MOGUĆNOSTI KORIŠĆENJA SENZORA INERCIJALNE MERNE JEDINICE ZA PROCENU SPOSOBNOSTI ODRŽAVANJA RAVNOTEŽE KOD STARIJIH OSOBA

ORIGINALNI RAD

ORIGINAL ARTICLE

POSSIBILITIES OF USING INERTIAL MEASUREMENT UNIT SENSOR FOR ASSESSING BALANCE ABILITIES IN THE ELDERLY

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SAŽETAK

Cilj rada: Ova studija imala je za cilj da proceni promene u posturalnoj stabilnosti kod zdravih starijih osoba korišćenjem senzora inercijalne merne jedinice (IMU) i da ispita klinički potencijal prenosive tehnologije za procenu ravnoteže u gerijatrijskoj populaciji.

Metode: Trideset četiri zdrava ispitanika starija od 65 godina podeljena su u dve starosne grupe (65–75 i > 75 godina). Ravnoteža je procenjena korišćenjem IMU senzora postavljenog na sakrum tokom 30-sekundnog stajanja u polu-tandem stavu u tri pokušaja.

Rezultati: Učesnici stariji od 75 godina pokazali su povećane oscilacije tela u odnosu na mlađu grupu. Polne razlike su otkrile veće medio-lateralne oscilacije kod muškaraca ($p = 0,038$). Nisu uočene značajne razlike u brzini oscilacija ili površini elipse, što ukazuje na efikasne kompenzatorne mehanizme u statičkim uslovima.

Zaključak: IMU-bazirana procena ravnoteže pokazuje osetljivost u otkrivanju suptilnih promena povezanih sa starošću, sa praktičnim prednostima za klinička i zajednička okruženja.

Ključne reči: posturalna stabilnost, starenje, prevencija padova, prenosiva tehnologija, procena ravnoteže

ABSTRACT

Aim: This study aimed to evaluate age-related changes in postural stability among healthy older adults using inertial measurement unit (IMU) sensors and assess the clinical potential of wearable technology for balance assessment in geriatric populations.

Methods: Thirty-four healthy participants aged > 65 years were divided into two age groups (65–75 and > 75 years). Balance was assessed using a sacrum-mounted IMU sensor during a 30-second semi-tandem stance in three trials.

Results: Participants > 75 years showed increased postural sway compared to younger counterparts. Gender differences revealed greater medio-lateral sway in males ($p = 0.038$). No significant differences were observed in sway velocity or ellipse area, suggesting effective compensatory mechanisms in static conditions.

Conclusion: IMU-based balance assessment demonstrates sensitivity in detecting subtle age-related postural changes, with practical advantages for both clinical and community settings.

Keywords: postural stability, aging, fall prevention, wearable technology, balance assessment

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UVOD

Ravnoteža je osnovna komponenta ljudskog kretanja. Funkcija ravnoteže održava se pomoću specifičnih fizioloških mehanizama koji regulišu posturalnu stabilnost kroz preciznu prostorno-vremensku kontrolu centra mase (COM) u odnosu na bazu oslonca [1]. Ovo zahteva kontinuiranu integraciju više senzornih ulaza, uključujući gravitacione signale, karakteristike podloge, vizuelne informacije i proprioceptivne povratne informacije, kako bi se postigla optimalna orijentacija tela [2].

Održavanje ravnoteže tokom antigravitacionih aktivnosti i pravilnog držanja tela predstavlja osnovu za izvođenje složenijih pokreta. Ovi sekundarni pokreti omogućavaju nam da se krećemo kroz prostor ili da stupamo u interakciju sa okruženjem [3]. Ravnoteža i hod imaju ključnu ulogu u očuvanju opšte dobrobiti i nezavisnosti starijih osoba.

Nažalost, starije osobe suočavaju se sa povećanim rizikom od padova zbog fizioloških promena povezanih sa starenjem – uključujući usporene reakcije ravnoteže, senzorne deficite, efekte lekova i neuromišićnu degeneraciju, što narušava složenu senzorimotornu koordinaciju koja je osnova posturalne kontrole [4].

Poteškoće u ovim oblastima ne samo da povećavaju rizik od padova i povreda, već doprinose i smanjenoj pokretljivosti i socijalnoj izolaciji. Studije pokazuju da približno 13% osoba uzrasta od 65 do 69 godina prijavljuje probleme sa ravnotežom, dok se taj procenat naglo povećava na 46% kod osoba starijih od 85 godina. Slično tome, poremećaji hoda predstavljaju čest problem, pogađajući oko 35% starijih od 70 godina koji nisu institucionalizovani. Ovi poremećaji nisu povezani samo sa smanjenom pokretljivošću, već i sa 2,2 puta većim rizikom od institucionalizacije i smrtnosti u poređenju sa osobama bez poremećaja hoda [5]. Ove statistike naglašavaju hitnu potrebu za ranom identifikacijom, preventivnim strategijama i prilagođenim intervencijama kako bi se očuvala pokretljivost i smanjili zdravstveni rizici u starijoj populaciji. Imajući u vidu ozbiljne posledice padova kod starijih osoba, procena poremećaja ravnoteže predstavlja standardnu i ključnu praksu u gerijatrijskoj nezi i rehabilitaciji. Rano otkrivanje i intervencija mogu značajno smanjiti rizik od padova, očuvati nezavisnost i poboljšati kvalitet života.

Klinički alati kao što su Bergova skala ravnoteže, Timed Up and Go (TUG) test, Functional Reach test i Tinetti test široko se koriste zbog svoje efikasnosti, pouzdanosti i mogućnosti da pruže vredne uvide u rizik od padova. Međutim, ovi testovi se u velikoj meri oslanjaju na subjektivnu procenu ispitivača, što može ugroziti njihovu tačnost i doslednost. Takođe, često nemaju dovoljnu osetljivost da razlikuju osobe u relativno zdravoj

INTRODUCTION

Balance is a fundamental component of human movement. The function of balance is maintained by specific physiological mechanisms that regulate postural stability through precise spatiotemporal regulation of the center of mass (COM) relative to the base of support [1]. This requires the continuous integration of multiple sensory inputs, including gravitational cues, support surface characteristics, visual information, and proprioceptive feedback, to achieve optimal body orientation [2].

Maintaining balance during anti-gravitational activities and sustaining proper posture form the foundation for executing more complex movements. These secondary movements enable us to propel ourselves through space or interact with our surrounding environment [3]. Balance and gait play a vital role in maintaining the overall well-being and independence of elderly individuals.

Unfortunately, older adults face an increased risk of falls due to age-related physiological changes - spanning slowed balance reactions, sensory deficits, medication effects, and neuromuscular deterioration, which disrupt the complex sensorimotor coordination underlying postural control [4].

Difficulties in these areas not only increase the risk of falls and injuries but also contribute to reduced mobility and social isolation. Studies show that approximately 13% of adults aged 65 to 69 report balance-related issues-a figure that rises sharply to 46% among those aged 85 and older. Similarly, gait disorders are a prevalent concern, affecting approximately 35% of non-institutionalized adults aged 70 and older. These disorders are not only linked to reduced mobility but also correlate with a 2.2-fold increase in the risk of institutionalization and mortality compared to those without gait issues [5]. These statistics underscore the urgent need for early identification, prevention strategies, and tailored interventions to maintain mobility and reduce health risks in aging populations. Given the serious consequences of falls among older adults, assessing balance disorders is a standard and essential practice in geriatric care and rehabilitation. Early identification and intervention can significantly reduce the risk of falls, preserve independence, and improve overall quality of life.

Clinical tools such as the Berg Balance Scale, Timed Up and Go (TUG) test, Functional Reach Test, and Tinetti Test are widely used due to their efficiency, reliability, and ability to provide valuable insights into fall risk. However, these assessments rely heavily on subjective interpretation by evaluators, which can compromise their accuracy and consistency. Furthermore, they may lack the sensitivity required to distinguish between individuals in relatively healthy populations, limiting their utility in early or subtle balance impairments [6].

populaciji, što ograničava njihovu primenu u otkrivanju ranih ili suptilnih poremećaja ravnoteže [6].

Ove kliničke potrebe dovele su do razvoja instrumentalne procene ravnoteže tokom mirovanja, koja je standardizovana u kliničkoj praksi sredinom 20. veka. Među različitim tehnološkim pristupima, posturografija pomoću platformi za merenje sila izdvojila se kao zlatni standard, koristeći ugrađene senzore sila za kvantifikaciju dinamike centra pritiska. Ova tehnika je poznata pod različitim nazivima, uključujući stabilometrija ili stabilografija [7].

Ipak, tradicionalna stabilometrija ima određena ograničenja. Stabilometrijske platforme često imaju velike dimenzije i težinu zbog tehničkih zahteva, što ograničava njihovu prenosivost u kliničkom kontekstu. Pored toga, da bi se dobili podaci u koordinatnom sistemu pacijenta – onom koji uzima u obzir orijentaciju i položaj stopala – neophodno je da pacijent postavi stopala na platformu na unapred definisan način. Postoje utvrđeni standardi za postavljanje stopala koji regulišu ovaj proces. U nekim slučajevima, dimenzije stopala pacijenta koriste se za definisanje koordinatnog sistema u kome se prikazuju rezultati ispitivanja [7]. Međutim, ova praksa može uneti varijabilnost i dovesti do relativizacije rezultata merenja, potencijalno utičući na njihovu konzistentnost i uporedivost.

Prikladna alternativa tradicionalnoj stabilometriji jeste merenje parametara ravnoteže pomoću inercijalnih senzora, poput inercijalnih mernih jedinica (IMU), koje obično sadrže trokomponentne akcelerometre. Suštinski, IMU sistemi se zasnivaju na specijalizovanom čipu koji sadrži senzore raspoređene u tri međusobno upravne ravni. Optimalno postavljanje senzora zavisi od zadatka, pri čemu se anatomska pozicija bira strateški da bi se registrovali relevantni kinematički parametri ciljanog posturalnog zadatka [8]. Nosivi inercijalni senzori se najčešće postavljaju u predelu struka ili trupa radi kvantifikacije posturalnog njihanja i kinematike ubrzanja trupa. Alternativne pozicije (donji ekstremiteti, grudna kost, gornji ekstremiteti ili čelo) omogućavaju segment-specifične podatke o pokretima, dok troosne konfiguracije omogućavaju sveobuhvatnu 3D prostorno-vremensku analizu dinamike zglobova i segmenata tela [9].

Važno je napomenuti da su IMU sistemi isplativi, lagani i omogućavaju sprovođenje procene ravnoteže u različitim uslovima, bez prostornog ograničenja, što ih čini naročito pogodnim za testiranje starije populacije. Najznačajnija prednost jeste to što pružaju detaljne informacije o suptilnim promenama u posturalnom njihaju, kako u statičkim, tako i u dinamičkim uslovima.

U našem istraživanju cilj je da pomoću IMU senzora procenimo ravnotežu kod osoba starijih od 65 godina i ispitamo njihovu sposobnost održavanja stabilnosti.

These clinical needs drove the development of instrumental balance assessment during quiet stance, which became standardized in clinical practice during the mid-20th century. Among the various technological approaches developed, force platform posturography emerged as the gold-standard methodology, utilizing embedded force sensors to quantify center-of-pressure dynamics. This technique is also known by several names, including stabilometry or stabilography, among others [7].

The fact is that traditional stabilometry, as it is, has certain limitations. Stabilometric platforms very often have relatively large dimensions and weight due to technical requirements. Therefore, in a clinical context, their use is hampered by a lack of portability. Apart from the mentioned, to obtain data in the patient's coordinate system—specifically, one that considers the orientation and position of the patient's feet—it is necessary to position the feet on the measurement platform in a predefined manner. Established standards for foot placement exist to guide this process. In some instances, the dimensions of the patient's feet are also used to define the coordinate system in which examination results are presented [7]. However, this practice can introduce variability and lead to a relativization of the measurement outcomes, potentially affecting their consistency and comparability.

A suitable alternative to traditional stabilometry is the measurement of balance parameters using inertial sensors, such as inertial measurement units (IMUs), which typically contain three-component accelerometers. Essentially, IMU systems are based on a specialized chip that contains sensors located in three mutually perpendicular planes. Optimal sensor positioning is task-dependent, with anatomical placement strategically selected to capture relevant kinematic parameters for the targeted postural assessment [8]. Wearable inertial sensors are typically positioned at the waist or trunk to quantify postural sway and trunk acceleration kinematics. Alternative mounting locations (lower limbs, sternum, upper extremities, or forehead) provide segment-specific movement data, with triaxial configurations enabling comprehensive 3D spatiotemporal analysis of joint and body segment dynamics [9].

After all, it is worth noting that IMU systems, being cost-effective, lightweight, and capable of administering postural assessments in diverse environments without spatial constraints, are particularly suitable for testing the elderly population. The most important aspect is that they provide detailed information on subtle changes in postural sway for both static and dynamic conditions.

In our study, we aim to use an IMU sensor to assess individuals over 65 years of age and evaluate their ability to maintain balance.

METODE

Učesnici

U istraživanju je učestvovalo 34 zdrava odrasla ispitanika (muškaraca 5; žena 29), starosti 65 godina i više, podeljenih u dve grupe (65–75 godina i >75 godina). Isključeni su ispitanici sa neurološkim, ortopedskim ili kardiovaskularnim oboljenjima koja utiču na ravnotežu, oni koji koriste pomagala za kretanje, kao i osobe koje uzimaju relevantne lekove. Svi učesnici dali su pismeni pristanak, a istraživanje je odobrio Etički komitet FSBI pri Centru za mozak i neurotehnologiju (br. 7, 19. jul 2021), u skladu sa Helsinškom deklaracijom.

Dizajn studije i postupci merenja

Procena ravnoteže vršena je pomoću Neurosoft IMU senzora (Neurosoft, Ivanovo, Rusija), postavljenog u nivou sakruma (L2–S2) pomoću elastičnog pojasa, u skladu sa utvrđenom metodologijom [8] (Slika 1). Ovakvo pozicioniranje omogućava registrovanje oscilacija tela u blizini centra mase, uz praćenje pokreta karlice. Ispitanici su stajali u polu-tandem položaju (dominantna noga napred, ruke na kukovima) sa otvorenim očima u trajanju od 30 sekundi, mirno i bez pokreta. Nakon inicijalne probe za upoznavanje sa zadatkom, sprovedene su tri test-repeticije, sa pauzama od po 10 sekundi između svake probe. Ugrađeni troosni akcelerometar beležio je podatke frekvencijom od 200 Hz, uz bežični prenos na namenski softver na računaru radi analize.

U istraživanju smo analizirali parametre posturalne stabilnosti merenjem pomoću IMU senzora. Za svakog ispitanika izračunate su prosečne vrednosti iz tri merenja za sledeće pokazatelje:

- sway mean X – prosečan pomeraj centra pritiska (COP) u levo-desno (X) pravcu,
- sway mean Y – prosečan pomeraj COP u antero-posteriornom (Y) pravcu,
- prosečna brzina pomeranja,
- površina elipse koja obuhvata 95% oscilacija.

Statistička analiza

Kolmogorov–Smirnov i Shapiro–Wilk testovi korišćeni su za procenu normalnosti distribucije podataka. Pošto podaci nisu pratili normalnu distribuciju, za poređenje razlika između dve grupe korišćen je Mann–Whitney U test, a rezultati su prikazani kao medijane (sa minimalnim i maksimalnim vrednostima).

REZULTATI

Grupa ≥75 godina pokazala je veće prosečne oscilacije u oba smera, X i Y, što može ukazivati na veću nestabilnost (Tabela 1). Međutim, ove razlike nisu bile statistički značajne ($p > 0{,}05$). Slično tome, nisu uočene značajne razli-

METHODS

Participants

The study included 34 healthy adults (male, 5; female, 29) aged 65 years or older, divided into two groups (65-75 years and >75 years). We excluded participants with neurological, orthopedic, or cardiovascular conditions that affected balance, those using mobility aids, and individuals taking relevant medications. Participants provided written informed consent, and the study was approved by the Ethical Committee of FSBI at the Center for Brain and Neurotechnology (No. 7, July 19, 2021), in accordance with the Declaration of Helsinki.

Study design and measurement procedures

Balance assessments were performed using the Neurosoft IMU sensor (Neurosoft, Ivanovo, Russia), positioned near the sacrum level (L2-S2) via an elastic band holder, in accordance with established methodology [8] (Figure 1). This placement captures body oscillations near the center of mass while monitoring pelvic movements. Participants maintained a semi-tandem stance (dominant leg forward, hands on hips) with eyes open for 30 seconds, remaining motionless. Following an initial familiarization trial, three test repetitions were conducted, with 10-second rests between each trial. The integrated triaxial accelerometer recorded data at 200 Hz, with wireless transmission to dedicated PC software for analysis.

Slika 1. Postavljanje IMU senzora za merenje ravnoteže

Figure 1. Set up for balance measurements with the IMU sensor

Tabela 1. Poređenje grupa (<75 vs. ≥75)

Table 1. Group comparisons (< 75 vs. ≥ 75)

Parametar / *Parameter*	**Grupa / *Group* <75 Median (min, max)**	**Grupa / *Group* ≥75 Median (min, max)**	***p*-vrednost / *p-value***
Sway Mean X (⁰)	0.026 (-0.584-0.968)	0.086 (-0.110-0.780)	0.255
Sway Mean Y (⁰)	0.047 (-1.093-0.910)	0.280 (-0.638-1.320)	0.581
Sway Velocity (⁰/s)	2.189 (1.342-3.286)	1.910 (0.780-3.638)	0.241
Ellipse Area (°^{2})	3.905 (1.589-32.884)	4.084 (0.780-9.242)	0.679

ke u brzini pomeranja niti u površini elipse, što sugeriše da se grupe ne razlikuju u ukupnoj posturalnoj kontroli.

Muškarci su pokazali statistički značajno veće oscilacije u X pravcu (p = 0,038), dok su žene imale veću brzinu pomeranja i površinu elipse, iako te razlike nisu bile statistički značajne (Tabela 2).

DISKUSIJA

Istraživanje posturalne stabilnosti kod zdravih starijih osoba pomoću IMU senzora otkrilo je određene trendove, iako većina rezultata nije dostigla statističku značajnost. Ovi nalazi mogu pružiti uvid u proces starenja i njegov uticaj na ravnotežu, istovremeno otvarajući pitanja za dalja istraživanja.

Povećane oscilacije u X i Y pravcu kod ispitanika starijih od 75 godina (Tabela 1) u skladu su sa prethodnim studijama koje ukazuju na progresivno pogoršanje ravnoteže sa starenjem [10,11]. Ovo se može pripisati opadanju senzorne i motoričke funkcije, uključujući gubitak mišićne mase i oštećenje vestibularnog sistema [11,12]. Međutim, odsustvo statistički značajnih razlika u brzini njihanja i površini elipse može ukazivati na to da zdrave starije osobe održavaju stabilnost u statičkim uslovima pomoću kompenzatornih mehanizama [13]. Blago povećanje oscilacija kod starijih ispitanika može imati klinički značaj, jer prethodna istraživanja pokazuju da čak i male promene mogu povećati rizik od padova [14,15].

In the study, we analyzed parameters of postural stability measured using IMU sensors. For each participant, average values were calculated from three measurements for the following indicators:

- sway mean X – mean center of pressure (COP) displacement in the left-right (X) direction,
- sway mean Y – mean COP displacement in the anterior-posterior (Y) direction,
- mean sway velocity,
- ellipse area encompassing 95% of oscillations.

Statistical analysis

The Kolmogorov–Smirnov and Shapiro–Wilk tests were used to assess the normality of data distribution. Since the data did not follow a normal distribution, the Mann–Whitney U test was used to compare differences between the two groups, and the data were presented as medians (with minimum and maximum values).

RESULTS

The group ≥ 75 showed greater mean oscillations in both the X and Y directions, which may indicate higher instability (Table 1). However, these differences were not statistically significant (p > 0.05). Similarly, there were no significant differences in sway velocity or ellipse area, suggesting that the groups did not differ in overall postural control.

Tabela 2. Gender comparisons (Female vs. Male) for both subgroups

Table 2. Gender comparisons (Female vs. Male) for both subgroups

Parametar / *Parameter*	**Žene /*Female* Median (min, max)**	**Muškarci / *Male* Median (min, max)**	***p*-vrednost / *p-value***
Sway Mean X (⁰)	0.026 (-0.584-0.739)	0.181 (0.063-0.780)	0.038*
Sway Mean Y (⁰)	0.208 (-1.093-1.320)	0.147 (-0.638-0.880)	0.847
Sway Velocity (⁰/s)	2.057 (1.342-3.638)	1.797 (0.780-2.447)	0.192
Ellipse Area (°^{2})	4.132 (1.589-32.884)	3.812 (0.780-5.449)	0.530

*p < 0,05 se smatra statistički značajnim

*p < 0.05 considered statistically significant

Polne razlike u posturalnoj kontroli manifestuju se prvenstveno u mediolateralnom njihaju tokom statičkog stajanja [16,17]. Posebno, stabilizacija stava (šire postavljanje stopala) dovodi do veće redukcije njihanja kod starijih muškaraca u poređenju sa ženama, što sugeriše da muškarci pokazuju slabiju stabilnost u uskim stavovima [18]. Iako su ove razlike suptilne, one ukazuju na potrebu za polno specifičnim pristupima u proceni i tretmanu poremećaja ravnoteže.

Upotreba IMU senzora omogućila je jednostavnu i objektivnu procenu ravnoteže u prirodnim uslovima. Ovi senzori su pouzdani alati za merenje posturalne stabilnosti, posebno u mediolateralnom pravcu kod zadataka niskog nivoa težine [19]. U kontekstu predviđanja padova, inercijalne merne jedinice (IMU), najčešće predstavljene akcelerometrima, korišćene su za razlikovanje osoba sklonih padovima od onih koji nisu, kao i za procenu rizika od padanja [20].

Međutim, mali uzorak i homogena populacija mogli su doprineti odsustvu značajnih razlika. Buduća istraživanja trebalo bi da uključe veći broj ispitanika i osobe sa blagim poremećajima ravnoteže kako bi se bolje razumeli rani znaci rizika od padova. Takođe, procena dodatnih parametara (npr. frekvencijski spektar oscilacija) mogla bi dati preciznije zaključke.

Iako su razlike bile male, kontinuirano praćenje posturalne stabilnosti pomoću IMU senzora može biti korisno za rano otkrivanje promena koje prethode padovima [20]. Ova tehnologija nudi prednosti u odnosu na kliničke testove omogućavajući kvantitativnu i ponovljivu procenu sa minimalnom opremom. Perspektivno, kombinovanje IMU senzora sa drugim modalitetima, kao što su EEG ili elektromiografija, moglo bi pružiti dublji uvid u mehanizme održavanja ravnoteže [21].

ZAKLJUČAK

Ovo istraživanje može doprineti razumevanju promena u kontroli ravnoteže povezanih sa starenjem i ukazuje na potencijalnu kliničku primenu IMU senzora za procenu posture. Praktične prednosti našeg protokola sa IMU senzorom postavljenim na sakrum – uključujući prenosivost, primenjivost u realnim uslovima i biomehaničku relevantnost za kretanje COM – čine ovaj pristup vrednim alatom za gerijatrijske procene u zajednici.

Buduća istraživanja trebalo bi da se fokusiraju na proširenje uzorka i integraciju podataka dobijenih senzorima sa kliničkim merama ravnoteže kako bi se omogućila preciznija stratifikacija rizika.

Sukob interesa: Nije prijavljen.

Males exhibited statistically significantly greater oscillations in the X direction ($p = 0.038$), while females showed higher sway velocity and ellipse area, although these differences were not statistically significant (Table 2).

DISCUSSION

The investigation of postural stability in healthy older adults using IMU sensors revealed specific trends, although most results did not reach statistical significance. These findings may provide insights into the aging process and its impact on balance, while simultaneously raising questions for further research.

Increased oscillations in the X and Y directions in participants older than 75 years (Table 1) are consistent with existing studies, which indicate a progressive deterioration of balance with age [10,11]. This can be attributed to the decline in sensory and motor functions, including loss of muscle mass and impairment of the vestibular system [11,12]. However, the absence of statistically significant differences in sway velocity and ellipse area may suggest that healthy older adults maintain stability in static conditions through compensatory mechanisms [13]. The slight increase in oscillations among older participants may have clinical significance, as previous research shows that even minor changes can increase fall risk [14,15].

Gender differences in postural control manifest primarily in mediolateral sway during static standing [16,17]. Notably, stance stabilization (wider foot placement) produces greater sway reduction in older males compared to females, suggesting males exhibit poorer stability in narrow stance configurations [18]. These differences, though subtle, indicate the need for gender-specific approaches in balance disorder assessment and treatment.

The use of IMU sensors enabled a simple and objective assessment of balance in natural conditions. Those are reliable tools for measuring postural stability, particularly excelling in the mediolateral direction for low-difficulty tasks [19]. In the context of fall prediction, inertial measurement units (IMUs), typically represented by accelerometers, have been used to distinguish between fallers and non-fallers, as well as to assess the risk of falling [20].

However, the small sample size and homogeneous population may have contributed to the lack of significant differences. Future studies should include larger participant numbers and individuals with mild balance disorders to understand the early signs of fall risk better. Additionally, evaluating further parameters (e.g., the frequency spectrum of oscillations) could yield more precise conclusions.

Although the differences were slight, continuous monitoring of postural stability using IMU sensors could be beneficial for early detection of changes that precede falls [20]. This technology offers advantages over clinical tests by enabling quantitative and repetitive assessment with minimal equipment. Prospectively, combining IMU sensors with other modalities, such as EEG or electromyography, could provide deeper insight into the mechanisms of balance maintenance [21].

CONCLUSION

This study may contribute to the understanding of age-related changes in balance control and demonstrates the potential clinical utility of IMU sensors for postural assessment. The practical advantages of our sacral-mounted IMU protocol – including portability, real-world applicability, and biomechanical relevance to COM movements – position this approach as a valuable tool for community-based geriatric assessments.

Future research should focus on expanding the sample size and integrating sensor-derived data with clinical balance measures to enable more precise risk stratification.

Conflict of interest: None declared

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