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BOTTOM-UP ANALYSIS OF TELEMONITORING COSTS: A CASE STUDY IN SLOVENIAN PRIMARY CARE

ANALIZA STROŠKOV TELEMONITORINGA OD SPODAJ NAVZGOR: ŠTUDIJA PRIMERA V SLOVENSKEM PRIMARNEM ZDRAVSTVU

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ABSTRACT

Introduction: Telemonitoring improves clinical outcomes in patients with arterial hypertension (AH) and type 2 diabetes (T2D), however, cost structure analyses are lacking. This study seeks to explore the cost structure of telemonitoring for the elderly with AH and T2D in primary care and identify factors influencing costs for potential future expansions.

Methods: Infrastructure, operational, patient participation, and out-of-pocket costs were determined using a bottom-up approach. Infrastructure costs were determined by dividing equipment and telemonitoring platform expenses by the number of participants. Operational and patient participation costs were determined by considering patient training time, data measurement/review time, and teleconsultation time. The change in out-of-pocket costs was assessed in both groups using a structured questionnaire and 12-month expenditure data. Statistical analysis employed an unpaired sample t-test, Mann-Whitney U test, and chi-square test.

Results: A total of 117 patients aged 71.4±4.7 years were included in the study. The telemonitoring intervention incurred an annual infrastructure costs of €489.4 and operational costs of €97.3 (95% CI 85.7-109.0) per patient. Patient annual participation costs were €215.6 (95% CI 190.9-241.1). Average annual out-of-pocket costs for both groups were €345 (95% CI 221-469). After 12 months the telemonitoring group reported significantly lower out-of-pocket costs (€132 vs. €545, p<0.001), driven by reduced spending on food, dietary supplements, medical equipment, and specialist check-ups compared to the standard care group.

Conclusion: To optimise the cost structure of telemonitoring, strategies like shortening the telemonitoring period, developing a national telemonitoring platform, using patient devices, integrating artificial intelligence into platforms, and involving nurse practitioners as telemedicine centre coordinators should be explored.

Keywords:
Costs
Telemonitoring
Primary care
Elderly
Diabetes
Hypertension

IZVLEČEK

Uvod: *Telemonitoring predstavlja učinkovit pristop za izboljšanje urejenosti bolnikov z arterijsko hipertenzijo (AH) in sladkorno boleznijo (SB) tipa 2, vendar analize stroškovne strukture niso na voljo. Namen raziskave je raziskati stroškovno strukturo telemonitoringa pri starejših bolnikih z AH in SB tipa 2 v primarnem zdravstvenem varstvu in ugotoviti dejavnike, ki vplivajo na stroške za morebitne prihodnje širitve.*

Metode: *S pomočjo pristopa od spodaj navzgor smo ocenili infrastrukturne in operativne stroške, stroške sodelovanja bolnikov in stroške iz žepa. Infrastrukturne stroške smo izračunali tako, da smo stroške nakupa telemedicinske opreme in spletne platforme delili s številom sodelujočih bolnikov. Operativne stroške in stroške sodelovanja bolnikov smo izračunali z upoštevanjem časa za usposabljanje bolnikov, časa za pregled/opravljanje meritev ter časa za telekonzultacije. Spremembe v stroških iz žepa smo ocenili s pomočjo strukturiranega vprašalnika, v katerem so bolniki v obeh skupinah poročali o stroških iz žepa v preteklem letu. Pri statistični analizi smo uporabili t-test za neparne vzorce, Mann-Whitneyev U test in hi-kvadrat test.*

Rezultati: *V raziskavo je bilo vključenih 117 bolnikov, starih povprečno 71,4 ± 4,7 leta. Letni infrastrukturni stroški telemonitoringa so znašali 489,4 €, operativni stroški pa 97,3 € (95 % interval zaupanja [IZ] 85,7-109,0) na bolnika. Letni stroški sodelovanja bolnikov so znašali 215,6 € (95 % IZ 190,9-241,1). Povprečni letni stroški iz žepa za obe skupini so znašali 345 € (95 % IZ 221-469). Po 12 mesecih je skupina s telemonitoringom poročala o bistveno nižjih stroških iz žepa (132 € proti 545 €, p < 0,001), pri čemer so se pomembno zmanjšali stroški za hrano in prehranska dopolnila, medicinsko opremo in samoplačniške specialistične preglede.*

Zaključek*: Za optimizacijo stroškovne strukture telemonitoringa je potrebno preučiti strategije, kot so skrajšanje obdobja telemonitoringa po stabilizaciji kliničnih parametrov, razvoj nacionalne platforme za spremljanje na daljavo z možnostjo prenosa mobilne aplikacije na osebne naprave bolnikov, vključevanje umetne inteligence v spletne platforme in povečanje vloge diplomirane medicinske sestre na mestu koordinatorja telemedicinskega centra.*

Ključne besede:
stroški
telemonitoring
primarno zdravstveno varstvo
starejši
sladkorna bolezen
hipertenzija

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1 INTRODUCTION

The escalating demands on global health systems resulting from the management of chronic diseases have underscored the need for innovative solutions. Arterial hypertension (AH) and type 2 diabetes (T2D) are among the most prevalent chronic conditions worldwide, with projections indicating a surge in their prevalence, particularly among the elderly (1-3).

In response to the mounting burden of chronic diseases in primary care, telemonitoring has emerged as a practical solution. Telemonitoring involves using medical devices to collect real-time physiological data, such as blood pressure (BP) and blood glucose (BG), which is then directly transmitted to a telemonitoring centre, where it triggers a response from a healthcare provider, often complemented by a teleconsultation (3, 4).

Previous studies reported that telemonitoring can effectively lower overall costs by reducing interaction time with healthcare professionals, preventing early health deterioration, reducing hospital admissions, cutting patient travel costs, and transferring specific elements of care from professionals to patients (4-6).

To seamlessly integrate telemonitoring into healthcare systems, it is crucial to pinpoint and optimise factors that influence costs. A successful strategy for identifying these factors involves employing a bottom-up approach that considers both healthcare provider and societal (patient) perspectives. This method entails a thorough examination of individual cost components, starting from specific aspects within the healthcare provider's realm and extending to the broader societal context. The provider perspective primarily focuses on medical costs, encapsulating telemonitoring technology infrastructure and operational expenses. Simultaneously, the societal perspective encompasses more extensive effects, including indirect and non-health-related costs such as patient and caregiver time, out-of-pocket costs, and productivity loss (7, 8).

Slovenia, a high-income country in central Europe with the Bismarck healthcare model, has made significant efforts to implement an integrated care package for individuals with AH and T2D in primary care settings (9). However, the national-scale implementation of telemonitoring in Slovenia is still pending despite its prior evaluation in pilot studies (10-13). This delay could be attributed to the absence of comprehensive clinical impact and cost analyses, which would enable decision-makers to extend financial support towards telemonitoring initiatives.

To address this gap, we have designed a pilot multicentre randomised controlled trial (3) aimed at assessing the feasibility, acceptability, and clinical effectiveness of telemonitoring for older people with AH and T2D in primary care in Slovenia. The aim of this sub-study is to explore the cost structure of telemonitoring for the elderly with AH and T2D in primary care and identify factors influencing costs for potential future expansions.

2 METHODS

2.1 Study design

Upon completion of the 12-month follow-up period, we conducted a cross-sectional survey of patients who participated in the multicentre randomised controlled trial (3) between March 2021-March 2022 and May 2022-May 2023 as part of the SCUBY international project.

2.2 Study setting

The study took place in three primary health centres (PHCs) in Slovenia. PHC Ljubljana represented the urban population, while the peripheral PHCs of Trebnje and Slovenj Gradec represented the rural population.

2.3 Study population and sampling strategy

The study included patients aged 65 years or older who had both AH and T2D. Participants were conveniently sampled, as they were invited to take part in the study by their general practitioners (GPs). Once they agreed, they were randomly assigned in a 1:1 ratio to either telemonitoring or standard care groups.

The inclusion criteria were: (a) ≥65 years of age, (b) confirmed diagnosis of AH and T2D for at least one year, and (c) the ability to use telemonitoring equipment.

The exclusion criteria were: (a) <65 years of age, (b) T2D requiring insulin treatment, (c) gestational diabetes or type 1 diabetes, (d) cognitive impairment, or (e) an inability to use telemonitoring equipment for any reason.

2.4 Telemonitoring intervention

We supplemented standard care with telemonitoring intervention (3). Participants were provided with a telemonitoring package including a smartphone and monitors for BP and BG. Over a 12-month period, participants were instructed to measure their BP twice a week and their BG once a month, with a more intensive regimen in case of derailments. The results were transmitted to a telemedicine platform for review by a telemedicine centre coordinator (GP). Patient management followed established clinical protocols, and if necessary the coordinator communicated with patients or their GPs through a mobile app or phone, providing additional health analysis.

2.5 Cost structure assessment and data collection

Considering prior research on the cost dynamics in telemonitoring in patients with AH or T2D (14-22), we gathered data encompassing both the healthcare provider's and patient's perspectives (Table 1). Infrastructure costs were determined by the third-party telemonitoring solution provider and were independent of this study. Operational costs and patient participation costs were extracted from telemedicine platform data and medical records. Out-of-pocket costs were explored through a structured questionnaire, capturing self-reported expenses from the past year.

2.6 Data analysis

In conducting the cost analysis, we employed a bottom-up approach, considering perspectives from both the healthcare provider and patient/society (7, 8).

The infrastructure costs per patient were determined by dividing the total expenses incurred for equipment acquisition, maintenance, depreciation, and subscription to the telemedicine platform by the total number of participants.

The operational costs per patient were determined by considering training time, data review time, and teleconsultation time. Training time was calculated by dividing the total training time by the number of patients. Time spent on data review was calculated by multiplying the average number of measurements per patient per year by the interpretation time for each measurement. Teleconsultation time was calculated by multiplying the average number of teleconsultations per patient per year by the average teleconsultation duration. Each cost subcategory's average time was then multiplied by the corresponding gross hourly values for the service provider. Hourly rates for the nurse practitioner and GP were calculated using the rates agreed in the General Agreement of the Slovenian Health Insurance Institute for the year 2022 (23).

Table 1. Breakdown of telemonitoring costs from various perspectives.

Perspective	Category	Cost subcategory	Definition
Healthcare provider	Infrastructure costs	Equipment acquisition Equipment maintenance Equipment depreciation Telemedicine platform subscription	Costs for obtaining necessary devices Ongoing costs for device functionality and long service life Costs of spreading equipment cost over its service life Costs covering technology infrastructure, data security, and user support for telemonitoring and video calls
Healthcare provider	Operational costs	Patient training investment Cost of data review by coordinator Teleconsultation costs	Initial costs for patient training to ensure proper device usage Labour costs for the analysis of patient data Labour costs for conducting teleconsultations
Patient or society	Patient participation costs	Training time costs Measurements time costs Teleconsultation time costs	Costs associated with training in device usage Costs for BP and BG measurement time Costs for teleconsultation sessions Costs related to travel
Patient or society	Change in out-of-pocket costs	Transportation and parking Food and dietary supplement Exercise and fitness Education Rehabilitative services Out-of-pocket checkups Medical devices Customised footwear	Costs for dietary needs Costs for physical activity Costs for educational materials or programmes Costs for rehabilitation or physiotherapy Costs for non-covered or quicker checkups at private institutions Costs for monitors and BG strips Costs for specialised diabetes footwear

Legend: BP – blood pressure; BG – blood glucose

Patient participation costs were computed based on training time, measurement time, and teleconsultation time, using the previously mentioned principles. Hourly rates for patients were calculated using the average gross salary data for Slovenia in 2022 (24). The choice of using average gross salary data for our population was deliberate. Assessing the value of time for retired individuals is complex due to the diversity of their activities, and there was a small minority of people who were still working. Furthermore, previous studies have predominantly centred around the working population, making the adoption of average gross salary data a strategic decision to ensure comparability of our results with existing research (5).

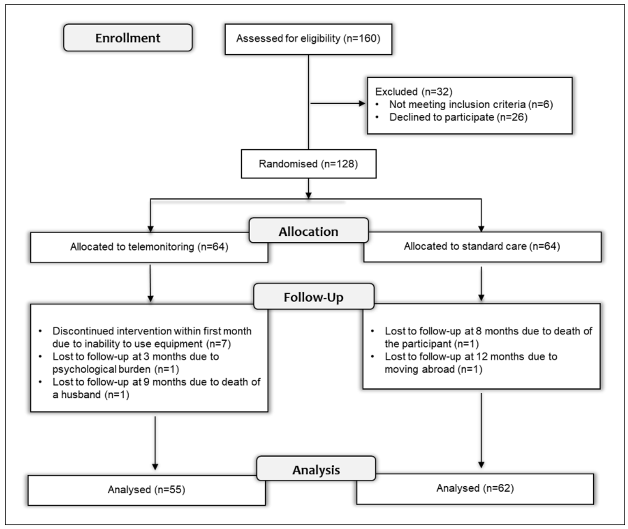
Statistical analysis was performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp, Armonk, NY). The distributional characteristics of the samples were assessed using the Shapiro-Wilk test. Socio-demographic characteristics were found to follow a normal distribution, while out-of-pocket costs followed a non-normal distribution. Differences between groups were examined using t-tests for numerical variables with a normal distribution and Mann-Whitney U-test for variables with a non-normal distribution. Categorical variables were analysed with the chi-square test. Statistical significance was defined as a p-value <0.05.

3 RESULTS

3.1 Randomisation process

The randomisation process is presented in Figure 1. A total of 128 patients were randomised to either telemonitoring or standard care groups, of whom 120 (93.8%) attended follow-up visit at 6 months, and 117 (91.4%) at 12 months.

Figure 1. CONSORT flow diagram illustrating the randomisation process.



3.2 Socio-demographic and clinical data

The study comprised 117 participants, with an average age of 71.4±4.7 years, of whom 60.7% were male. Most of the patients had received primary or vocational school education, were married, and had slightly elevated BP and HbA1c values. There were no significant differences between groups in terms of their socio-demographic and clinical characteristics (Table 2).

Table 2. Baseline socio-demographic and clinical data.

Variable	All patients (N=117)	Telemonitoring (N=55)	Standard care (N=62)	*P*
Age, years, mean (SD)	71.4±4.7	70.6±4.3	72.0±5.0	0.123
Sex				
Male (N)	71	34	37	0.813
Female (N)	46	21	25	
Highest education achieved				
Primary school (N)	18	7	11	0.518
Vocational school (N)	69	33	36	
High school (N)	16	10	6	
Bachelor’s degree (N)	10	3	7	
Master’s degree (N)	4	2	2	
Region				
Urban (N)	54	27	27	0.548
Rural (N)	63	28	35	

Variable	All patients (N=117)	Telemonitoring (N=55)	Standard care (N=62)	*P*
Marital status				
Married (N)	86	41	45	0.527
Divorced (N)	8	2	6	
Widowed (N)	5	2	3	
Single (N)	18	10	8	
Clinical data				
Duration of type 2 diabetes, years, mean (SD)	9.5±7.6	9.8±6.3	9.2±8.6	0.672
Duration of hypertension, years, mean (SD)	14.5±10.6	13.7±10.6	15.2±10.6	0.667
Systolic blood pressure, mmHg, mean (SD)	136.7±14.1	135.8±14.9	137.7±13.1	0.458
Diastolic blood pressure, mmHg, mean (SD)	76.5±8.2	75.6±7.0	77.2±9.0	0.280
Glycated haemoglobin, %, mean (SD)	7.2±1.0	7.2±1.2	7.1±0.8	0.411

Legend: N – number; SD – standard deviation

3.2 Costs of telemonitoring intervention

3.2.1 Infrastructure costs

The infrastructure costs related to equipment acquisition, maintenance, depreciation, and telemedicine platform subscription totalled €29,361 for 60 users. This equates to an annual cost of €489.4 per patient.

3.2.2 Operational costs

Operational costs, as delineated in Table 3, comprised patient training costs, costs of data review, and teleconsultations costs.

The average time for initial patient training was 82 minutes (95% CI 75-89). The telemedicine centre coordinator, who spent an average of 1 minute on each measurement interpretation, spent 201 minutes (95% CI 178-225) per year reviewing data per patient. Teleconsultations, which lasted an average of 15 minutes and took place 2.5 times per patient per year (95% CI 2.0-2.9), contributed to an average of 38 minutes (95% CI 31-44) of teleconsultation time per patient per year. Considering the costs of nurse training, data review, and teleconsultations, the average annual operational costs per patient were €97.3 (95% CI 85.7-109.0).

3.2.3. Patient participation costs

Patient participation costs consisted of training time costs, measurement time costs, and teleconsultation time costs (Table 4).

Table 3. Breakdown of operational costs per patient.

Cost subcategory	Mean annual time per action (min, 95% CI)	Gross value per hour (EUR)	Mean annual gross costs per patient (EUR, 95% CI)
Patient training	82 (75-89)	10.3	14.1 (12.9-15.3)
Data review	201 (178-225)	20.9	70.0 (62.0-78.4)
Teleconsultations	38 (31-44)	20.9	13.2 (10.8-15.3)
Mean annual total gross costs (EUR, 95% CI)	/	/	**97.3 (85.7-109.0)**

Legend: min – minutes; 95% CI – 95% confidence interval; EUR – euros

Table 4. Breakdown of participation costs per patient.

Cost subcategory	Mean annual time per action (min, 95% CI)	Gross value per hour (EUR)	Mean annual gross costs per patient (EUR, 95% CI)
Patient training	82 (75-89)	11.5	15.7 (14.4-17.1)
Data review	1,005 (890-1,125)	11.5	192.6 (170.6-215.6)
Teleconsultations	38 (31-44)	11.5	7.3 (5.9-8.4)
Mean annual total gross costs (EUR, 95% CI)	/	/	**215.6 (190.9-241.1)**

Legend: min – minutes; 95% CI – 95% confidence interval; EUR – euros

Patients took an average of 5 minutes for a single BP or BG measurement. On average, patients performed 140 (95% 122-158) BP measurements per year and 61 (95% CI 49-72) BG measurements per year, for a total of 201 (95% CI 178-225) measurements per patient per year. This resulted in an average of 1,005 (95% CI 890-1125) minutes spent on measurements per patient per year.

When considering costs for training, measurements, and teleconsultations, the average annual patient participation costs per patient were €215.6 (95% CI 190.9-241.1).

3.2.4 Change in out-of-pocket costs

The average annual self-reported out-of-pocket costs for patients in both groups at the end of the 12-month follow-up period were €345 (95% CI 221-469). The telemonitoring group exhibited significantly lower costs compared to the standard care group (€132 vs. €545, p <0.001). Specifically, the telemonitoring group reported reduced expenses for food and dietary supplements, personal payments for specialist checkups, and the acquisition of medical devices (Table 5).

Table 5. Comparison of out-of-pocket costs across groups.

Cost subcategory	All patients (N=117), mean (min, max)	Telemonitoring (N=55), mean (min, max)	Standard care (N=62), mean (min, max)	*P*
Transportation and parking (EUR)	27 (0-1,200)	9 (0-180)	43 (0-1,200)	0.149
Food and dietary supplements (EUR)	151 (0-2,400)	83 (0-2,400)	214 (0-2,400)	0.015
Exercise and fitness (EUR)	38 (0-1,440)	20 (0-480)	56 (0-1,440)	0.784
Education (EUR)	1 (0-60)	0 (0-0)	1 (0-60)	0.334
Rehabilitative services (EUR)	20 (0-840)	0 (0-0)	39 (0-840)	0.050
Out-of-pocket checkups (EUR)	23 (0-900)	0 (0-0)	45 (0-900)	0.016
Medical devices (EUR)	56 (0-1,200)	9 (0-72)	101 (0-1,200)	<0.001
Customised footwear (EUR)	6 (0-180)	2 (0-50)	10 (0-180)	0.198
Miscellaneous (EUR)	23 (0-1,200)	9 (0-480)	36 (0-1,200)	0.972
Mean annual total costs (EUR, 95% CI)	**345 (221-469)**	**132 (32-231)**	**545 (332-757)**	**<0.001**

Legend: N – number; 95% CI – 95% confidence interval; min – minimum; max – maximum; EUR – euros

4 DISCUSSION

In Slovenian primary care, the use of telemonitoring interventions for individuals with AH and T2D yielded notable economic benefits. The annual infrastructure costs per patient were €489.4, coupled with operational costs of €97.3 (95% CI 85.7-109.0). Additionally, patient participation costs were €215.6 (95% CI 190.9-241.1) annually, demonstrating the multifaceted financial benefits of telemonitoring. Importantly, the telemonitoring group exhibited a significant 12-month reduction in out-of-pocket costs compared to the standard care group, showcasing the potential economic benefits of our intervention (€132 vs. €545).

Previous studies have revealed varying telemonitoring costs, influenced by factors such as healthcare systems, hourly rates, and intervention intensity. For instance, a Canadian study in 2019 reported BP telemonitoring costs of €279 for the first three months and €300 annually for the next 20 years (16). In a European context the rates were higher, such as €2,104 in the United Kingdom (5), €4,859 in the Netherlands (21), and €1,962 in Italy (22). However, previous studies often required more frequent interactions between patients and healthcare workers, with operational costs being the primary driver and infrastructure costs accounting for only about one-third of the total costs (9, 16).

In our study, infrastructure costs emerged as the principal cost driver. To optimise these, we propose establishing a national or institutional telemonitoring platform. This platform, complete with the user-friendly mHealth application, has the potential to reduce additional expenses related to mobile phones and service subscriptions (4, 12). However, the feasibility of this approach hinges on factors such as the existing infrastructure, technological readiness, data protection, financial resources, and national healthcare system priorities (4, 12, 25).

The operational costs in our study were predominantly driven by data review and teleconsultation costs led by GPs. Patients exceeded the expected number of BP and BG measurements by 46.5% and 252.8%, respectively. This is an important finding, as patients voluntarily continued to take measurements even when not required, especially for BG, driving up operational costs. To address this issue, we suggest shortening the telemonitoring interval to six months, when clinical parameters stabilise (3, 12), and conducting nurse follow-up meetings every three months after the telemonitoring period to maintain the self-management behaviour learned through telemonitoring (4, 12).

Additionally, the delegation of measurement interpretation to nurses (12, 26) or the introduction of artificial intelligence for automated responses (27) could significantly lower operational costs. As nurse practitioners gain expertise, they could gradually handle teleconsultations, allowing GPs to focus primarily on making any changes to therapy that are needed (4, 12, 26).

Due to our focus on an elderly demographic, we specifically calculated patient participation costs, omitting the impractical comparison of productivity losses. In our study the patients devoted 18.8 hours (95% CI 16.6-21.0) annually to participate in telemonitoring. This is less than in previous studies where patients reported spending 10-12 hours per year on self-monitoring BP and 13-46 hours on self-monitoring BG (28, 29), and more than the expected 12 hours based on our measurement protocol (3). Implementing a less intensive BP measurement protocol (i.e., once a week) (12) and shortening the telemonitoring interval could further optimise patient participation costs.

One critical aspect from a societal perspective is the impact of telemonitoring on out-of-pocket costs. Previous studies found that these payments made up almost one quarter of all AH and T2D treatment costs in Slovenia (30, 31). In our study, both groups had an average annual out-of-pocket cost of €345, with the telemonitoring group reporting significantly lower expenses after a 12-month follow-up. The reduction in medical device costs was in line with expectations, as telemonitored patients received BP and BG monitors with BG test strips, while decreases in expenses for food, dietary supplements, and specialist check-ups could be associated with improved patient education received during training and teleconsultations (32).

Notably, there was no significant reduction in self-reported transportation costs. Older individuals in the intervention group continued regular preventative activities, including visits to their GPs for other health consultations. This was deemed essential for ethical reasons, given the study population's various associated health conditions. However, a more restrictive approach might prove feasible and efficient in younger populations with isolated AH or T2D (17-19).

The strength of this study lies in its integration into a randomised controlled trial with elderly participants from diverse backgrounds, an underexplored demographic in telemedicine research. Nevertheless, limitations include a small sample size and the inclusion of motivated participants, potentially limiting generalisability. Moreover, we only examined the change in out-of-pocket costs at the end of a 12-month period, while a baseline assessment should be performed to compare groups and verify the results. Additionally, there were costs related to educating GPs and registered nurses on the proper use of the telemedicine platform and devices. Given that this was a one-time expense that fell significantly with increased patient volume, we have excluded it from our calculations for clarity. In future research, it is advisable to estimate costs associated with unpaid caregiver time and delve into further medical aspects of telemonitoring's cost-saving potential, encompassing the prevention of secondary complications and hospital admissions.

5 CONCLUSION

In conclusion, this study provides valuable insights into the cost structure of integrating telemonitoring into established clinical pathways for older people with AH and T2D in primary care. To optimise the cost structure of telemonitoring, strategies like shortening the telemonitoring period, developing a national telemonitoring platform, using patient devices, integrating artificial intelligence into platforms, and involving nurse practitioners as telemedicine centre coordinators should be explored. Future research should build on these findings, testing new models and estimating the savings resulting from telemonitoring to provide evidence-based insights into the economic impact of telemonitoring in primary care.

CONFLICTS OF INTEREST

The authors declare that no conflicts of interest exist.

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ETHICAL APPROVAL AND REGISTRATION

The study was approved by the National Medical Ethics Committee of Slovenia (approval number: 0120-219/2019/4) and is registered in the ISRCTN registry (https://doi.org/10.1186/ISRCTN31471852).

AVAILABILITY OF DATA AND MATERIAL

The datasets can be obtained from the corresponding author upon a reasonable request.

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