PREGLEDNI RAD

UDK BROJEVI: 616-001-084-053.9
DOI: https://www.doi.org/10.5937/zdravzast53-51500

SAVREMENI PRISTUPI U PREVENCIJI PADOVA KOD STARIJIH OSOBA

Dragana Kljajić[1], Marija Trajkov[1], Gordana Grbić[1], Ana Pantović[1], Kristina Stevanović[2]

[1]Akademija strukovnih studija Beograd, Odsek Visoka zdravstvena škola, Beograd, Republika Srbija
[2]Dom zdravlja „Dr Milutin Ivković“, Beograd, Republika Srbija

[*] Korespondencija: dr Dragana Kljajić, Akademija strukovnih studija Beograd, Odsek Visoka zdravstvena škola, Cara Dušana 254, 11080 Beograd, Republika Srbija; e-mail: dragana.kljajic@assb.edu.rs

SAŽETAK

Starenjem dolazi do smanjenja funkcionalnih sposobnosti, što utiče na pojavu padova koji neretko mogu dovesti do invaliditeta. Cilj ovog preglednog rada je analiza savremenih pristupa u okviru mera prevencije i kontrole padova kod starijih osoba. Kao izvori podataka u ovom radu korišćeni su publikovani naučni radovi, objavljeni u periodu 2003-2023. godine. Terapijske vežbe primenjene tokom rehabilitacije i postrehabilitacije čine osnovu dobre posturalne stabilnosti. Različiti programi sistematskog vežbanja imaju svoje značajno mesto, ali treba da budu zasnovani na dokazima i precizno dozirani. Sa razvojem tehnologije postaje dostupno sve više metoda i opreme koja se na savremeni način može iskoristiti u prevenciji padova. Robotski sistemi, aplikacije, prenosivi hardverski uređaji, aparatura za virtuelnu realnost, kao i sistemi detekcije i prevencije padova, predstavljaju samo neke od novijih tehnologija koje se primenjuju u prevenciji padova. Multidisciplinarni pristup, koji se odnosi na pružanje informacija, timski rad stručnjaka iz različitih oblasti i praćenje novih tehnologija, bi mogao značajno doprineti prevenciji padova i unapređenju kvaliteta života starijih osoba.

Ključne reči: starija populacija, prevencija, padovi, terapijske vežbe, fizička aktivnost, robotika

Uvod

Prema nedavno objavljenim rezultatima popisa stanovništva iz 2022. godine Republičkog zavoda za statistiku, 22,1% stanovnika u Republici Srbiji čine osobe starosti od 65 i više godina (1). U odnosu na prethodni popis iz 2011. godine, udeo ovih lica u ukupnom broju stanovnika je porastao za 4,7% (1). Predviđa se da će se broj osoba starijih od 65 godina u svetu udvostručiti do 2050. godine (2). Proces starenja je neizbežan i tokom njega se povećava verovatnoća za razvoj bolesti, te se funkcionalnost određenih procesa u telu ograničava i smanjuje. Simptomi starenja su izraženi na telesnom, kognitivnom i psihičkom planu, što zahteva angažovanje multidisciplinarnog tima stručnjaka u cilju što dužeg očuvanja zdravlja (3).

Promene se dešavaju kako na kardiovaskularnom i respiratornom sistemu, tako i na mišićnoskeletnom, nervnom i senzornom sistemu. Starenjem kosti postaju porozne, tkiva ko zgloba gube elastičnost i menja se biomehaničko opterećenje zglobova. Dolazi do gubitka mišićne mase, snage i kontraktilnih sposobnosti mišića (4). Pored toga, smanjuje se funkcija centralnog i perifernog nervnog sistema što uzrokuje oslabljenu koordinaciju, usporeno kretanje i otežano održavanje uspravnog stava (5). Kontrola uspravne posture je dinamičan proces usklađivanja reakcije tela na senzorne informacije koje stižu iz različitih receptora sa periferije ka centralnom nervnom sistemu. Zahvaljujući inputima iz somatosenzornog, vizuelnog i vestibularnog sistema sa jedne strane i alternativnim akcijama antagonističkih mišićnih grupa sa druge strane, sprečavaju se prekomerne balansne reakcije i telo se održava u ravnoteži (6).

Svetska zdravstvena organizacija (SZO) definiše pad kao „iznenadnu i nenamernu promenu položaja koja uzrokuje da se osoba nađe na podu, tlu ili nižem nivou, isključujući namerne promene položaja dok se odmara na nameštaju, zidu ili

© 2024 Health Care. Published under the terms of the CC BY 4.0 license

REVIEW ARTICLE

UDK NUMBERS: 616-001-084-053.9
DOI: https://www.doi.org/10.5937/zdravzast53-51500

MODERN APPROACHES TO FALLS PREVENTION IN ELDERLY PERSONS

Dragana Kljajić[1], Marija Trajkov[1], Gordana Grbić[1], Ana Pantović[1], Kristina Stevanović[2]

[1]Academy of Applied Studies Belgrade, The College of Health Sciences, Belgrade, Republic of Serbia
[2]Health Center „Dr Milutin Ivković“, Belgrade, Republic of Serbia

[*] Correspondence: dr Dragana Kljajić, Academy of Applied Studies Belgrade, The College of Health Sciences, Cara Dušana 254, 11080 Belgrade, Republic of Serbia; e-mail: dragana.kljajic@assb.edu.rs

SUMMARY

Aging leads to the decrease in functional abilities, which affects the occurrence of falls that can often lead to disability. The aim of this review article is to analyze the contemporary approaches within the framework of measures for the prevention and control of falls in elderly persons. Published scientific works from the period 2003-2023 were used as data sources.Therapeutic exercises applied during rehabilitation and post-rehabilitation form the basis of good postural stability. Various systematic exercise programs have a significant place, but they need to be evidence-based and precisely applied. With the development of technology, several different methods and equipment are becoming available that can be used in the prevention of falls in a modern way. Robotic systems, applications, portable hardware devices, virtual reality equipment, as well as fall detection and prevention systems are just some of the newer technologies used in fall prevention. A multidisciplinary approach, which refers to the provision of information, teamwork of experts from different fields and monitoring of new technologies, could significantly contribute to the prevention of falls and improvement in the quality of life of the elderly.

Keywords: elderly population, prevention, falls, therapeutic exercises, physical activity, robotics

Introduction

According to the recently published results of the 2022 Census of the Statistical Office of the Republic of Serbia, 22.1% of inhabitants in the Republic of Serbia are persons aged 65 years and over (1). In comparison to the previous Census from 2011, the share of these persons in the total population increased by 4.7% (1). It is estimated that the number of persons older than 65 will double by 2050 (2). The process of ageing is inevitable and during this process the probability of developing diseases increases, so the functionality of certain processes in the body is limited and reduced. The symptoms of ageing are present at the physical, cognitive and psychological level, which demands the engagement of a multidisciplinary team of professionals aimed at preserving health as long as possible (3).

Changes occur in the cardiovascular and respiratory system, as well as in the musculoskeletal, nervous and sensory system. With ageing, bones become porous, surrounding joint tissues lose elasticity and the biomechanical load of joints changes. There is a loss of muscle mass, strength and contractile abilities of muscles (4). In addition, the function of the central and peripheral nervous system decreases, which causes decreased coordination, slow movement and inability to maintain upright posture (5). Controlling the upright posture is a dynamic process of coordinating the body’s reaction to sensory information that arrives from various receptors from the periphery to the central nervous system. Thanks to inputs from somatosensory, visual and vestibular system on the one hand and alternative actions of antagonistic muscle groups on the other hand, excessive balance reactions are prevented and the body is kept in balance (6).

The World Health Organization (WHO) defines a fall as a “sudden and inadvertent change of position which results in a person coming to rest

© 2024 Health Care. Published under the terms of the CC BY 4.0 license

drugom predmetu“ (7). U proseku jedna od tri osobe starosti 65 i više godina padne jedanput godišnje, a trećina njih prilikom pada doživi teške prelome kuka (8). U starijem životnom dobu padovi su jedan od vodećih uzroka smrtnosti, gubitka funkcionalne nezavisnosti i invaliditeta (9).

Stručnjaci iz oblasti rehabilitacije posturalnu stabilnost ispituju testovima stajanja na jednoj nozi, testovima za procenu stabilnosti tela u pokretu, Rombergovim testom, funkcionalnim testom „dosezanja“ i „tandem“ hodom - hodom po pravoj liniji. Tehnološkim napretkom i uvođenjem kompjuterizovane tehnike u vidu kineziološke platforme omogućeno je objektivno ispitivanje posturalne stabilnosti kroz njenu vizuelnu, vestibularnu i proprioceptivnu komponentu (10).

Cilj ovog preglednog rada je analiza savremenih pristupa u okviru mera prevencije i kontrole padova kod starijih osoba.

Metod

Kao izvori podataka u ovom radu korišćeni su publikovani naučni radovi, koji su identifikovani pretraživanjem sledećih elektronskih baza podataka: Srpski citatni indeks – SCIIndeks, Konzorcijuma biblioteka Srbije za objedinjenu nabavku – KoBSON, *Google Scholar* napredne pretrage i platforma *PubMed*. Pretraga elektronskih baza podataka je izvršena za period 2003-2023. godine. Ključne reči prilikom pretrage literature bile su: starija populacija, prevencija, padovi, terapijske vežbe, fizička aktivnost i robotika. Na osnovu naslova i sažetaka radova izdvojili smo 30 publikacija na srpskom i engleskom jeziku.

Mere prevencije i kontrole padova kod starijih osoba

U cilju održavanja zdravlja i prevencije padova, starijim osobama se preporučuju multimodalne vežbe koje obuhvataju vežbe za jačanje mišićne snage i izdržljivosti, balansa i fleksibilnosti kroz terapijske vežbe, programirano vežbanje ili vežbanje kroz aktivnosti svakodnevnog života. Preporuka je da se započne sa jednom vrstom vežbi, da bi se postepeno dodavale i druge, najviše zbog odlaganja zamora i prilagođavanja (11,12).

Terapijske vežbe u prevenciji padova

Terapijske vežbe (kineziterapija) za stariju populaciju su stručno vođene i dozirane vežbe od strane fizioterapeuta i mogu se sprovoditi u krevetu, na terapijskom stolu, na strunjači, u sali za kineziterapiju i rekreaciju, u bazenu, u prirodi, individualno ili grupno. Nakon analize medicinske dokumentacije, uzimanja anamneze i utvrđivanja faktora rizika, funkcionalnom procenom se definišu mišićnoskeletna ograničenja, posebno ona koja se odnose na mišićnu snagu, izdržljivost, ravnotežu i hod. Koje terapijske vežbe će se primenjivati zavisi od nivoa funkcionalnih sposobnosti, mogućnosti održavanja određenog položaja tela i transfera. Takođe, važno je i da starija osoba učestvuje u donošenju odluka koje se tiču oblika vežbi (npr. u vodi, kroz sportske aktivnosti, kroz radnu terapiju i sl.), kao i da li će vežbe sprovoditi individualno, pod nadzorom ili grupno (13).

Druga vrsta terapijskih vežbi se odnose na pacijente u fazi rehabilitacije zbog trenutnog stanja ili faze bolesti, ali isto tako i u fazi postrehabilitacije, gde postoji potreba za održavanjem postignutog stanja i prevencijom ponovne aktivacije bolesti. Fizioterapeut prilagođava i dozira terapijske vežbe imajući u vidu osnovnu bolest, hronične bolesti i stanja, kao i nivo samostalnosti u funkcionisanju i obavljanju aktivnosti svakodnevnog života (12,13). Terapijski pokret se prilagođava svakom pacijentu u odnosu na početni položaj koji mora obezbediti maksimalnu moguću stabilnost, što predstavlja važnu meru prevencije padova. Pored toga, neophodno je izbegavati one položaje koji zahtevaju veliko opterećenje zglobova, kao što su položaji u visu (kada je telo preko ruku okačeno o neku čvrstu podlogu, švedske lestve, šipku od razboja i sl.), u uporu (npr. osloncem šakama na šipke razboja, sa nogama odvojenim od podloge) i klečeći početni položaj. Vežbe se izvode do granice bola, uz poštovanje principa zamora i prepoznavanja reakcija organizma na napor kroz praćenje vitalnih znakova (pulsa, krvnog pritiska, disanja, temperature i stanja svesti). Takođe, treba biti obazriv kod primene statičkih kontrakcija koje dugo traju, koje uključuju značajno angažovanje velikih mišića, zbog rasta krvnog pritiska i kompresije krvnih sudova (13).

Hod osoba starijih od 70 godina, pored toga što je više gegajući, ima sledeće karakteristike: veća je dinamička površina oslonca, kraća je dužina koraka i javljaju se promene u brzini hoda (12). Na poboljšanje karakteristika hoda značajno utiču višekomponentni programi, kojima po potrebi prethode vežbe za poboljšanje mišićne snage i ravnoteže,

on the floor, ground or lower levels, excluding intentional changes in position to rest in furniture, wall or other objects" (7). On average, one out of three persons aged 65 years and over falls once a year, while a third of them experience severe hip fractures (8). In the elderly, falls present one of the leading causes of mortality, loss of functional independence and disability (9).

Experts from the field of rehabilitation examine postural stability with the help of tests including standing on one leg, tests for the assessment of body stability during motion, Romberg test, functional reach test and tandem walking on a straight line. Technological progress and the introduction of computerized techniques in the form of kinesiology platforms enable the objective examination of postural stability through its visual, vestibular and proprioceptive components (10).

The aim of this review article is to analyze modern approaches within measures for the prevention and control of falls in the elderly.

Method

Published scientific studies were used as a source of data in this review article, and they were identified by searching the following electronic databases: Serbian Citation Index – SCI Index, the Serbian Library Consortium for Coordinated Acquisition – KoBSON, Google Scholar advanced search, and the PubMed platform. The search of electronic databases was conducted for the period 2003-2023. Key words during the literature search were the following: elderly population, prevention, falls, therapeutic exercises, physical activity and robotics. Thirty publications in Serbian and English were selected based on the titles and summaries of articles.

Measures for the prevention and control of falls in older adults

In order to maintain health and prevent falls, older adults are recommended multimodal exercises that include exercises for improving muscular strength and endurance, balance and flexibility through therapeutic exercises, programmed workout or exercising through activities of daily life. It is recommended to start with one type of exercises, to gradually add others, mostly in order to postpone fatigue and to adapt (11,12).

Therapeutic exercises in falls prevention

Therapeutic exercises (kinesitherapy) for the elderly population are professionally guided and dosed by physiotherapist and they can be done in bed, on a treatment table, on a mat, in a kinesitherapy and recreation room, in a swimming pool, in nature, individually or in groups. After the analysis of medical documentation, medical history taking and determination of risk factors, functional assessment defines musculoskeletal limitations, especially those related to muscular strength, endurance, balance and gait. Which therapeutic exercises will be applied depends on the level of functional abilities, the possibility of maintaining certain body positions and transfer. Also, it is important that an older adult takes part in making decisions related to the type of exercises (e.g. in the water, through sport activities, through occupational therapy etc.), as well as whether the exercises will be done individually, under supervision or in groups (13).

Another type of therapeutic exercises refers to patients in the rehabilitation phase due to the current condition or stage of the disease, as well as in the post-rehabilitation phase, where there is a need to maintain the achieved state and prevent the recurring acute phase of the disease. The physiotherapist adjusts and doses therapeutic exercises, taking into account the underlying disease, chronic diseases and conditions, as well as the level of independence related to functioning and carrying out of everyday activities (12,13). The therapeutic movement is adapted to each patient in relation to the initial position, which must ensure the maximum possible stability that is an important measure for the prevention of falls. In addition, it is necessary to avoid those positions that require great joint loading, such as hanging positions (when the body is hanging with both hands from a solid surface, Swedish ladder, stall bars, etc.), resistance training (e.g. when one is supported with hands on stall bars, while legs are separated from the floor) and the kneeling starting position. Exercises are done to the point of pain, while respecting the principle of fatigue, and recognizing the body's reactions to effort through monitoring vital signs (pulse, blood pressure, breathing, temperature and state of consciousness). Also, one should be careful when applying static contractions that last for a

a kasnije i aerobne vežbe. U početku, ovi programi su vrlo dozirani, a trajanje komponente je 5-10 minuta tokom prvih nedelja, a potom 20-30 minuta (14). Starije osobe neretko koriste pomagala prilikom hoda, ne samo u fazama rehabilitacije i postrehabilitacije, nego i kasnije. U cilju prevencije padova važno je i adaptirati prostor u kojem žive starije osobe, ukloniti sve fizičke barijere i postaviti rukohvate i pomagala za aktivnosti svakodnevnog života (15).

Programirano vežbanje kod starijih osoba

Sistematski programi za starije osobe koji su grupno vođeni nisu brojni i za njihovo sprovođenje ima više kontraindikacija nego kada se sprovode u zrelom dobu. Važno je da starije osobe shvate da telo ima sposobnost da se adaptira na vežbanje nezavisno od toga da li su ranije primenjivali vežbe ili ne (16).

Prema preporuci SZO osobe u trećem životnom dobu bi trebalo da primenjuju raznovrsnu fizičku aktivnost umerenog ili većeg intenziteta, tri i više dana u nedelji, kako bi se poboljšao funkcionalni kapacitet i prevenirali padovi (17). Za poboljšanje neuromišićnog i kardiovaskularnog sistema kod ovih osoba fizička aktivnost treba da se izvodi kroz trening sa opterećenjem dva do tri puta nedeljno, kroz tri serije od 8 do 12 ponavljanja, sa progresivnim intenzitetom 20-30% od 1RM (*Repetition Maximum* - maksimalna težina, odnosno težina koju osoba može da podigne samo jednom). U cilju poboljšanja funkcionalnih sposobnosti preporučuju se treninzi izdržljivosti (npr. pešačenje) u trajanju od 5 do 30 minuta. Kombinaciju vežbi snage, izdržljivosti i ravnoteže bi trebalo izvoditi uz postepeno povećavanje obima, intenziteta i težine vežbi (18). Istraživanja pokazuju da primena samo šetnje ne utiče na smanjenje broja padova, iako doprinosi boljoj kondiciji i ima druge blagotvorne efekte na zdravlje. Samo sistematskim i organizovanim delovanjem na slabe tačke pojedinaca specifičnim programima i prilagođenim planovima treniranja se dobijaju najbolji rezultati (19).

Treninzi za razvoj ravnoteže uglavnom uključuju vežbe sa elementima prenosa težine sa jedne na drugu nogu, hodanje po liniji, hod peta-prsti, a jedan od najpoznatijih je modifikovani *Tai Chi* program (18). *Tai Chi* program se pokazao efikasnim u smanjenju straha od pada i stope pada kod žena koje su primenjivale ovaj program u kućnim uslovima (20). Zbog zdravstvenog stanja, mnogim starijim osobama je neophodan trening ravnoteže pre primene aerobnih vežbi zbog zahtevnijih položaja ili pokreta. Međutim, i tokom izvođenja treninga ravnoteže postoji mogućnost iznenadnih padova (21).

Program za starije osobe za poboljšanje ravnoteže i smanjenje rizika od pada može da se odvija i u vodenoj sredini. Vodena sredina pojačava osećaj sigurnosti kod starijih osoba, a rizik od povređivanja je izuzetno mali. Za ovaj program potrebno je da temperatura vode u bazenu bude nešto toplija, odnosno između 29-31 stepen Celzijusa. Vežbe koje se primenjuju u ovom programu obično sadrže komponente *Tai chi*-a, *Ai chi*-a i joge (22).

„Funkcionalne vežbe integrisane u životni stil“ (engl. *Lifestyle-integrated Functional Exercise* (LiFE)) predstavlja savremeni program koji ima za cilj implementaciju vežbi snage donjih ekstremiteta i ravnoteže u svakodnevne aktivnosti kod starijih osoba. Rezultati istraživanja pokazuju da je rizik od pada smanjen za 30% kod ispitanika koji su koristili ovaj program u odnosu na program koji je sadržao lagane vežbe i program koji se sastojao od tradicionalno struktuisanih vežbi (23). Primenom LiFE programa unapređuje se održavanje statičke i dinamičke ravnoteže, utiče se na vestibularni sistem, poboljšava se ravnoteža i snaga stabilizatora donjih ekstremiteta. Vežbe su kreirane tako da se u većoj meri primenjuju u svakodnevnom životu, poput stajanja na jednoj nozi tokom peglanja, stajanja na peti i ljuljanja tela do granice stabilnosti tokom telefoniranja, izvođenja čučnjeva tokom kupovine da bi se došlo do predmeta na nižim policama i slično (23).

„Program za prevenciju padova za starije osobe koji žive u zajednici“ (engl. *Steady As You Go* (SAYGo)) ima kognitivno-bihejvioralni i fokus životne sredine. Odnosi se na kreiranje uslova u kojima starija lica pomažu jedna drugima da identifikuju sopstvene rizike od pada i daju praktične predloge o tome šta da urade kako bi smanjili te rizike. Najznačajnije promene u smanjenju zastupljenosti faktora rizika od pada su uočene unapređenjem obrazaca ponašanja poput „obraćanja pažnje“ i „preuzimanje rizika“, a usled povećanih socijalnih kontakata poboljšao se društveni život i motivacija starijih osoba (24).

long time, which include significant engagement of large muscles, due to the increase in blood pressure and compression of blood vessels (13).

The gait of persons older than 70, in addition to being somewhat waddling, has the following characteristics: the dynamic surface of support is greater, the length of steps is shorter, and there are changes in gait speed (12). The improvement of gait characteristics is influenced by multi-component programs, preceded by, if necessary, exercises to improve muscular strength and balance, and later by aerobic exercises. In the beginning, these programs are carefully dosed, while the duration of the component is 5-10 minutes during the first weeks, and later 20-30 minutes (14). Older adults often use aids while walking, not only in the rehabilitation and post-rehabilitation phases, but also later. In order to prevent falls, it is important to adapt the living space of the elderly, to remove all physical barriers and install hand rails and aids for daily activities (15).

Programmed workout for the elderly

There are not many systematic programs for the elderly that are group-led and there are more contraindications for their implementation than when they are implemented at a mature age. It is important for the elderly to understand that the body has the ability to adapt to exercise no matter whether they have done exercises before or not (16).

According to the WHO recommendations, the elderly should use diversified physical activities of moderate or greater intensity, three or more days a week, in order to improve the functional capacity and prevent falls (17). In order to improve the neuromuscular and cardiovascular system in these persons, physical activity should be performed through weight training two to three times a week, in three series of 8 to 12 repetitions, with progressive intensity of 20-30% of 1RM (Repetition Maximum – maximum weight, that is, the load for which only one repetition can be performed). In order to improve functional abilities, endurance training (e.g. walking) from 5 to 30 minutes is recommended. The combination of strength, endurance and balance exercises should be done with a gradual increase in the volume and intensity of exercises (18). Research shows that when only walking is applied, it does not reduce the number of falls, although it contributes to better physical fitness and has other beneficial effects on health. Only systematic and organized treatment of weak points of an individual with the help of specific programs and adjusted training plans give the best results (9).

Training that develops balance mostly includes exercises that shift weight from one leg to another, walking along a straight line, heel-toe walking, and one of the most famous is the modified Tai Chi program (18). Tai Chi program was shown to be effective in reducing the fear of falling and fall rates in women who applied this program at home (20). Due to their health condition, many elderly people need balance training before aerobic exercises are applied because of some demanding positions and movements. However, even during balance training there is a possibility of sudden falls (21).

A program which is used to improve balance and reduce the risk of falls among the elderly can also take place in the aquatic environment. The aquatic environment enhances the sense of security among the elderly, while the risk of injuries is extremely low. For this program, the temperature of the water in the pool needs to be slightly warmer, between 29 and 31 degrees Celsius. The exercises that are applied in this program usually contain the components of Tai chi, Ai chi and yoga (22).

Lifestyle-integrated functional exercises (LIFE) is a modern program that aims to implement strengthening exercises for lower limbs and balance exercises in daily activities among the elderly. Research results show that the risk of fall was reduced by 30% in subjects who used this program compared to the program that contained light intensity exercises and the program that consisted of traditionally structured exercises (23). The application of LIFE program improves the maintenance of static and dynamic balance, affects the vestibular system, improves the balance and strength of the lower limbs stabilizing muscles. Exercises are designed to be more applicable in everyday life, such as standing on one leg while ironing, standing on a heel, swinging the body to the margin of stability while using the phone, doing squats while shopping to reach items on lower shelves etc. (23).

Steady As You Go (SAYGo), the fall prevention program has a cognitive-behavioral and environmental focus. It implies creating conditions

Nove tehnologije i robotika u prevenciji padova

Sa razvojem tehnologije postaje dostupno sve više metoda i opreme koja se na savremeni način može iskoristiti u prevenciji padova. Postoji veliki broj rešenja koja se baziraju na otkrićima iz robotike, a koja se mogu primeniti sprovođenjem programa koji poboljšavaju sposobnost održavanja ravnoteže i posture tela. Neki robotski sistemi koji su predstavljeni u vidu elektromehaničkih uređaja sa specifičnim senzorima mogu da stupaju u interakciju sa ljudskim telom. U svrhu treninga koji utiče na smanjenje verovatnoće dešavanja pada koriste se uređaji kao što su perturbacione platforme, trake za hodanje i pokretna podnožja. Pojedine sprave mogu se koristiti u vidu konektora na telu (kukovima ili udovima) ili se mogu sastojati od spoljašnje konstrukcije koja je prilagođena da prati pokrete osobe ili je fiksirana u odnosu na okolinu. Često se susreću i kombinacije robotskih sistema u obliku opreme koja se nosi na telu i pokretnih traka i platformi po kojima se osoba kreće ili stoji. Ovim putem omogućeno je obavljanje složenih i posebno konstruisanih vežbi za poboljšanje kvaliteta hoda, koraka, održavanje statičke i dinamičke ravnoteže tela i sakupljanje digitalnih podataka čijom obradom se može usavršiti tehnika prevencije pada (25).

Pojedini robotski sistemi predstavljeni su kao inovacije koje olakšavaju život starijih ljudi u svojim domovima i predstavljeni su u vidu softverskih „robotskih trenera“, koji imaju mogućnost pokazivanja odgovarajućih vežbi i praćenja progresa tokom treninga. U ovom slučaju robotski pratilac ima važnu ulogu u praćenju učinka i motivisanja subjekta, kroz zanimljiv i zabavan interfejs. Scenario primene obuhvata učenje i ponavljanje vežbi od stručnog lica putem posmatranja i imitacije. Dok tokom rada robot izvodi vežbe i vrši nadgledanje učesnika, fizioterapeut ili drugo stručno lice povremeno vrši kućne posete i revidira program vežbanja starijih osoba (26).

Postoje roboti koji koriste pametne sisteme kako bi olakšali kretanje i upozorili korisnike na postojanje rizika od pada. Sam robot kreće se pomoću tri točka i poseduje produžetak za koji se korisnici mogu držati tokom hodanja. Poseduje i komponente u vidu kompjutera i senzora koji prate tačku težišta tela i položaja nogu osobe preračunavajući i predviđajući tok kretanja. Primena ovakve tehnologije ima velike prednosti, jer pored toga što se može koristiti u rehabilitaciji starijih osoba, može pronaći primenu i u svakodnevnim aktivnostima osoba koje imaju otežano kretanje ili povećani rizik od pada (27).

Posebno dizajnirani programi se mogu putem pametne tehnologije ugraditi u domove starijih osoba i učestvovati u njihovim svakodnevnim aktivnostima, upućivati ih u treninge i pravilno izvođenje vežbi, pratiti njihovo stanje i napredak. „Otago program vežbanja“ (engl. *The Otago Exercise Program* (OEP)) je jedan od programa zasnovanih na dokazima (jednostranih ili višestrukih) koji značajno smanjuje rizik od padova i povreda nastalih padom (16). U istraživanju publikovanom 2021. godine ovaj program je primenjivan kroz zajedničku tehnološku platformu tri puta nedeljno, tokom osam nedelja, u kućnim uslovima. Aplikacija *„FallSensing Home“* i prenosivi hardver uređaj *„Kallisto“* su omogućavali otkrivanje i prevenciju padova, a učesnici su imali pozitivne kritike. Ukazali su na potencijal koji tehnologija može pružiti u prevenciji padova i poboljšanju kvaliteta života starijih osoba (28).

U istraživanju koje je sprovedeno u pet zemalja (Belgija, Izrael, Italija, Holandija i Ujedinjeno Kraljevstvo) korišćena je aparatura za virtuelnu realnost u kombinaciji sa pokretnom trakom. Ispitanike su činile osobe starosti između 60 i 90 godina, a vežbe kognitivnih i fizičkih sposobnosti, putem ovog sistema, su realizovane tokom 6 nedelja. Sistem virtuelne realnosti se sastojao od kamere koja prati pokrete i kompjuterske simulacije projektovane na platno oko učesnika. Ovim putem stvara se iluzija stvarnog prostora u kom se osoba nalazi, a program je osmišljen tako da se učesnik suočava sa svakodnevnim problemima poput prepreka, izborom putanje i raznim faktorima distrakcije. Rezultati istraživanja pokazali su da je ovaj tip treninga doprineo smanjenoj stopi padova među učesnicima u odnosu na klasičan trening na pokretnoj traci bez virtulene realnosti (29).

Sistemi detekcije i prevencije padova još uvek predstavljaju novinu u gerijatriji, ali se velikom brzinom usavršavaju. Funkcionišu po principu prikupljanja podataka koje obrađuju putem statističkih alata i tehnika mašinskog učenja. Ovakvi sistemi mogu se sastojati od komponenti koje se instaliraju u neposrednu okolinu korisnika i kamerama prate njegovo kretanje, upozoravajući ga na određeni način o potencijalnim rizicima od pada. Takođe,

where older persons help each other to identify their own risks of falling and make practical suggestions about what to do to reduce those risks. The most significant changes in reducing the prevalence of risk factors related to falls were observed when behavioral patterns were improved, such as "paying attention" and "taking risks", while the social life and motivation of the elderly were improved due to increased social contacts (24).

New technologies and robotics in falls prevention

With the development of technology, more and more methods and equipment are becoming available that can be used in a modern way for falls prevention. There are a lot of solutions that are based on discoveries from the field of robotics, which can be applied using programs that improve the ability of maintaining balance and body posture. Some robotic systems that were presented as electromechanical devices with specific sensors can interact with the human body. Machines such as perturbation platforms, walking pads and treadmills are used for training, which affects the reduction of falling. Certain devices can be used in the form of connectors on the body (hips or limbs) or they can consist of external structure that is adapted to follow the movements of the person or is fixed in relation to the environment. Combinations of robotic systems are often seen and they include the equipment which is worn on the body and walking pads and platforms on which a person moves or stands. Thus, it is possible to do complex and specially designed exercises for improving the quality of gait, steps, maintaining the static and dynamic balance and collecting digital data, whose analysis can improve the technique of falls prevention (25).

Certain robotic systems are presented as innovations that facilitate the lives of the elderly in their homes, as well as software "robotic trainers", which are able to show appropriate exercises and monitor progress during training. In this case, the robotic companion has an important role in monitoring the performance and motivating the subject, through an interesting and fun interface. The scenario of application includes learning and repeating exercises through watching and imitating the professional. While the robot does exercises and monitors participants, the physiotherapist or other professional periodically visits the elderly at home and revises their workout program (26).

There are robots that use smart systems to facilitate movement and warn users about the risk of falling. The robot itself moves using three wheels and it has an extension that the users can hold on to while walking. It also has components in the form of computers and sensors that track the center of gravity of the body and position of the person's legs by calculating and predicting the course of moving. The application of this technology has great advantages because in addition to being used in the rehabilitation of the elderly, it can also be used in everyday activities of people who have difficulty while moving or an increased risk of falling (27).

Specially designed programs can be installed in the homes of the elderly through smart technology and take part in their daily activities, instruct them to train and do exercises correctly, monitor their condition and progress. The Otago Exercise Program (OEP) is one of the evidence-based programs (unilateral or multilateral) that significantly reduces the risk of falls and fall-related injuries (16). In a study, which was published in 2021, this program was implemented using a common technological platform three times a week, during eight weeks, in home environment. The application "FallSensing Home" and the portable hardware device "Kallisto" enabled the detection and prevention of falls, and the participants had positive reviews. They pointed to the potential that technology can provide in preventing falls and improving the quality of life of the elderly (28).

In a study, which was conducted in five countries (Belgium, Israel, Italy, the Netherlands, and the United Kingdom), virtual reality equipment was used in combination with a treadmill. The participants were persons aged 60 to 90 years, while exercises of cognitive and physical abilities, through this system, were realized during six weeks. The virtual reality system included a camera that tracked movements and computer simulations that were projected on the screen around the participants. Thus, the illusion of real space was created, and the program was designed in such a way that the participant faced everyday problems, such as obstacles, path selection and various distraction factors. The results of the study

postoje i senzorni uređaji nosivog tipa koji se lako nose na telu korisnika i koji prate njegovo izlaganje riziku od pada. Senzori su programirani i prate određene algoritme u zavisnosti od situacije u kojoj se korisnik nalazi. Ovi sistemi mogu dodatno biti podržani robotskim komponentama koje mehaničkim putem mogu pomoći osobi koja želi da napravi određeni pokret, dok su mogućnosti softverske komponente gotovo neograničene, s obzirom na to da se radi o pametnoj tehnologiji (30).

Zaključak

Prevencijom padova se bave stručnjaci iz različitih oblasti i svako sa svog aspekta treba da učestvuje u unapređenju psihofizičkih sposobnosti i kvaliteta života starijih osoba. Terapijske vežbe primenjene kroz proces rehabilitacije i postrehabilitacije imaju za cilj da kroz tretman osnovne bolesti osposobe starije osobe i na različita posturalna opterećenja, što ima krucijalni značaj u prevenciji padova. Preventivni programi vežbanja i primene fizičke aktivnosti imaju svoje značajno mesto i treba raditi na stalnom unapređenju postojećih i osmišljavanju novih programa zasnovanih na dokazima. Širenje svesti o benefitima primene terapijskih vežbi i preventivnih programa jeste značajna uloga rehabilitacionog tima, kako u centrima za rehabilitaciju, tako i u široj zajednici. Nove tehnologije, primenu robotike i veštačke inteligencije je potrebno pomno pratiti, jer mogu značajno da doprinesu poboljšanju funkcionisanja starijih osoba i prevenciji padova.

Konflikt interesa

Autori su izjavili da nema konflikta interesa.

Reference

1. Popis stanovništva, domaćinstava i stanova 2022. Starost i pol. Beograd: Republički zavod za statistiku; 2023.
2. United Nations, Department of Economic and Social Affairs, Population Division. World Population Ageing 2019 (ST/ESA/SER.A/444). New York: United Nations; 2020.
3. Li Z, Zhang Z, Ren Y, Wang Y, Fang J, Yue H, et al. Aging and age-related diseases: from mechanisms to therapeutic strategies. Biogerontology. 2021;22(2):165-87. doi: 10.1007/s10522-021-09910-5.
4. Clark BC. Neural mechanisms of age-related loss of muscle performance and physical function. J Gerontol A Biol Sci Med Sci. 2023;78(Suppl 1):8-13. doi: 10.1093/gerona/glad029.
5. Jafari H, Gustafsson T. Optimal controllers resembling postural sway during upright stance. PLoS One. 2023;18(5):e0285098. doi: 10.1371/journal.pone.0285098.
6. Jovanović L, Kovačević R, Ereš S, Kljajić D. Držanje tela-postura; kineziterapija u cilju prevencije i korekcije poremećaja držanja tela. Beograd: Atosprint; 2014.
7. World Health Organization. WHO global report on falls prevention in older age. Geneva (Switzerland): World Health Organization; 2007.
8. Roos PE, Dingwell JB. Using dynamic walking models to identify factors that contribute to increased risk of falling in older adults. Hum Mov Sci. 2013;32(5):984-96. doi: 10.1016/j.humov.2013.07.001.
9. Park SH. Tools for assessing fall risk in the elderly: a systematic review and meta-analysis. Aging Clin Exp Res. 2018;30(1):1-16. doi: 10.1007/s40520-017-0749-0.
10. Trajkov M, Jovanović S, Kljajić D. Ispitivanje posturalne stabilnosti pomoću Neurocom balance master kineziometrijske platforme. Zdravstvena zaštita. 2015;44(5):53-9. doi: 10.5937/ZZ1505053T.
11. Fragala MS, Cadore EL, Dorgo S, Izquierdo M, Kraemer WJ, Peterson MD, et al. Resistance training for older adults: position statement from the national strength and conditioning association. J Strength Cond Res. 2019;33(8):2019-52. doi: 10.1519/JSC.0000000000003230.
12. Fiatarone-Singh MA, Izquierdo M, Morley JE. Physical fitness and exercise. In: Sinclair AJ, Morley JE, Vellas B, Cesari M, Munshi M, editors. Pathy's principles and practice of geriatric medicine. 6th ed. Oxford: John Wiley and Sons Ltd; 2022. p. 77-107.
13. Jovanović L, Kovačević R, Ereš S, Kljajić D. Osnovi kineziterapije. Beograd: Atosprint; 2016.
14. Izquierdo M, Merchant RA, Morley JE, Anker SD, Aprahamian I, Arai H, et al. International exercise recommendations in older adults (ICFSR): expert consensus guidelines. J Nutr Health Aging. 2021;25(7):824-53. doi: 10.1007/s12603-021-1665-8.
15. Fejzić E. Osobe umanjenih tjelesnih sposobnosti i arhitektonske barijere. Kotor: EXPEDITIO-Centar za održivi prostorni razvoj; 2007.
16. Yang Y, Wang K, Liu H, Qu J, Wang Y, Chen P, Zhang T, Luo J. The impact of Otago exercise programme on the prevention of falls in older adult: a systematic review. Front Public Health. 2022;10:953593. doi: 10.3389/fpubh.2022.953593.
17. 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(24):1451-62. doi: 10.1136/bjsports-2020-102955.
18. Božić D, Zelenović M. Uticaj fizičke aktivnosti na prevenciju i broj padova kod starijih osoba. SportLogia. 2022;18(1):42-56. doi: 10.5550/sgia.221801.se.bz.
19. Voukelatos A, Merom D, Sherrington C, Rissel C, Cumming RG, Lord SR. The impact of a home-based walking programme on falls in older people: the easy steps

showed that this type of training contributed to a reduced rate of falls among participants compared to classic training on a treadmill without virtual reality (29).

Systems of falls detection and prevention are still a novelty among the elderly, but they are being improved rapidly. They function based on the principle of collecting data, which they analyze with the help of statistical tools and machine learning techniques. Such systems can consist of components that are installed in the immediate surroundings of the user and monitor his movements using cameras, thus warning him about potential risks of falling. Also, there are sensory devices that can easily be worn on the user's body and that monitor his exposure to the risk of falling. The sensors are programmed to monitor certain algorithms depending on the user's situation. These systems can additionally be supported by robotic components that can mechanically help the person who wants to make a certain movement, while the possibilities of software components are almost unlimited, given that it is smart technology (30).

Conclusion

Experts from different fields deal with falls prevention and everyone from their own perspective should take part in improving the psychophysical abilities and quality of life of the elderly. Therapeutic exercises applied in rehabilitation and post-rehabilitation processes, with the treatment of the underlying disease, aim to train older adults for different postural loads, which is of crucial importance in falls prevention. Preventive workout programs and implementation of physical activities have a significant place and therefore, the existing programs should be constantly improved and new ones should be designed based on evidence. Raising awareness about the benefits of applying therapeutic exercises and preventive programs is an important role of the rehabilitation team in rehabilitation centers, as well as in the wider community. New technologies, the application of robotics and artificial intelligence should be carefully monitored, as they can significantly contribute to the improvements related to the functioning of the elderly and falls prevention.

Competing interests

The authors declared no competing interests.

References

1. 2022 Census of Population, Households and Dwellings. Age and Sex. Belgrade: Statistical Office of the Republic of Serbia; 2023.
2. United Nations, Department of Economic and Social Affairs, Population Division. World Population Ageing 2019 (ST/ESA/SER.A/444). New York: United Nations; 2020.
3. Li Z, Zhang Z, Ren Y, Wang Y, Fang J, Yue H, et al. Aging and age-related diseases: from mechanisms to therapeutic strategies. Biogerontology. 2021;22(2):165-87. doi: 10.1007/s10522-021-09910-5.
4. Clark BC. Neural mechanisms of age-related loss of muscle performance and physical function. J Gerontol A Biol Sci Med Sci. 2023;78(Suppl 1):8-13. doi: 10.1093/gerona/glad029.
5. Jafari H, Gustafsson T. Optimal controllers resembling postural sway during upright stance. PLoS One. 2023;18(5):e0285098. doi: 10.1371/journal.pone.0285098.
6. Jovanović L, Kovačević R, Ereš S, Kljajić D. Body posture; kinesitherapy aimed at the prevention and correction of body posture disorders. Belgrade: Atosprint; 2014.
7. World Health Organization. WHO global report on falls prevention in older age. Geneva (Switzerland): World Health Organization; 2007.
8. Roos PE, Dingwell JB. Using dynamic walking models to identify factors that contribute to increased risk of falling in older adults. Hum Mov Sci. 2013;32(5):984-96. doi: 10.1016/j.humov.2013.07.001.
9. Park SH. Tools for assessing fall risk in the elderly: a systematic review and meta-analysis. Aging Clin Exp Res. 2018;30(1):1-16. doi: 10.1007/s40520-017-0749-0.
10. Trajkov M, Jovanović S, Kljajić D. Examination of postural stability with Neurocom balance master platform. Health Care. 2015;44(5):53-9. doi: 10.5937/ZZ1505053T.
11. Fragala MS, Cadore EL, Dorgo S, Izquierdo M, Kraemer WJ, Peterson MD, et al. Resistance training for older adults: position statement from the national strength and conditioning association. J Strength Cond Res. 2019;33(8):2019-52. doi: 10.1519/JSC.0000000000003230.
12. Fiatarone-Singh MA, Izquierdo M, Morley JE. Physical fitness and exercise. In: Sinclair AJ, Morley JE, Vellas B, Cesari M, Munshi M, editors. Pathy's principles and practice of geriatric medicine. 6th ed. Oxford: John Wiley and Sons Ltd; 2022. p. 77-107.
13. Jovanović L, Kovačević R, Ereš S, Kljajić D. Basics of kinesitherapy. Belgrade: Atosprint; 2016.
14. Izquierdo M, Merchant RA, Morley JE, Anker SD, Aprahamian I, Arai H, et al. International exercise recommendations in older adults (ICFSR): expert consensus guidelines. J Nutr Health Aging. 2021;25(7):824-53. doi: 10.1007/s12603-021-1665-8.

randomised controlled trial. Age Ageing. 2015;44(3):377-83. doi: 10.1093/ageing/afu186.

20. Wolf SL, Sattin RW, Kutner M, O'Grady M, Greenspan AI, Gregor RJ. Intense tai chi exercise training and fall occurrences in older, transitionally frail adults: a randomized, controlled trial. J Am Geriatr Soc. 2003;51(12):1693-701. doi: 10.1046/j.1532-5415.2003.51552.x.
21. Sherrington C, Michaleff ZA, Fairhall N, Paul SS, Tiedemann A, Whitney J, et al. Exercise to prevent falls in older adults: an updated systematic review and meta-analysis. Br J Sports Med. 2017;51(24):1750-8. doi: 10.1136/bjsports-2016-096547.
22. Aquatic Exercise Association. Aquatic fitness professional manual. 7th ed. United States: Human Kinetics; 2017.
23. Jansen CP, Nerz C, Labudek S, Gottschalk S, Kramer-Gmeiner F, Klenk J, et al. Lifestyle-integrated functional exercise to prevent falls and promote physical activity: results from the LiFE-is-LiFE randomized non-inferiority trial. Int J Behav Nutr Phys Act. 2021;18(1):115. doi: 10.1186/s12966-021-01190-z.
24. Robson E, Edwards J, Gallagher E, Baker D. Steady as you go (SAYGO): a falls-prevention program for seniors living in the community. Can J Aging. 2003;22(2):207-16. doi:10.1017/S0714980800004529.
25. Thompson LA, Badache M, Brusamolin JAR, Savadkoohi M, Guise J, de Paiva GV, et al. Multidirectional overground robotic training leads to improvements in balance in older adults. Robotics (Basel). 2021;10(3):101. doi: 10.3390/robotics10030101.
26. Avioz-Sarig O, Olatunji S, Sarne-Fleischmann V, Edan Y. Robotic system for physical training of older adults. Int J Soc Robot. 2021;13(5):1109-24. doi: 10.1007/s12369-020-00697-y.
27. Di P, Hasegawa Y, Nakagawa S, Sekiyama K, Fukuda T, Hujang J, et al. Fall detection and prevention control using walking-aid cane robot. IEEE/ASME Trans Mechatron. 2016; 21(2):625-37. doi: 10.1109/TMECH.2015.2477996.
28. Araújo F, Nogueira MN, Silva J, Rego S. A technological-based platform for risk assessment, detection, and prevention of falls among home-dwelling older adults: protocol for a quasi-experimental study. JMIR Res Protoc. 2021;10(8):e25781. doi: 10.2196/25781.
29. Mirelman A, Rochester L, Maidan I, Del Din S, Alcock L, Nieuwhof F, et al. Addition of a non-immersive virtual reality component to treadmill training to reduce fall risk in older adults (V-TIME): a randomised controlled trial. Lancet. 2016;388(10050):1170-82. doi: 10.1016/S0140-6736(16)31325-3.
30. Delahoz YS, Labrador MA. Survey on fall detection and fall prevention using wearable and external sensors. Sensors (Basel). 2014;14(10):19806-42. doi: 10.3390/s141019806.

License: This is an open access article under the terms of the Creative Commons Attribution 4.0 License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2024 Health Care.

Primljen: 07.06.2024. **Revizija:** 22.08.2024. **Prihvaćen:** 28.08.2024.

15. Fejzić E. People with disabilities and architectural barriers. Kotor: EXPEDITIO-Center for sustainable spatial development; 2007.
16. Yang Y, Wang K, Liu H, Qu J, Wang Y, Chen P, Zhang T, Luo J. The impact of Otago exercise programme on the prevention of falls in older adult: a systematic review. Front Public Health. 2022;10:953593. doi: 10.3389/fpubh.2022.953593.
17. 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(24):1451-62. doi: 10.1136/bjsports-2020-102955.
18. Božić D, Zelenović M. Uticaj fizičke aktivnosti na prevenciju i broj padova kod starijih osoba. SportLogia. 2022;18(1):42-56. doi: 10.5550/sgia.221801.se.bz.
19. Voukelatos A, Merom D, Sherrington C, Rissel C, Cumming RG, Lord SR. The impact of a home-based walking programme on falls in older people: the easy steps randomised controlled trial. Age Ageing. 2015;44(3):377-83. doi: 10.1093/ageing/afu186.
20. Wolf SL, Sattin RW, Kutner M, O'Grady M, Greenspan AI, Gregor RJ. Intense tai chi exercise training and fall occurrences in older, transitionally frail adults: a randomized, controlled trial. J Am Geriatr Soc. 2003;51(12):1693-701. doi: 10.1046/j.1532-5415.2003.51552.x.
21. Sherrington C, Michaleff ZA, Fairhall N, Paul SS, Tiedemann A, Whitney J, et al. Exercise to prevent falls in older adults: an updated systematic review and meta-analysis. Br J Sports Med. 2017;51(24):1750-8. doi: 10.1136/bjsports-2016-096547.
22. Aquatic Exercise Association. Aquatic fitness professional manual. 7th ed. United States: Human Kinetics; 2017.
23. Jansen CP, Nerz C, Labudek S, Gottschalk S, Kramer-Gmeiner F, Klenk J, et al. Lifestyle-integrated functional exercise to prevent falls and promote physical activity: results from the LiFE-is-LiFE randomized non-inferiority trial. Int J Behav Nutr Phys Act. 2021;18(1):115. doi: 10.1186/s12966-021-01190-z.
24. Robson E, Edwards J, Gallagher E, Baker D. Steady as you go (SAYGO): a falls-prevention program for seniors living in the community. Can J Aging. 2003;22(2):207-16. doi:10.1017/S0714980800004529.
25. Thompson LA, Badache M, Brusamolin JAR, Savadkoohi M, Guise J, de Paiva GV, et al. Multidirectional overground robotic training leads to improvements in balance in older adults. Robotics (Basel). 2021;10(3):101. doi: 10.3390/robotics10030101.
26. Avioz-Sarig O, Olatunji S, Sarne-Fleischmann V, Edan Y. Robotic system for physical training of older adults. Int J Soc Robot. 2021;13(5):1109-24. doi: 10.1007/s12369-020-00697-y.
27. Di P, Hasegawa Y, Nakagawa S, Sekiyama K, Fukuda T, Hujang J, et al. Fall detection and prevention control using walking-aid cane robot. IEEE/ASME Trans Mechatron. 2016; 21(2):625-37. doi: 10.1109/TMECH.2015.2477996.
28. Araújo F, Nogueira MN, Silva J, Rego S. A technological-based platform for risk assessment, detection, and prevention of falls among home-dwelling older adults: protocol for a quasi-experimental study. JMIR Res Protoc. 2021;10(8):e25781. doi: 10.2196/25781.
29. Mirelman A, Rochester L, Maidan I, Del Din S, Alcock L, Nieuwhof F, et al. Addition of a non-immersive virtual reality component to treadmill training to reduce fall risk in older adults (V-TIME): a randomised controlled trial. Lancet. 2016;388(10050):1170-82. doi: 10.1016/S0140-6736(16)31325-3.
30. Delahoz YS, Labrador MA. Survey on fall detection and fall prevention using wearable and external sensors. Sensors (Basel). 2014;14(10):19806-42. doi: 10.3390/s141019806.

License: This is an open access article under the terms of the Creative Commons Attribution 4.0 License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2024 Health Care.

Received: 06/07/2024 **Revised:** 08/22/2024 **Accepted:** 08/28/2024