellpánt, pedométer) folyamatos otthoni ellenőrzését, nyomonkövetését, a kóros folyamatok vagy az inaktivitás időben történő felismerését, megelőzését (4). Egyre népszerűbb és megfizethető ma már nemcsak az élsportolók körében, hanem a fizioterápiában is a páciensek otthoni tréningjeinek, fizikai aktivitásának telemonitorozása különböző „okos" eszközökkel és ingyenesen letölthető mobiltelefonos applikációkkal. A telekommunikációs fejlesztéseknek köszönhetően, a távkonzultáció továbbá alkalmas eszköz lehet még a betegek széles körű oktatásában, kihasználva mindkét oldal felé az interaktivitást, illetve az egészségügyi szakemberek, gyógytornászok oktatásában, továbbképzésében is hasznos segítséget ad.

Az egészségügyi veszélyhelyzetben a Magyar Kormány által kiadott 157/2020. (IV.29.) Kormányrendelet alapján bizonyos egészségügyi szolgáltatások nyújtásának nem feltétele a beteg személyes jelenléte, azaz távkonzultációs eszközzel végzett szolgáltatás már hivatalosan is nyújtható és finanszírozottá vált (megfelelő dokumentáció, szakmai protokoll alapján és a betegadatok védelmére nagy hangsúlyt fektetve) sok más terület mellett, a fizioterápia területén is Magyarországon (12).

A Metabolikus szindróma (MetS) és fizioterápiás kezelési lehetőségei

A fejlett országokban szinte népbetegségnek számít, a populáció kb. egy negyedét érinti ez a komplex anyagcserebetegség, a Metabolikus szindróma (MetS). A különböző országokban kissé eltérő kritériumrendszereket alkalmaztak a szindróma definiálására a különböző szervezetek, mint például a WHO, az IDF (International Diabetes Federation = Nemzetközi Diabétesz Szövetség) vagy az AHA (American Heart Association = Amerikai Szívgyógyászati Társaság). Azonban 2009-ben született egy konszenzus és elfogadtak egy harmonizált kritériumrendszert. (13). Magyarországon a Magyar Diabétesz Társaság (MDT) Metabolikus Munkacsoportja 2002-ben fogalmazta meg a tünetegyüttes definícióját: „A metabolikus szindróma civilizációs népbetegség -genetikai prediszpozíció, helytelen életmód és táplálkozás hatására tünetszegényen, lappangva kialakuló anyagcserezavar-, amely atherosclerotikus elváltozásokat okoz és korai cardiovascularis halálozással jár. A folyamat hátterében inzulinrezisztencia áll, amely hyperinsulinaemiával, hypertoniával, centrális elhízással, atherogen dyslipidaemiával, valamint glukózintoleranciával társulhat, de együtt járhat egyéb anyagcsere- és haemostasis-zavarral. A folyamatos progresszió veszélye miatt a kórkép felismerése és az érintett egyének időben történő kezelése népegészségügyi szempontból fontos" (14) és leginkább a IDF kritériumrendszere terjedt el. Hazánkban az előfordulási gyakoriság Szigethy és mtsai 2012-ben publikált, korábbi 20-69 éves populáció reprezentatív felmérése alapján a férfiaknál 38%-ra, a nőknél 30%-ra volt tehető (15), amely egyre fiatalabbaknál, már gyermekkorban is megjelenik (16). Kékes és munkatársai „Magyarország Átfogó Egészségvédelmi Szűrőprogramja 2010–2020" keretén belül 2010 és 2012 között 65 267 egyént mértek fel és vizsgálták a Metabolikus szindróma előfordulását. Eredményeik alapján a Metabolikus szindróma előfordulása 30–37% között mozgott, azt tapasztalták, hogy 45 éves korig a férfiak körében volt gyakoribb, míg 46–65 év között (a menopauza időszakában) a nők körében volt szignifikánsan gyakoribb a szindróma megjelenése, illetve kijelenthető, hogy a magyar populációra jellemző a kóros elhízással összefüggő szénhidrátanyagcsere-zavar és vérnyomás-emelkedés, főleg az aktív, munkaképes korú korosztályban (17). A Metabolikus szindróma rizikófaktorai (centrális/hasi típusú elhízás, magas vérnyomás, emelkedett éhomi vércukorszint, vérzsír értékek és alacsony HDL koleszterinszint) önállóan is, de együtt előfordulva halmozottan kockázatnövelők; a kardiovaszkuláris betegségek (CVD, Cardiovascular Diseases) és a 2-es típusú cukorbetegség (T2DM) előfordulását 2-5-szörösére, míg a betegségből fakadó korai halálozás kockázatát 1,8-szorosára emelik (18). A betegség prevalenciája folyamatosan növekszik annak ellenére, hogy a páciensek saját, aktív közreműködésével, nem gyógyszeres terápiával, azaz rendszeres fizikai tréningen és megfelelő diétán alapuló életmódváltással megelőzhető lehetne.

CÉL

Kutatásunk célja a telemedicinával felügyelt 12 hetes otthoni, önálló fizikai tréning hatására, a MetS betegeknél a különböző felmért paraméterekben bekövetkező változások vizsgálata volt.

ANYAG ÉS MÓDSZER

Vizsgálatunk a Szegedi Tudományegyetem Egészségtudományi és Szociális Képzési Kar Fizioterápiás Tanszék és a Szegedi Tudományegyetem Általános Orvostudományi Kar Preventív Medicina Tanszék együttműködésében zajlott, Szegeden (ETT TUKEB etikai engedély szám: 50780-2/2017EKU). A beteg bevonási időszak 2018. szeptemberétől 2020. januárjáig tartott, ezután a Covid-19 pandémia által bevezetett korlátozások meggátolták a további jelenléti mérések elvégzését. A 25 és 70 év közötti önkéntes résztvevőket háziorvosi praxisokból, Szegedről és kb. 40 km-es vonzáskörzetéből toboroztuk, az alábbi bevonási kritériumoknak megfelelően: alacsony fizikai aktivitású egyén (kevesebb, mint heti 30 óra testmozgást végez) és az alábbi 5 Metabolikus szindróma rizikófaktorból legalább 3-mal egyidejűleg rendelkezik (13):

1) A haskörfogat: férfiaknál 102 cm feletti, nőknél 88 cm feletti;
2) Igazolt 2-es típusú cukorbetegség vagy az éhomi vércukorszint 5,6 mmol/L feletti;
3) Gyógyszeresen kezelt magasvérnyomás vagy a spontán mért vérnyomás ≥130/85 Hgmm;
4) Gyógyszeresen kezelt hipertrigliceridémia vagy a szérum triglicerid szint 1,7 mmol/L feletti;
5) A szérum HDL koleszterinszint értéke: férfiaknál 1,03 mmol/L alatti és nőknél 1,3 mmol/L alatti.

Emellett a résztvevőknek kellett bizonyos alap informatikai jártassággal is rendelkezniük a kiadott "okos" eszközök használatához (mobiltelefon kezelés, tréning indítás, leállítás, tréningadat szinkronizálás), amelyhez természetesen oktatásban részesültek.

A kizárási kritériumok az alábbiak voltak: közeljövőben tervezett invazív kardiológiai beavatkozás (PTCA, koronária bypass vagy billentyű műtét), nem kontrollált magasvérnyomás (>160/100 Hgmm), 1-es típusú cukorbetegség, 2-es típusú cukorbetegség, amely napi egynél több dózis inzulint igényel, krónikus szívelégtelenség, krónikus veseelégtelenség (eGFR < 60 ml/min), rosszindulatú daganatos megbetegedés, súlyos kognitív diszfunkció, kooperáció hiánya, bármely egyéb állapot vagy betegség, amely súlyosan befolyásolja a mentális vagy kognitív képességet, bármely egyéb betegség, amely megakadályozza a rendszeres fizikai tréning elvégzését.

1. ábra | A derékkörfogat mérése

2. ábra | A haskörfogat mérése

Az alap koncepció szerint két karon zajlott volna a kutatás, egy intézetbe bejáró, gyógytornászok személyes felügyelete alatt tréningező és egy távmonitorizált, otthon tréningező csoportban. Mivel a csoportokba sorolás nem teljesen random módon történt (figyelembe vettük a betegek személyes preferenciáit és például a lakhelyüket is), ezért a tréningekre személyesen bejáró csoportba sokkal kevesebb résztvevőt tudtunk bevonni, mint a telemonitorozott, otthon tréningezőbe, így a két csoport statisztikailag nem lett összehasonlítható. Jelen tanulmány tehát csak vizsgálatunk telemonitorozott ágát mutatja be.

A vizsgálatokat az első vizit és a 12 hetes otthoni program végét követően, a záró vizit alkalmával is elvégeztük. A résztvevők felmérése szakorvosi anamnézis felvétellel, fizikális vizsgálattal, nyugalmi és terheléses EKG vizsgálattal kezdődött, majd ezt követően a gyógytornászok felmérték a különböző anthropometriai paramétereket (testmagasság, testtömeg, derék-, has- és csípőkörfogatok) a gyakorlatban használt és elfogadott Egészségügyi Világszervezet (WHO, World Health Organisation) iránymutatásai alapján (19, 20). A testmagasságot (TM) cipő nélkül, álló helyzetben, függőleges falfelület mellett, a falra felszerelt magasságmérő segítségével mértük, méterben megadva. A testtömeget (TT) digitális személymérlegre állva, cipő nélkül és kevés ruházatban mértük, kilogrammban megadva. A testtömeg indexet (BMI, Body Mass Index) a test tömeg (kg) / testmagasság négyzete (m^2) képlet alapján kalkuláltuk. A derékkörfogatot (DK) az alsó bordák és a csípőtaréj közötti terület legkeskenyebb részén (lásd 1. sz. ábra), a haskörfogatot (HK) a köldök magasságában (lásd 2. sz. ábra), a csípőkörfogatot (CSK) pedig a csípő legszélesebb pontján (a trochanter major magasságában) mértük centiméter szalaggal, álló helyzetben a kilégzési fázis végén, centiméterben megadva.

A funkcionális állapot felmérése 6 perces járásteszttel (6MWT) történt az elfogadott ATS (American Thoracic Society) irányelve alapján. Egy 50 m-es (méterenként beosztott) kültéri pályán 6 percig kellett sétálni a résztvevőknek, lehető leggyorsabb tempójukban. A 6 perc alatt megtett távolságot (6MWD), a nyugalmi és a teszt utáni szívfrekvenciát, illetve a teszt közben érzett szubjektív nehézlégzés és kifáradás mértékét (Borg Skála 0-10) dokumentáltuk (21). A páciensek maximális terhelhetőségét terheléses EKG vizsgálat alapján határozták meg, mely szakorvosi felügyelet mellett, futópadon történt (CardioSys, MDE Diagnostic) a módosított Bruce protokollt követve, az elért MET értéket (ml/kg/perc), a nyugalmi és a maximális vérnyomás (Hgmm) és pulzus (ütés/perc) értékeket és a maximális terhelési szint eléréséig tartó időt (perc) dokumentálták.

Az otthoni tréningprogram és a távmonitorozás eszközei

A telemonitorozott tréningcsoportban a pácienseknek a nemzetközi irányelveknek megfelelően (22, 23, 24) heti minimum 150 perc fizikai aktivitást, tréninget kellett teljesíteni, egy-egy alkalommal minimum 30 perces aktivitás volt az elvárt, ezt kértük folyamatosan növelni. Azt, hogy pontosan milyen fizikai aktivitást végezzenek önállóan, nem határoztuk meg, de kaptak tájékoztatást arról, hogy melyek azok az aktivitási formák, tréningtípusok, amelyek ajánlottak Metabolikus szindróma esetén (kocogás, futás, kerékpározás, intervallum tréning stb.). A résztvevők cél tréning pulzus tartománya az első vizit alkalmával egyénileg meghatározásra került a terheléses vizsgálaton elért maximális teljesítmény alapján, illetve a maximális életkori pulzus 60-80%-a közötti tartományban kellett tartaniuk a pulzusukat az otthoni tréningek során.

A pulzus monitorozására kétféle eszközt használtunk:

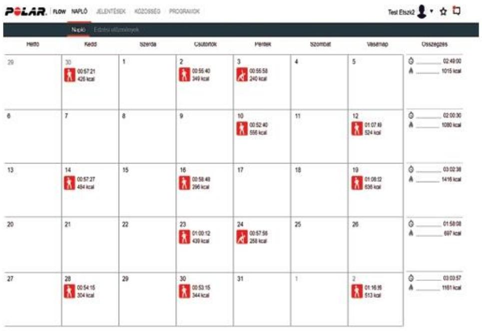
- szívfrekvenciamérő órát (Polar M430 GPS Running watch típusú, lásd 3. sz. ábra)

3. ábra | **Szívfrekvenciamérő óra, optikai érzékelővel**
(képek forrása: https://www.mypolar.hu/polar-m430-fekete-m-l)

- szívfrekvenciamérő mellpántot (Polar H10 típusú) „okos" telefonnal (Meizu M5c típusú) párosítva és a szükséges applikációval ellátva, lásd 4. sz. ábra)

4. ábra | **Szívfrekvenciamérő mellpánt, „okos" telefonnal és applikációval párosítva**

A szívfrekvenciamérő óráról a páciens saját maga önállóan tudja indítani és megállítani a tréningeket, viszont a tréningadatok nem automatikusan szinkronizálódnak az internetes felületre, hanem a páciensnek kell áttölteni azokat számítógéphez, laptophoz kapcsolódva vezetéken keresztül vagy anélkül. Ezzel szemben a mellpántról az adatok a hozzá párosított mobiltelefonon lévő applikációba (Polar Beat) töltődnek, innen automatikusan elérhetők és megtekinthetőek lesznek az internetes coach felületen is, a pácienseknek tehát a tréning indításon és leállításon kívül már nem kell külön szinkronizálni az adatokat. Az eszközöket ingyenesen biztosítottuk a résztvevőknek a 12 hétre, a kiadásuk nem teljesen random módon történt, itt is figyelembe vettük a páciensek igényeit, esetleges informatikai, technikai kérdéseket. A tréningek monitorozását gyógytornászok végezték, a szintén ingyenes Polar Flow internetes coach felületén (https://flow.polar.com/coach, lásd 5. sz. ábra). A páciensek tréningjeit heti szinten ellenőrizték és telefonon vagy emailben tartották a kapcsolatot a résztvevőkkel, akik így visszajelzést kaphattak a teljesített tréningekről, elért eredményekről, de technikai jellegű segítséget is kaphattak például az eszközhasználathoz vagy a tréningadatok áttöltése kapcsán.



5. ábra | **A monitorozó felületen a havi tréningek összesítése naptár nézetben**

Az eredményeket átlag±SD pontossággal adtuk meg. Páros t-tesztet használtunk a felmért paraméterek változásainak tekintetében, szignifikánsnak tekintettük, ha $p<0,05$ lett, illetve a felmért paraméterek korrelációját vizsgáltuk az elért átlagos heti tréningidő függvényében (R Statistical Software, R version 3.6.2, https://www.r-project.org/).

EREDMÉNYEK

A vizsgálat telemedicinális ágára összesen beválogatott 59 főből 55 MetS páciens (átlag életkoruk 49,19±7,93 év, 35 férfi, 20 nő) fejezte be a 12 hetes otthoni tréningprogramot. A résztvevők átlagos heti tréning ideje 152±116,2 perc volt, a páciensek 40%-a (22 fő) teljesítette az elvárt heti 150 perc önálló fizikai aktivitást vagy annál többet.

Minden mért körfogat (derék-, csípő és haskörfogat) esetén statisztikailag szignifikánsan javultak az eredmények a kiindulási adatokhoz képest (lásd 1. sz. táblázat).

Felmért körfogat	Kiinduláskor (átlag±SD)	Tréning után (átlag±SD)	Szignifikancia szint
DK (cm)	106,17±14,03	103,88±13,5	p<0,001
CSK (cm)	114,73±13,75	112,15±13,2	p<0,001

1. táblázat | **A felmért körfogatok változásai**

Rövidítések: DK=Derékkörfogat, CSK=Csípőkörfogat, HK=Haskörfogat, SD=Standard Deviáció

A résztvevők átlagos testtömege minimálisan, de szignifikánsan csökkent (98,72±21,7 kg-ról, 97,45±21,76 kg-ra, p=0,004), valamint az átlagos testtömeg indexük (BMI) is csökkent (32,98±6,69 kg/m^2-ről 32,58±6,73 kg/m^2-re, p=0,005), de nem változott a kategóriájuk.

A páciensek maximális teljesítménye (MET-ben), a maximális terhelési fokozatig eltöltött idő (perc) és a funkcionális kapacitás is jelentősen javult a kiindulási állapothoz viszonyítva (lásd 2. sz. táblázat).

	Kiinduláskor (átlag±SD)	Tréning után (átlag±SD)	Szignifikancia szint
Maximális teljesítmény MET-ben (ml/kg/perc) (n=51)	11,02±2,6	12,14±2	p<0,001
Max. terhelési fokozatig eltöltött idő (perc) (n=51)	13,74±3,29	15,66±2,64	p<0,001
6MWD (m) (n=54)	539,69±78,62	15,66±2,64	p<0,001

2. táblázat | **A terheléses paraméterek változása**

Rövidítések: MET= Metabolikus Ekvivalens, 6MWD=6 perces járástávolság, SD=Standard Deviáció

Emellett pozitív korrelációt találtunk a 6 perces járástávolság növekedése és az átlagos heti tréningidő között (r=0,3; p=0,029).

LIMITÁCIÓK

A tréningprogram 12 hétig tartott, mely alatt megfigyelhettünk kedvező hatásokat és eredményeket rövidtávon, de hosszútávú eredmények elérésére hosszabb időtartamú program és monitorozás (legalább 6 hónap), utánkövetés, illetve a bevont alanyok számának növelése lenne szükséges. A rendszeres mozgás mellett a Metabolikus szindróma terápiájában elengedhetetlen a megfelelő, egészséges étrend alkalmazása, jelen vizsgálatban nem történt diétás tanácsadás vagy táplálék monitorozás, a tréningek monitorozására fordítottuk a hangsúlyt. A pulzus monitorozáshoz kétféle eszközt használtunk (óra, mellkaspánt plusz telefon), a kétféle eszköz hatékonyságáról nem történt összehasonlítás. A jövőben tervezzük a különböző monitorozó eszközök összehasonlítását, illetve a telemonitorozás költséghatékonyságának vizsgálatát is.

MEGBESZÉLÉS

Már 12 hetes telemonitorozott tréning után is szignifikáns kedvező változások mutathatók ki a Metabolikus szindrómás betegek egyes anthropometriai és terheléses paramétereiben. Az anthropometriai paraméterek közül, a felmért körfogatok mindegyike (derék-, csípő- és has-) szignifikánsan csökkent, átlagosan 2 cm-t, de ezek közül is kiemelendő a haskörfogat, mivel az emelkedett haskörfogat, a centrális típusú elhízás BMI-től független mutatója, klinikai szempontból fontos paraméter, a Metabolikus szindróma egyik önálló rizikófaktora is egyben a harmonizált kritériumrendszer alapján (13, 25). De Koning és mtsai 2007-es metaanalízise alapján tudjuk, hogy 1 cm-es haskörfogat emelkedés, 2%-kal emeli a kardiovaszkuláris betegségek relatív rizikóját (26). Vizsgálatunkban a haskörfogatok mellett a páciensek testtömege és testtömegindexe is csökkent, bár minimális mértékben. Korábbi tanulmányokra hivatkozva elmondható, hogy a testtömeg és a haskörfogat csökkentése mérsékli a kardiovaszkuláris betegségek mellett a magas vércukorszint és a 2-es típusú diabétesz mellitusz (azaz a Metabolikus szindróma további rizikófaktorai) kialakulásának kockázatát (27).

A résztvevő Metabolikus szindrómás betegek a 12 hetes otthoni tréning után jobban teljesítettek mind a 6 perces járásteszten, mind a terheléses EKG vizsgálaton. Maximális terhelhetőségük átlagosan 1,12 MET-el nőtt, a maximális terhelési fokozaton eltöltött idő kb. 2 perccel javult és a 6 perces járástávolság átlagosan 30 méterrel növekedett. A maximális terhelhetőség, a fizikai aktivitás és a Metabolikus szindróma kialakulásának valószínűsége fordított arányosságot mutat. Lakka és mtsai 2003-as több, mint ezer fő középkorú férfit vizsgáló tanulmányában kimutatták, hogy azoknál a férfiaknál, akiknek a maximális oxigénfelvétele 29,1 ml/kg/perc vagy annál kisebb volt, 7-szer nagyobb volt az esély a MetS kialakulására, mint akiknél elérte a 35,5 ml/kg/percet (28).

A tréningmonitorozáshoz kereskedelmi forgalomban kapható, megfizethető árú „okos" eszközöket használtunk, illetve ingyenesen letölthető applikációt és internetes monitorozó felületet. Összességében elmondható, hogy a telemedicina használhatónak és eredményesnek bizonyult a Metabolikus szindrómás betegek otthoni tréningjének monitorozására. További vizsgálatokat tervezünk a telemedicina használatával kapcsolatban, illetve jelen vizsgálatunk további eredményeinek bemutatása nemzetközi publikálás után várható.

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FELHASZNÁLT IRODALOM

1. World Health Organization (WHO): Telemedicine: opportunities and developments in Member States: report on the second global survey on eHealth 2009. (Global Observatory for eHealth Series, 2). ISBN 978 92 4 156414 4, ISSN 2220-5462
2. https://fogalomtar.aeek.hu/index.php/Telemedicina
3. Győrffy Zs., Békási S., Szathmári-Mészáros N., Németh O.: A telemedicina lehetőségei a COVID–19-pandémia kapcsán a nemzetközi és a magyarországi tapasztalatok és ajánlások tükrében, Orv Hetil. 2020, 161(24): 983–992.
4. Daragó L., Jung Zs., Ispán F., Bendes R., Dinya E.: A telemedicina előnyei és hátrányai, Orv. Hetil. 2013, 154:1167–1171.
5. Ábrahám E. J., Máthéné Köteles É., Korom A., Vágvölgyi A., Szűcs M., Rafael B., Lengyel Cs., Barnai M., Kósa I.: Ambuláns versus otthoni telemonitorozott tréning. A választást befolyásoló tényezők, Cardiologia Hungarica 2020, 50: 337–342.
6. Chan C., Yamabayashi C., Syed N., Kirkham A., Camp P. G.: Exercise Telemonitoring and Telerehabilitation Compared with Traditional Cardiac and Pulmonary Rehabilitation: A Systematic Review and Meta-Analysis, Physiotherapy Canada 2016, 68(3);242–251.
7. Kraal J. J., Van den Akker-Van Marle M. E., Abu-Hanna A., Stut W., Peek N., MC Kemps H.: Clinical and cost-effectiveness of home-based cardiac rehabilitation compared to conventional, centre-based cardiac rehabilitation: Results of the FIT@Home study, European Journal of Preventive Cardiology 2017, 24(12):1260–1273.
8. Maddison R., Rawstorn J. C., Stewart R. A. H., Benatar J., Whittaker R., Rolleston A., Jiang Y., Gao L., Moodie M., Warren I., Meads A., Gant N.: Effects and costs of real-time cardiac telerehabilitation: randomised controlled noninferiority trial, Heart 2019, 105:122–129.
9. Haufe S., Kerling A., Protte G., Bayerle P., Stenner H. T., Rolff S., Sundermeier T., Kück M., Ensslen R., Nachbar L., Lauenstein D., Böthig D., Bara C., Hanke A. A., Terkamp C., Stiesch M., Hilfiker-Kleiner D., Haverich A., Tegtbur U.: Telemonitoring-supported exercise training, metabolic syndrome severity, and work ability in company employees: a randomised controlled trial, Lancet Public Health 2019, 4:343–352.
10. Frederix I., Hansen D., Coninx K., Vandervoort P., Vandijck D., Hens N., Van Craenenbroeck E., Van Driessche N., Dendale P.: Medium-Term Effectiveness of a Comprehensive Internet-Based and Patient-Specific Telerehabilitation Program With Text Messaging Support for Cardiac Patients: Randomized Controlled Trial, J Med Internet Res 2015, 17(7):e185
11. Kirwan M., Duncan M. J., Vandelanotte C., Mummery W. K.: Using Smartphone Technology to Monitor Physical Activity in the 10,000 Steps Program: A Matched Case–Control Trial, J Med Internet Res 2012, 14(2):e55
12. A Magyar Kormány 157/2020. (IV. 29.) Kormányrendelete a veszélyhelyzet során elrendelt egyes egészségügyi intézkedésekről, Magyar Közlöny 2020 évi 91. szám
13. Alberti K. G. M. M., Eckel R. H., Grundy S. M., Zimmet P., Cleeman J. I., Donato K. A., Fruchart J-C., James W. P. T., Loria C. M., Smith S. C.: Harmonizing the Metabolic Syndrome, A Joint Interim Statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity, Circulation 2009, 120(16):1640–1645.
14. Halmos T., Hidvégi T., Jermendy Gy., Káplár M., Korányi L., Pados Gy., Paragh Gy., Zajkás G.: Magyar Diabetes Társaság Metabolikus Munkacsoportja: A metabolikus szindróma definíciója, diagnosztikai kritériumrendszere és szűrése. Orv Hetil 2002, 143: 785-788.
15. Szigethy E., Széles Gy., Horváth A., Hidvégi T., Jermendy Gy., Paragh Gy., Blaskó Gy., Ádány R., Vokó Z.: Epidemiology of the metabolic syndrome in Hungary. Public Health 2012, 126:143-149.
16. Jermendy Gy., Barkai L., Halmos T., Hidvégi T., Korányi L., Madácsy L., Pados Gy., Winkler G.: A metabolikus szindróma klinikai jelentősége 2011-ben. A Magyar Diabetes Társaság Metabolikus Munkacsoportjának állásfoglalása. Orv Hetil 2011, 152(36):1450-1458.
17. Kékes E., Barna I., Daiki T., Dankovics G., Kiss I.: A metabolikus szindróma „Magyarország Átfogó Egészségvédelmi Szűrőprogramja 2010–2020" 2010–2012. évi tevékenységének tükrében. Hypertonia és Nephrologia 2013, 17(2):75-81.
18. Church T. S., Thompson A. M., Katzmarzyk P. T., Sui X., Johannsen N., Earnest C. P., Blair S. N.: Metabolic syndrome and diabetes, alone and in combination, as predictors of cardiovascular disease mortality among men. Diabetes Care 2009, 32(7):1289–94.
19. World Health Organization (WHO): Physical Status: the use and interpretation of anthropometry: report of a WHO Expert Committee, Geneva, 1995. ISBN 92 41208546
20. World Health Organization (WHO): Waist circumference and waist–hip ratio: report of a WHO Expert Consultation, Geneva, 2008. ISBN 978 92 4 1501491
21. American Thoracic Society (ATS) Statement: Guidelines for the Six-Minute Walk Test. Am J Respir Crit Care Med 2002, 166:111–117.
22. Thompson P. D., Buchner D., Pina I. L., Balady G. J., Williams M. A., Marcus B. H., Berra K., Blair S. N., Costa F., Franklin B., Fletcher G. F., Gordon N. F., Pate R. R., Rodriguez B. L., Yancey A. K., Wenger N. K.: Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). Circulation 2003, 107:3109–3116.
23. Arnett D. K., Blumenthal R. S., Albert M. A., Buroker A. B., Goldberger Z. D., Hahn E. J., Himmelfarb C. D., Khera A., Lloyd-Jones D., McEvoy J. W., Michos E. D., Miedema M. D., Munoz D., Smith S. C. Jr, Virani S. S., Williams K. A. Sr, Yeboah J., Ziaeian B.: 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Circulation 2019, 140:596–646.
24. Bull F. C., Al-Ansari S. S., Biddle S., Borodulin K., Buman M. P., Cardon G., Carty C., Chaput J-P., Chastin S., Chou R., Dempsey P. C., DiPietro L., Ekelund U., Firth J., Friedenreich C. M., Garcia L., Gichu M., Jago R., Katzmarzyk P. T., Lambert E., Leitzmann M., Milton K., Ortega F. B., Ranasinghe C., Stamatakis E., Tiedemann A., Troiano R. P., van der Ploeg H. P., Wari V., Willumsen J. F. et al.: World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med 2020, 54:1451–1462.
25. Ross R., Neeland I. J., Yamashita S., Shai I., Seidell J., Magni P., Santos R. D., Arsenault B., Cuevas A., Hu F. B., Griffin B. A., Zambon A., Barter P., Fruchart J-C., Eckel R. H., Matsuzawa Y., Després J-P.: Waist circumference as a vital sign in clinical practice: a Consensus Statement from the IAS and ICCR Working Group on Visceral Obesity. Nature Reviews Endocrinology 2020, 16:177-189.
26. de Koning L., Merchant A. T., Pogue J., Anand S. S.: Waist circumference and waist-to-hip ratio as predictors of cardiovascular events: meta-regression analysis of prospective studies. European Heart Journal 2007, 28:850–856.
27. Rothberg A. E., McEwen L. N., Kraftson A. T., Ajluni N., Fowler C. E., Nay C. K., Miller N. M., Burant C. F., Herman W. H.: Impact of weight loss on waist circumference and the components of the metabolic syndrome. BMJ Open Diabetes Research and Care 2017, 5:e000341.
28. Lakka T. A., Laaksonen D. E., Lakka H. M., Männikkö N., Niskanen L. K., Rauramaa R., Salonen J. T.: Sedentary lifestyle, poor cardiorespiratory fitness, and the metabolic syndrome. Med Sci Sports Exerc 2003, 35(8):1279-86.

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III.

TANULMÁNYOK

Fizikai tréning-ajánlások összefoglalása metabolikus szindrómás betegeknél

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ABSZTRAKT

Bevezetés: A metabolikus szindróma (MetS) Magyarországon népbetegség, megléte többszörösére növeli a kardiovaszkuláris megbetegedések és a korai halálozás rizikóját. Megelőzésében és nem gyógyszeres kezelésében kulcsfontosságú a megfelelő, rendszeres fizikai aktivitás, az egészséges életmód. A nemzetközi szakirodalom alapján többféle tréningezési mód hatásos lehet, de nincs egységesen kidolgozott ajánlás. A szakirodalmi áttekintés célja a MetS esetén alkalmazható, tudományosan is alátámasztott tréningtípusok összehasonlítása.

Anyag és módszer: Az adatgyűjtés a PubMed és PEDro adatbázisokból történt, fókuszálva az ajánlást megfogalmazó, tréningtípusokat összehasonlító tanulmányokra. A keresési feltételeknek legjobban megfelelő 16 nemzetközi tanulmány került elemzésre. Kulcsszavak: metabolic syndrome physical exercise, aerobic training (AT), high intensity interval training (HIIT), moderate intensity continuos training (MICT), moderate intensity interval training, resistance training (RT).

Eredmények: A közepes intenzitású folyamatos tréningek hatására bizonyítottan javul a fizikai állóképesség és pozitívan változnak a MetS rizikófaktorok. Összességében biztonságosnak és effektívnek értékelhető a magas intenzitású intervallum tréning (HIIT), amely bizonyos kardiometabolikus rizikótényezőkre egyforma, másokra kedvezőbb hatással lehet, mint a folyamatos intenzitású tréningek. A rezisztenciatréningek szignifikánsan csökkentik a szisztolés vérnyomást és a hosszú távú tréningek legalább olyan hatékonyak a glikémiás kontroll javításában, mint az állóképességi tréningek. A rezisztenciatréninget hatékony és költséghatékony módszernek írták le a kardiovaszkuláris betegségek megelőzésében és kezelésében. A kombinált (állóképességi és rezisztencia-) tréningek jelentősen és kedvezően befolyásolják a MetS-t és az egyes rizikófaktorokat, hatékonyan csökkentik a MetS és a 2-es típusú diabétesz prevalenciáját emellett növelik az izomerőt, ami fontos a korral járó izomtömegvesztés miatt. Hatásuk azonban nem bizonyul mindig jelentősen jobbnak, mint az egyes tréningtípusoké önmagukban.

Megbeszélés: A rendszeres fizikai tréning jelentősen növeli a kardiorespiratórikus állóképességet és hatékony a kardiovaszkuláris betegségek megelőzésében. Mind a folyamatos, mind az intervallum típusú aerob állóképességi tréningek hatékonyan csökkentik a MetS egyes rizikófaktorait (például éhomi vércukor, HbA1c, trigliceridszint). A rövid és hosszú távú magas intenzitású intervallumtréningek hatékonyak a túlsúlyos/elhízott emberek állóképességének és egyes kardiometabolikus rizikófaktorainak (például vérnyomás, éhomi vércukor) javításában. A rezisztenciatréningek csökkentik a szisztolés és a diasztolés vérnyomást, a HbA1c-t, a haskörfogatot, növelik az izomerőt és az állóképességet, az erek endothél funkcióit javítják. Rövid távon az aerob állóképességi tréningek hatékonyabbak, feltételezve, hogy a kombinált tréningnél 12 hétnél több időre van szüksége a szervezetnek a két különböző típusú tréninghez való adaptációhoz, hosszú távon viszont a kombinált tréningek a legeffektívebbek.

Kulcsszavak: fizikai tréning, metabolikus szindróma

SUMMARY OF PHYSICAL TRAINING TYPES SUGGESTED FOR METABOLIC SYNDROME PATIENTS

ABSTRACT

Introduction: *Metabolic syndrome (MetS) is endemic in Hungary, its presence highly increases the risks of cardiovascular diseases and the early mortality derived from them. In the prevention and non medical therapy the regular physical activity and a healthy lifestyle are the key elements. According to the literature, different types of training methods could be effective and there is no unified physiotherapy training protocol yet.*

Objective: *The aim of this literature review is to compare the applicability of evidence based training modalities used in MetS.*

Material and Methods: *Data collection was from PubMed and PEDro databases, focusing on studies drawing up training protocols or comparing different training types. 16 studies best matched the searching criterias are presented in this article. Keywords: metabolic syndrome physical exercise, aerobic training (AT), high intensity interval training (HIIT), moderate intensity continuos training (MICT), moderate intensity interval training, resistance training (RT).*

Results: *MICT improves cardiorespiratory fitness and other risk factors of MetS, but HIIT was also evaluated as a safe and effective treatment method. HIIT positively effects certain cardiometabolic risk factors equally as the continuos trainings, and it even has more favourable effect on other parameters. Resistance trainings significantly lowered the systolic* *blood pressure compared to the control group and the long-term trainings were found to be as effective as the dinamic endurance trainings in improving the glicaemic control. RT was also evaluated as an effective and cost-effective training method in the prevention and treatment of cardiovascular diseases. The combined (endurance and resistance) trainings have effected significantly and positively the MetS and its risk factors, the prevalence of type 2 diabetes, and the additional strengthening of the muscles were also considerable as we lose muscle mass with age. However their effect has not always been proven to be as effective as each training separately.*

Discussion: *Regular physical training improves the cardirespiratory fitness and is effective in the prevention of cardiovascular diseases. Both the continuos and the interval type aerobic trainings effectively decrease some risk factors of the MetS (eg. fasting blood sugar, HbA1c, triglyceride level). The short and long term high intensity interval trainings are beneficial in improving the cardiorespiratory fitness level and certain cardiometabolic risk factors (eg. blood pressure, fasting blood sugar) of the overweight/obese population. The resistence trainings decrease both the systolic and the dyastolic blood pressure, the HbA1c, the waist circumference, increase muscle strength and endurance, improve the endothelial function of blood vessels. In the short term the aerobic endurance trainings are more effective than the combined trainings, assuming that adopting to the two different type of trainings the body needs more than 12 weeks, but on the long term the combined trainings are more effective.*

Keywords: *physical training, Metabolic syndrome*

BEVEZETÉS

A hasi típusú **elhízás**, a **magas vérnyomás**, a **2-es típusú diabétesz mellitus** (DM2) és/vagy az **inzulinrezisztencia**, a **magas koleszterinszint** (egyéb zsíranyagcsere-zavarok) Magyarországon, de a fejlett országokban is népbetegségnek számítanak. Ezek mindegyikének egyenkénti megléte önmagában is növeli, együttes jelenlétük, azaz a **metabolikus szindróma** (MetS) pedig halmozottan megnöveli a kardiovaszkuláris megbetegedések és a korai halálozás rizikóját. A Nemzetközi Diabétesz Szövetség (International Diabetes Federation – IDF) szerint a metabolikus szindróma 5-szörösére emeli a 2-es típusú diabétesz, 2-szeresére a kardiovaszkuláris betegségek, 2-4-szeresére a sztroke és 3-4-szeresére a szívinfarktus kialakulásának az esélyét (1). Az IDF becslése alapján a Föld felnőtt lakosságának kb. egynegyede szenved metabolikus szindrómában, hazánkban az előfordulási gyakoriság 33–38% körüli. Az első említés a betegségről 1983-ban történt, majd 1988-ban Reaven nevéhez kötődik a koncepciójának a meghatározása és az X-szindróma elnevezés. Azóta számos néven illették a betegséget, jelenleg a metabolikus szindróma elnevezés az elfogadott, Magyarországon az IDF kritériumrendszere terjedt el (1), ez alapján a metabolikus szindróma klinikai diagnózisához az **emelkedett haskörfogat** mint kötelező elem mellett az alábbi négy kritérium közül **minimum kettőnek** jelen kell lenni:

- **emelkedett vérnyomás, 130/85 Hgmm feletti** (vagy gyógyszeresen kezelt),
- **emelkedett éhgyomri vércukorszint >5,6 mmol/l** (vagy gyógyszeresen kezelt), vagy már diagnosztizált **2-es típusú diabetes mellitus**
- **emelkedett triglicerid (TG) szint** (≥150mg/dL (1,7 mmol/l)
- **csökkent HDL-koleszterinszint** (férfiaknál <40mg/dL (1,0 mmol/l), nőknél <50mg/dL (1,3 mmol/l)

Ez a kritériumrendszer 2009-ben módosult a nemzetközi egységesítés és harmonizáció céljából (2). Az új meghatározásban nincs kötelezően kiemelt elem, mind az öt előbb említett kritérium egyenértékűnek számít és az **ötből három megléte esetén** kimondható a MetS diagnózis. A haskörfogat esetében a küszöbértékek populáció- és országspecifikusak és további kutatást tartanak szükségesnek a megítéléséhez. Az európai férfiaknál ≥ 94 cm és nőknél ≥ 80 cm, illetve férfiaknál 102 cm és nőknél 88 cm fölött már nagy kardiovaszkuláris rizikót jelent.

A FIZIKAI AKTIVITÁS SZEREPE A METABOLIKUS SZINDRÓMA KIALAKULÁSÁBAN

A MetS kialakulása szoros összefüggést mutat a fizikai aktivitás hiányával és a kardiopulmonális állóképesség csökkenésével. Lakka és mtsai (2003) 1069 középkorú férfin végzett felmérésében kimutatták, hogy azoknál a férfiaknál, akik összesen heti 1 órát vagy annál kevesebb ideig végeztek közepes intenzitású fizikai aktivitást, 60%-kal több esély volt a MetS kialakulására, mint azoknál, akik heti 3 vagy annál több órát mozogtak. Azoknál a férfiaknál, akiknek a maximális oxigénfelvétele (VO_{2max}) 29.1 ml/kg/min vagy annál kisebb volt, 7-szer nagyobb volt az esély a MetS kialakulására, mint akiknél elérte a 35.5 ml/kg/min-t vagy annál nagyobb volt (3). Kaur és mtsai (2013) áttekintő közleményében leírják, hogy már az egyszeri testmozgás is javítja az inzulinérzékenységet. Ez a hatás a mozgás után 24–48 óráig fennáll, 3–5 napon belül azonban megszűnik. A cikk egyértelműen bizonyítja, hogy hosszú távú, folyamatos kedvező hatást csak rendszeres mozgással lehet elérni. Inaktívnak azokat az egyéneket tekintik, akik heti 150 percnél kevesebb időt töltenek mozgással. Kiemelik, hogy ezeknél az egyéneknél duplájára nő a MetS kialakulásának az esélye, azokhoz képest, akik heti 150 percnél többet mozognak (4).

A nemzetközi ajánlások szerint legalább napi 30 perc vagy annál hosszabb idejű, legalább mérsékelt intenzitású aktivitás szükséges, a hét legtöbb napján. Ajánlott napi 60 perc gyors gyaloglás, további tevékenységekkel kiegészítve, amelyek többszöri, rövid 10-15 perces mozgások (például munkát megszakítva séta, kertészkedés, házkörüli munka), egyszerű eszközökön (például futópad) vagy jogging, úszás, kerékpározás, golfozás, csapatsportok, erőedzés beiktatása. Kerülni kell az üléssel járó szabadidős tevékenységeket (TV-nézés, számítógépezés). Gyors gyaloglásnál ajánlott a lépésszámláló használata, 3 naponta 500 lépéssel növelni a távot, a 10-12 000 lépés/nap eléréséig (5,6).

ANYAG ÉS MÓDSZER

A szakirodalom áttekintése a PubMed és PEDro adatbázisok segítségével, az elmúlt 11 év nemzetközi, angol nyelvű publikációira koncentrálva történt a következő kulcsszavak segítségével: *metabolic syndrome exercise, aerobic training (AT), high intensity interval training (HIIT), moderate intensity continuos training (MICT), moderate intensity interval training, resistance training (RT)*. A feltételeknek megfelelő tanulmányokból azok a cikkek kerültek be az áttekintésbe, melyekben ajánlást fogalmaztak meg a metabolikus szindrómában alkalmazható, hatékony tréningekről vagy összehasonlították a tréningformákat.

EREDMÉNYEK

Az elemzésbe végül 16, 2007 és 2017 között megjelent publikáció került be: 5 meta-analízis/MA (7, 8, 10, 13, 15), 4 meta-analízis és szisztematikus áttekintés/MA+SZÁK (12, 17, 18, 19), 1 szisztematikus áttekintés/SZÁK (14), és 6 randomizált kontrollált tanulmány/RCT (11, 16, 20, 21, 22, 23).

1. A fizikai tréning hatásai a metabolikus szindróma rizikófaktoraira

A mozgás metabolikus szindrómában a betegség egyes komponenseit pozitívan befolyásolja. A témában 2 meta-analízis került feldolgozásra (1. táblázat).

A szérum HDL-koleszterinkoncentráció változása

Kodama és mtsai (2007) 25 tanulmányt, 1404 fő adatait elemezve vizsgálták az aerob tréningek hatását csak a szérum HDL-koleszterin változására nézve. A fizikai tréning hatására kis mértékben, de szignifikánsan nőtt a HDL-koleszterinszint (2,53 mg/dL) (7). 2015-ben Lin és mtsai 160 randomizált kontrollált tanulmányt összehasonlítva, 7487 résztvevő adatai alapján vizsgálták a fizikai tréning hatásait a kardiorespiratorikus állóképességre és a kardiometabolikus biomarkerekre. A tréningező csoportoknál ők is a HDL-koleszterin szignifikáns növekedését írták le, magas és közepes intenzitású fizikai tréning hatására (8).

Egy korábbi tanulmány (9) leírja, hogy minden 1 mg/dL HDL-koleszterinszint emelkedés férfiaknál 2%-kal, nőknél 3%-kal csökkenti a kardiovaszkuláris megbetegedés esélyét. Min. heti 120 percnyi, de egy alkalommal több, mint 30 percnyi mozgás eredményezett csak szignifikáns HDL-szint növekedést.

Vizsgálták a tréninghossz, a frekvencia és az intenzitás összefüggését a HDL-szinttel (7). Csak a tréning időtartama korrelált pozitívan a HDL-szint növekedéssel; 10 perccel növelve az időt, 0,036 mmol/L-rel nőtt a HDL-szint. A tréninget hatékonyabbnak találták a kevésbé elhízott egyéneknél (BMI<28) és azoknál, akiknek az összkoleszterinszintjük magasabb volt, ám ennek okára magyarázatot nem találtak.

Lin és mtsai korábban említett tanulmányában a HDL-koleszterinszint emelkedése mellett igazoltnak találták a VO_2max szignifikáns növekedését, a TG-szint jelentős csökkenését mind a közepes, mind a magas intenzitású folyamatos tréningek hatására a kontrollcsoporttal összevetve. További szignifikáns javulást találtak az éhomi vércukor, HbA1c, HOMA-IR, és interleukin-18 értékeknél is. Összefüggést találtak az állóképességbeli javulás és a vizsgált egyének kora, neme és egészségi állapota között. Az 50 évnél fiatalabbak, a férfiak, a 2-es típusú diabéteszesek, a hipertóniások, a hiperlipidémiában vagy MetS-ban szenvedők nagyobb javulást mutattak a tréningek hatására (8).

Szerző(k), évszám	Típusa	Résztvevők száma	Tréning típus és időtartam	Eredmények
Lin és mtsai, 2015	MA, 160 RCT	7487 fő (18–90 év)	HICT, MICT vs CG	HICT, MICT ↑VO2max, ↑HDL, ↓TG, ↓éhomi vércukor, ↓HbA1c, ↓HOMA-IR, ↓IL-18
Kodama és mtsai, 2007	MA, 25 RCT	1404 fő (23–75 év)	AT vs CG átlag 27.4 hét	AT ↑HDL

Rövidítések: AT=Aerob tréning; CG=Kontroll csoport; HICT=Magas intenzitású folyamatos tréning; MICT=Közepes intenzitású folyamatos tréning; TG=Triglicerid; HOMA-IR=Homeostatic Model Assessment of Insulin Resistance; IL-18=Interleukin-18

1. táblázat | **A fizikai aktivitás hatásaira vonatkozó tanulmányok és főbb paramétereinek összefoglalása MetS-ban**

Szerző(k), évszám	Típusa	Résztvevők száma	Tréning típus és időtartam	Eredmények
Batacan és mtsai, 2017	MA, SZÁK 65 RCT	19 RCT MetS 37 RCT elhízott/túlsúlyos	ST HIIT vs CG LT HIIT vs CG 2–16 hét	ST HIIT: ↑VO_{2max}, ↓DBP, ↓éhomi vércukor LT HIIT: ↓WC, ↓testzsír %, ↑VO_{2max}, ↓nyugalmi pulzus, ↓SBP, ↓DBP
Kang és mtsai, 20162007	RCT	23 nő MetS	AT vs CG 12 hét	AT: ↓testsúly, ↓zsír%, ↓WC, ↓éhomi vércukor, ↓BP, ↓nyugalmi pulzus ↑VO_{2max}, ↑HDL, ↑izomerő
Fisher és mtsai, 2015	RCT	23 férfi túlsúlyosak	HIIT vs MICT 6 hét	MICT: ↑VO_{2max}
Weston és mtsai, 2014	MA, 10 RCT	273 fő MetS	HIIT vs MICT	HIIT: ↑VO_{2max}
Pattyn és mtsai, 2012	MA, 5 RCT, 2 CT	206 fő MetS	HICT, MICT vs CG ≥ 4 hé	HICT, MICT: ↓WC, ↓BP, ↑HDL, ↑VO_{2max}
Kessler és mtsai, 2012	SZÁK, 24 RCT	475 fő	HIIT vs MICT 2 hét-6 hónap	HIIT, MICT: ↑VO_{2max}
Hwang és mtsai, 2011	MA, 6RCT	153 fő MetS, túlsúlyos/ elhízottak, szívbetegek	HIIT vs MICT min. 10 hét	HIIT: ↑VO_{2max} ↓éhomi vércukor

Rövidítések: CT=kontrollált vizsgálat; AT=aerob tréning; CG=kontrollcsoport; HICT=nagy intenzitású folyamatos tréning; HIIT=nagy intenzitású intervallum tréning; MICT=közepes intenzitású folyamatos tréning; ST=rövid távú (<12hét); LT=hosszú távú (≥12hét); WC=haskörfogat; BP=vérnyomás; SBP=szisztolés vérnyomás; DBP=diasztolés vérnyomás

2. táblázat | **Az aerob állóképességi tréningekre vonatkozó tanulmányok és főbb paramétereik összefoglalása**

2. A különböző tréningformák eredményessége metabolikus szindrómában

Az aerob állóképességi tréningek hatásait vizsgálva 7 tanulmány került feldolgozásra (2. táblázat).

Pattyn és mtsai (2012) meta-analízisükben (n=206 fő) a közepes és magas intenzitású folyamatos aerob állóképességi tréningek hatását vizsgálták inaktív kontrollcsoporthoz képest. A tréningek hatására a haskörfogat és a vérnyomás szignifikánsan csökkent, a HDL-koleszterinszint szignifikánsan nőtt. A TG- és a vércukorszintek nem változtak. 5 tanulmányban a VO_2max is szignifikánsan javult. A többi rizikófaktor, az LDL-koleszterin, az összkoleszterin és a BMI is pozitívan változott, azaz csökkent (10).

Hasonló eredményeket kaptak Kang és mtsai (2016) kis esetszámú vizsgálatukban, ahol MetS nőbetegek, a maximális pulzusuk 60-80%-án végzett 12 hetes, folyamatos állóképességi tréningjének hatásait vizsgálták. A betegek testsúlya, testük zsírszázaléka, haskörfogatuk, éhomi vércukorszintjük, nyugalmi pulzusuk és vérnyomásuk szignifikánsan csökkent, HDL-koleszterinszintjük pedig szignifikánsan nőtt a kiindulási állapothoz képest; ugyancsak javult az állóképességük (VO_2max), az izomerejük és izomerő állóképességük is (11).

Az állandó vagy intervallum típusú aerob tréningek mellett, legalább olyan hatásosnak, de gyakran még kedvezőbbnek mutatkozik a magas intenzitású intervallum tréning (HIIT), amelyben váltakoznak a magas intenzitású (a VO_2max 75-85%-án), rövid idejű tréning fázisok és az alacsonyabb intenzitású „megnyugvási" fázisok. Előnye, hogy a nagy intenzitású fázis csak nagyon rövid ideig tart, ehhez könnyebben adaptálódik a szervezet, és így az edzetlen, idősebb páciensek is nagyobb teljesítményre lehetnek képesek, mint a folyamatos (steady state típusú) tréningezés során, illetve jelentős a tréning befejezése után is fennmaradó zsírégető hatásuk (after-burning effect). Batacan és mtsai (2017) 65 tanulmányt elemezve a magas intenzitású intervallum tréningek hatásait vizsgálták inaktív kontrollcsoporthoz képest. A tanulmányok harmadában a résztvevőknek volt egészségügyi problémája (MetS, hipertónia, diabétesz, koszorúsér problémák, szívinfarktus utáni állapot) és több, mint felében a résztvevők a BMI alapján túlsúlyosak vagy elhízottak voltak. A tanulmányokat 2 csoportba osztották a tréningek időtartama alapján: rövid távú (ST HIIT), 12 hétnél rövidebb és hosszú távú (LT HIIT), 12 hetes vagy annál hosszabb tréningekre. Az eredményeket a tréning hossza és a vizsgált populáció testsúlya alapján csoportosították. A rövid távú HIIT-tréningek szignifikánsan javították a VO_{2max}-ot, a diasztolés vérnyomást és az éhomi vércukor szintet a túlsúlyos/elhízott egyéneknél. A hosszú távú HIIT-tréningek hatására a VO_2max növekedett, a haskörfogat, a testzsír százalék, a nyugalmi pulzus, a szisztolés és a diasztolés vérnyomás értékek csökkentek szignifikánsan a túlsúlyos/elhízott egyéneknél. Normál súlyú egyéneknél a rövid és a hosszú távú HIIT-tréningek csak a VO_{2max}-ra voltak szignifikáns hatással (12).

A HIIT és a folyamatos tréningek hatásait számos tanulmányban összehasonlították. 2011-ben Hwang és mtsai 6 klinikai vizsgálatot összegeztek (n=153 fő). A 6-ból 4 esetben a HIIT-tréningek szignifikánsan emelték a VO_{2max}–ot és az éhomi vércukorszint csökkenő tendenciáját is megfigyelték. A többi rizikófaktor változásában (vérnyomás, haskörfogat, BMI, lipid szintek) nem volt jelentős különbség a közepes intenzitású folyamatos tréninghez képest (13). 2012-ben Kessler és mtsai 13 tanulmányt összegeztek a témában (n=475 fő). 5 tanulmányban a folyamatos tréninggel egyenértékű, 8 tanulmányban pedig kedvezőbb eredmények születtek a HIIT hatására. Azokban a tanulmányokban, ahol ezt vizsgálták, az inzulinérzékenység és az állóképesség is szignifikánsan javult a HIIT hatására, de ezek az eredmények nem mindig voltak jobbak, mint a folyamatos tréningeké. 7-ből 4 tanulmányban minimum 12 hét kellett ahhoz, hogy az éhomi vércukorszint javuljon és 10-ből 3 tanulmányban pedig minimum 8 hét kellett ahhoz, hogy a HDL-koleszterinszint is növekedjen az intervallumtréning hatására. Egyik tanulmányban sem változtak jelentősen az összkoleszterin-, az LDL-koleszterin és a TG-szintek (14). Hasonló eredményre jutottak Weston és mtsai is 2014-ben, ők 10 tanulmányt (n=273 fő) összesítettek, krónikus kardiometabolikus betegségben szenvedő betegek esetében. A HIIT hatására a VO_{2max} szignifikánsan nagyobb mértékben javult a közepes intenzitású folyamatos tréninghez viszonyítva (15). Fisher és mtsai (2015) ezzel ellentétes eredményekre jutottak, kis esetszámú vizsgálatukban, ahol 23 fiatal, túlsúlyos férfinál hasonlították össze a 6 hetes HIIT és a közepes intenzitású folyamatos tréningek hatásait. A HIIT során heti 3-szor 20 percig kerékpároztak, 30 másodpercig a VO_{2max} 85%-án, majd 4 percig a 15%-án, 4-szer ismételve, levezetésképp 2 percig a 15%-on tekertek. A folyamatos tréningezők heti 5-ször, 45-60 percig tréningezek a VO_{2max} 55-65%-án. A folyamatos közepes intenzitású tréning hatására a VO_{2max} szignifikánsan emelkedett, 11,1%-kal, szemben a HIIT-el, ahol a javulás csak 2,8% volt (16).

A rezisztenciatréningek hatásait vizsgálva 3 tanulmány került elemzésre (3. táblázat). Cornelissen és mtsai (2013) 93 tanulmány (n=5223 fő) elemzésével vizsgálták az aerob állóképességi, a dinamikus rezisztencia, az izometriás rezisztencia és a kombinált (állóképességi és rezisztencia) tréningek hatását a vérnyomásra inaktív kontrollcsoporthoz képest. A kezdeti értékeik alapján a résztvevőket normál vérnyomású, prehipertenzív és hipertóniás csoportokra bontották. Az állóképességi tréningek, a dinamikus és izometriás rezisztenciatréningek különböző mértékben, de szignifikánsan csökkentették a szisztolés vérnyomást, míg a kombinált tréningeknek nem volt szignifikáns hatása. A diasztolés vérnyomást az összes tréningtípus szignifikánsan csökkentette. Az állóképességi tréningek hatására létrejövő szisztolés és diasztolés vérnyomás csökkenés a hipertóniás résztvevők esetében volt a legnagyobb mértékű, a normál vérnyomású és a prehipertenzív egyénekhez képest, illetve a férfiaknál több mint kétszeres volt a csökkenés a nőkhöz képest. A 6 hónapnál rövidebb állóképességi tréningek nagyobb vérnyomáscsökkenést eredményeztek, mint az ennél hosszabbak, ami pont ellentétes a legtöbb eddigi tanulmánnyal. Ezt azzal magyarázták, hogy a hosszabb tréningeknél több volt a lemorzsolódás, illetve már otthoni, nem felügyelt tréningek voltak (17). Hasonló eredményeket kaptak Lemes és mtsai is, akik 2016-ban (n=519 fő) a rezisztenciatréning kontrollcsoporthoz viszonyított hatásait vizsgálták a vérnyomás és a többi MetS rizikófaktor tekintetében. A rezisztenciatréning jelentősen csökkentette a szisztolés vérnyomást. A diasztolés vérnyomás és a haskörfogat csökkenő tendenciát mutatott, de a javulás nem volt szignifikáns. A többi rizikófaktor (éhomi vércukor, TG, HDL-koleszterin) esetében sem volt jelentős a változás. A tanulmányokat összehasonlították a bennük szereplő tréningprogramok időtartama alapján is. A hosszú távú (>6 hónap) tréningek jelentősen hatékonyabban csökkentették a szisztolés vérnyomást, mint a rövid távú (<6 hónap) tréningek (18). Strasser és mtsai (2010) tanulmányukban (n=513 fő) szintén a rezisztenciatréning hatását vizsgálták az elhízáshoz kapcsolódó glükóztolerancia károsodásra és a 2-es típusú diabéteszre nézve MetS-ban. Az eredményeket a kontrollcsoporthoz vagy az állóképességi tréninghez viszonyították, illetve állóképességi tréninggel kombinálva vizsgálták a kontrollcsoporthoz viszonyított változást. A rezisztenciatréning hatására csökkent a $HbA1_C$, a szisztolés vérnyomás és a zsírtömeg is, de nem történt szignifikáns változás a diasztolés vérnyomás, a HDL-, LDL-, összkoleszterin- és TG-értékekben. Akkor javult jelentősen a $HbA1_C$, amikor közepes-magas intenzitású rezisztenciatréninget alkalmaztak, vagy amikor a tréning 10 hetes vagy hosszabb időtartamú volt. További összefüggéseket kerestek a rezisztenciatréning intenzitása, időtartama, frekvenciája és a metabolikus hatások között. A hosszabb ideig (>10 hét) tartó tréningek kedvezőbben befolyásolták a glikémiás kontrollt, mint az ennél rövidebbek. A tréning gya-

Szerző(k), évszám	Típusa	Résztvevők száma	Tréning típus és időtartam	Eredmények
Lemes és mtsai, 2016	A, SZÁK 8 RCT	519 fő MetS	RT vs CG 12 hét – 9 hónap	<u>RT:</u> ↓SBP
Cornelissen és mtsai, 2013	MA, SZÁK 93 RCT	5223 fő normál tenzió, prehipertenzív hipertóniásak	AT vs CG RT vs CG RT izometriás vs CG RT+AT vs CG 4–52 hét	<u>AT, RT, RT izometriás:</u> ↓SBP <u>AT, RT, RT izometriás, RT+AT:</u> ↓DBP
Strasser és mtsai, 2010	MA, SZÁK 13 RCT	513 fő glükóz intoleranciások, DM2	RT vs CG RT vs AT RT+AT vs CG 6 hét – 2 év	<u>RT:</u> ↓HbA_{1C}, [illegible] SBP, ↓zsírtömeg <u>Glikémiás kontroll javítása:</u> RT≈AT

Rövidítések: AT=aerob tréning; RT=rezisztenciatréning; CG=kontrollcsoport; SBP=szisztolés vérnyomás; DBP=diasztolés vérnyomás; HbA1c= glikolizált hemoglobin molekula

3. táblázat **| A rezisztenciatréningekre vonatkozó tanulmányok és főbb paramétereik összefoglalása**

korisága és a vérnyomáscsökkentő hatás között pozitív összefüggést, míg a tréning időtartama és a diasztolés vérnyomás csökkenés között kisfokú pozitív korrelációt találtak, viszont a tréning intenzitása és a glikémiás kontroll között nem találtak pozitív korrelációt (19).

A kombinált (állóképességi+rezisztencia) tréningek hatásait vizsgálva nincs elérhető áttekintő elemzés vagy metaanalízis. 4 randomizált kontrollált tanulmány (2 rövid és 2 hosszú távú) került elemzésre (4. táblázat).

Earnest és mtsai (2014) 262 fő MetS és 2-es típusú diabéteszes betegen vizsgálták az állóképességi, a rezisztencia és a 2 tréning kombinációjának hatásait a MetS-t jellemző Z-pontszámra és a szindróma prevalenciájára nézve. Az állóképességi csoportban heti 3-5-ször, közepes-nagy intenzitású futópados tréninget végeztek, ami kb. 150 perc/hét mozgásnak felelt meg. A rezisztenciatréning csoportban heti 3-szor edzették a felsőtest, az alsó végtagok és a törzs különböző izmait 2-3 sorozatban, 10-12-es ismétlésszámmal. A kombinált csoport heti 3-5 futópados és heti 2 rezisztenciatréninget végzett, de kevesebb ideig, mint az állóképességi csoport és kevesebb gyakorlatot, mint a rezisztenciatréninges csoport. Az aerob és a kombinált tréningek hatására a Z-pontszám és a szindróma előfordulása is szignifikánsan csökkent a rezisztencia- és a kontrollcsoportokhoz képest. Mindegyik tréning hatására csökkenő tendenciát mutatott a haskörfogat; a csökkenés a kombinált csoportban volt a legnagyobb. Az aerob tréning hatására szignifikánsan csökkent a szisztolés vérnyomás. Az állóképességi és a kombinált tréningek hatására is kis mértékű, de szignifikáns javulást tapasztaltak a VO_{2max}-ban (20). Tibana és mtsai (2014) kis esetszámú vizsgálatukban hasonló eredményekre jutottak. 13 MetS nőbetegnél vizsgálták a 10 hetes kombinált aerob állóképességi és rezisztenciatréning hatásait. A résztvevők heti 3-szor 30 percig futópadon tréningeztek a szívfrekvencia rezerv 70-80%-án, és heti 3-szor edzették a felső testfél, az alsó végtagok és a törzs izmait 3 szériában, 8-12 ismétlésszámmal. A kombinált tréning hatására szignifikánsan csökkent a szisztolés vérnyomás, az artériás középnyomás, a MetS-Z-pontszám, bizonyos gyulladásos markerek szintje, nőtt az izomerő, javult a funkcionális kapacitás (ülésből felállási teszt) (21). Bateman és mtsai (2011) 144 fő részvételével ugyanezt vizsgálták inaktív, diszlipidémiás, túlsúlyos és MetS betegeken. Az aerob tréning során futópadon, elliptikus trénerен vagy kerékpáron edzettek a VO_{2max} 65-85%-án. A rezisztenciatréning heti 3-szor 3 szériában, 8-12 ismétlésszámmal a felső és alsó testfél 4-4 nagy izomcsoportjának edzését jelentette. A kombinált csoportban a két tréning kombinációját végezték. Mindhárom tréningtípus hatására szignifikánsan javult a VO_{2max}; az állóképességi és a kombinált tréningek hatására nagyobb mértékben, mint a rezisztenciatréningnél. A testtömeg és a TG-szint szignifikánsan csökkent az állóképességi és a kombinált tréning hatására. Az izomerő szignifikánsan nőtt a rezisztencia és a kombinált tréning hatására. A haskörfogat, a diasztolés vérnyomás, az artériás középnyomás és a MetS-Z-pontszám szignifikánsan csak a kombinált tréning hatására csökkent. A rezisztenciatréning érdemben nem befolyásolta a MetS rizikófaktorait vagy a MetS-Z-pontszámot, szemben az állóképességi tréninggel, amely hatékonyabbnak bizonyult a MetS kezelésében. A kombinált tréning szintén hatékony volt, de nem jobban, mint az állóképességi tréning önmagában (22). Hasonlóképpen vizsgálták Stensvold és mtsai 2010-es tanulmányukban, de itt az álló-

Szerző(k), évszám	Típusa	Résztvevők száma	Tréning típus és időtartam	Eredmények
Earnest és mtsai, 2014	RCT	262 fő inaktív, MetS+DM2	AT vs CG AT+RT vs CG RT vs CG 9 hónap	↓MetS-Z-Pontszám, ↓MetS prevalencia, ↑VO_{2max} AT: ↓SBP
Tibana és mtsai, 2014	RCT	13 nő MetS	AT+RT pre vs post 10 hét	AT+RT: ↓SBP, ↓artériás középnyomás, ↓MetS-Z-Pontszám, ↓NO, ↓egyéb gyulladásos markerek, ↑izomerő
Bateman és mtsai, 2011	RCT	144 fő inaktív, túlsúlyos, dislipidémiás, ebből 86 fő MetS	AT, RT, AT+RT pre vs post 8 hónap	AT: ↑VO_{2max}, ↓testtömeg, ↓TG, AT+RT: ↑VO_{2max}, ↓MetS-Z-Pontszám, ↓testtömeg, ↓WC, ↓TG, ↓DBP, ↓artériás középnyomás, ↑izomerő RT: ↑VO_{2max}, ↑izomerő
Stensvold és mtsai, 2010	RCT	43 fő MetS elhízottak, szívbetegek	AIT vs RT vs AIT+RT vs CG 12 hét	AIT: ↓WC, ↑ VO_{2max}, ↑endothél funkció AIT+RT: ↓WC, ↑VO_{2max}, ↑ izomerő, ↑endothél funkció

Rövidítések: AT=aerob tréning; AIT=aerob intervallumtréning; RT=rezisztencia tréning; CG=kontrollcsoport; WC=haskörfogat; SBP=szisztolés vérnyomás; DBP=diasztolés vérnyomás; NO=nitrogén-monoxid

4. táblázat **| A kombinált (AT+RT) tréningekre vonatkozó tanulmányok és főbb paramétereik összefoglalása**

képességi tréning heti 3-szor 45 perces futópados magas intenzitású intervallumtréningből állt. A bemelegítés után 4 percig a maximális pulzus 90-95%-án, majd 3 percig a 70%-án tekertek, 4-szer ismételve az intervallumokat, majd 5 perc volt a levezetés. A rezisztencia csoportban heti 3-szor 40-50 percet tréningeztek; az 1RM 60-80%-án, 3 szériában, 8-12 ismétlésszámmal edzették a felső és alsó testfél nagy izomcsoportjait. A kombinált csoport heti 2-szer az aerob intervallum tréninget és heti 1-szer a rezisztenciatréninget végezte. Mindhárom típusú tréning hatására szignifikánsan csökkent a haskörfogat és javult a vizsgált érendothél funkció. Az aerob intervallum és a rezisztenciatréning hatására szignifikánsan csökkent a zsírtömeg. A kombinált tréning hatására szignifikánsan növekedett a zsírmentes testtömeg. Az intervallum- és a kombinált tréning hatására javult a VO_2max és az aerob tréning hatására a vérnyomás csökkenő tendenciáját figyelték meg (23).

MEGBESZÉLÉS

A rendszeres fizikai tréning jelentősen növeli a kardiorespiratórikus állóképességet (VO_{2max}) (8, 10, 11, 12, 13, 14, 15, 16, 20, 22, 23), amelynek csökkenése a kardiovaszkuláris betegségek rizikóinak és mortalitásának független előre jelző faktora. A tanulmányok eredményei alapján elmondható, hogy a gyógyszeres kezeléshez képest alacsony mellékhatású fizikai aktivitás hatékonyan segíti a kardiovaszkuláris betegségek megelőzését (3, 4, 7, 8). A fizikai aktivitás kétségtelenül pozitív hatással van a MetS rizikófaktoraira. Az áttekintett tanulmányok igazolják a rendszeres fizikai aktivitás HDL-koleszterinszint növelő hatását (7, 8, 9, 10, 11). Mind a folyamatos (közepes és magas intenzitású), mind az intervallum típusú aerob állóképességi tréningek hatékonyan csökkentik az éhomi vércukrot (8, 11, 12, 13), a HbA1c-t (8,19), a trigliceridszintet (8, 22) és kedvezően befolyásolják a HOMA-IR, IL-18-szinteket (8). A rövid és hosszú távú magas intenzitású intervallumtréningek hatékonyak a túlsúlyos/elhízott emberek állóképességének (12, 13, 14, 15, 23) és egyes kardiometabolikus rizikófaktorok (például a vérnyomás, éhomi vércukor) javításában (12, 13). Limitálja az ajánlás megfogalmazását, hogy a különböző tanulmányokban a HIIT-re vonatkozó tréningprotokollok nem egységesek. Összességében biztonságosnak és effektívnek értékelhető ez a tréningtípus, amely bizonyos kardiometabolikus rizikótényezőkre egyforma, más tényezőkre kedvezőbb hatással lehet, mint a közepes intenzitású folyamatos tréningek.

Eddig is ismert volt és a most elemzett tanulmányok alapján is elmondható, hogy a folyamatos aerob állóképes-