Assessment of visual training on physical skills and visual functions in older adults from Bucaramanga, Colombia

Evaluación del entrenamiento visual sobre habilidades físicas y funciones visuales en adultos mayores de Bucaramanga, Colombia

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Abstract

Introduction: Visual training has been used to improve locomotion fall risk in older adults. **Objective:** This study evaluates the effects of visual training on physical abilities and visual functions of older adults from Bucaramanga, Colombia. **Methodology:** A quasi-experimental study of older adults who underwent visual evaluation and assessment of physical abilities through the Senior Fitness Test, a standardized obstacle course, and the eye-hand coordination test. For 10 weeks, all adults attended daily recreational physical activities. Additionally, those assigned to the experimental group received a weekly session of visual training. **Results:** A total of 52 adults with a median age of 68.5 years were enrolled. Of the participants, 84.21% (48) were female and 93.94% were obese. Normal values were presented for aerobic resistance and lower and upper limb strength. Overall, 91.3% (21) had no ocular pathologies impacting visual acuity. Those who received visual training showed statistically significant improvements in the time it took to run the obstacle course and on the eye-hand coordination test. **Conclusions:** Visual training has a positive effect on hand-eye coordination, vision-mediated locomotion, and balance in older adults. These results suggest that virtual reality may enhance reaction speed, balance, and coordination.

Keywords: Older adult; Visual acuity; Postural balance; Visual training.

Resumen

Introducción: el entrenamiento visual ha venido utilizándose para mejorar la locomoción y el riesgo de caídas en los adultos mayores. Evaluar los efectos del entrenamiento visual sobre las habilidades físicas y funciones visuales en adultos mayores de Bucaramanga. **Metodología:** estudio cuasi-experimental que incluyó adultos mayores, a quienes se les realizó evaluación visual y valoración de habilidades físicas mediante el Senior Fitness Test, el circuito de obstáculos y el test de coordinación ojo mano. Todos los adultos asistieron a jornadas diarias de actividad física

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recreativa durante 10 semanas, los asignados al grupo experimental adicionalmente recibieron una sesión semanal de entrenamiento visual **Resultados:** participaron 52 adultos con una mediana de edad de 68.5 años, el 84.21 % (48) eran de sexo femenino, y el 93.94 % tenían obesidad. Los participantes presentaron valores normales para la resistencia aeróbica, fuerza de miembros inferiores y superiores. 91.3 % (21) no tenían patologías oculares que impactaran sobre la agudeza visual. El grupo que recibió entrenamiento visual evidenció mejoras estadísticamente significativas en los tiempos del circuito de obstáculos y el test de coordinación ojo mano. **Conclusiones:** el entrenamiento visual tiene un efecto positivo en la coordinación ojo mano, la locomoción mediada por la visión y el equilibrio de los adultos mayores. La incorporación de sesiones de realidad virtual al entrenamiento visual contribuye a potenciar la velocidad de reacción, el equilibrio y la coordinación.

Palabras clave: Anciano; Agudeza visual; Balance postural; Calidad de vida.

Introduction

In older adults (OA), falls are considered the second cause of death due to incidental injuries[1]. In 2018, they caused 646 000 deaths worldwide more than 80 % of which were registered in low and middle income countries, with an increasing trend in institutionalized patients[2,3]. Visual and perceptual skills in older adults have been little investigated in Latin America. The importance and impact these functions have on the daily life of people in this group goes beyond their independence and is directly related to locomotion and fall risk[4,5].

Factors that increase risk in this age group include gait, mobility and balance alterations, visual[6,7], auditory and vestibular alterations, disorientation, confusional state or delirium, and cognitive deterioration. In recent times, visual training with video game consoles[8,9] or virtual reality, augmented reality[10], and balance[11,12] have been applied as a strategy to enhance visual skills related to locomotion in older adults[13,14] showing improvement in eye-hand coordination, visual-spatial skills, and balance[15].

The purpose of this study was to assess the effects of visual training (VT) on physical abilities and visual functions in a group of older adults in the city of Bucaramanga, Colombia.

Methods

A quasi-experimental study involving adults over 60 years of age enrolled in a sports and recreation program at Santo Tomás University in Bucaramanga was performed participants with visual acuity worse than 20/50 with optical correction, or stereopsis, less than 60 seconds of arc, were excluded. The study also omitted people with Parkinson's disease, essential tremors, and hemiplegia or oculomotor paralysis. The medical record was reviewed to verify the selection criteria.

Additionally, a complete optometric and ophthalmological exam was done to assess visual conditions, ocular fondus, and intraocular pressure related to selection criteria.

The univariate analysis was carried out considering the nature of the variables studied. To this end, measures of central tendency and dispersion were calculated, as well as absolute and relative frequencies. Working with two structured, exposed, and unexposed study groups, the Exact Fisher test and t-Student for pared tests were used to compare the results.

Pre-and post-intervention assessment

The baseline assessment for agility, aerobic endurance, muscle strength, and flexibility in both upper and lower limbs was measured by the Senior Fitness Test (SFT)[16], validated in the Colombian population[17], containing tests such as sitting down and getting up from a chair, flexing the elbow and the back, joining the hands behind the back, walking in six minutes and the step test in two minutes.

Dynamic balance[18] and gait pattern were assessed with the Tinetti scale that was validated in the Colombian population[19] and included seven questions to evaluate the gait pattern and nine for dynamic balance. The maximum score in assessing dynamic balance is 16 points and 12 for walking, with a total of 28 points. Minimal risk of falling is considered when the result is between 19-24 points and high risk when the result is ≤ 19[20].

For a comprehensive assessment of vision-guided mobility, the obstacle course proposed by Reed-Jones and his group[11] was selected. Information input stimulus is purely visual through obstacle recognition, and motor integration occurs through body movement to elude them thereby testing the adaptive locomotion of the OA. Lower limbs, peripheral vision[21] visuospatial ability, and balance working together to avoid contact with obstacles. The circuit ends when the OA sits back in the chair used at onset. For this case study, both the time (T) invested in completing the circuit and the number of collisions (contact with any of the obstacles) were penalized with 2.23 seconds each. Penalization time was added to the total executed time (TT), and the result corresponds to the average obtained from the two circuit performances

Eye-hand coordination was evaluated according to the speed and precision of the upper limbs using the Plate Tapping test. This test is part of the Fitness Condition for Older Adults battery (ECFA by its acronym in Spanish)[22,23].

Involvement

The older adults were randomly assigned to one of two groups: one receiving only recreational and physical sessions three times a week (**Table 1**), while the other group additionally received 10 visual training sessions – lasting one hour weekly (**Table 2**) – that aimed to enhance visual and perceptual skills.

Table 1: Physical activity program for older adults 2019-1

Week	Days of the week	Month	Ability to work
1	4-8	March	Strength-Endurance
2	11-15		
3	18-22		Aerobic endurance
4	25-29		
5	1-5	April	Speed
6	8-12		
7	22-26		Stretching
8	29-3	April/May	Coordination
9	6-10	May	Balance
10	13-17		Rhythm

Source: Authors

Table 2. Visual training protocol

Session	Visual and perceptual skills (n = 25)	In-Office training (n = 27)	Home training
1	Eye-hand coordination	Rotator Virtual reality. Play Station 4	Throwing-catching rise bags
2	Visual attention + Saccadic movements	Asteroid Defense* Rotator. Throwing-catching rise bags 1 and 2 hands Virtual reality. Play Station 4	Reading numbers on the wall. Bounce balls 1 hand. Peripheral awareness: Puppy chart**
3	Peripheral awareness Saccadic movements	Puppy chart/ Peripheral Circle, slow. Throwing-catching rise bags 1 and 2 hands. Virtual reality. Play Station 4	Puppy chart. Name the Arrows. / Slap-Tap letter reading**
4	Directionality/laterality Eye-hand coordination Saccadic movements (anti-suppression control)	Name the Arrows. / Slap-Tap letter reading. Saccade Pop (red, and green)* Virtual reality. Play Station 4	Puppy chart. Name the Arrows. / Slap-Tap letter reading** Brock String.

5	Red-green saccadic movements. Peripheral awareness	Saccade Pop (red-green) * Balloon Count Peripheral Awareness*, Virtual reality. Play Station 4	Brock String. Peripheral Circle slow**
6	Eye-hand coordination. Stereopsis.	Virtual reality Play Station 4.	Brock String. Peripheral Circle slow**.
7	Vergence facility. Fusional vergence amplitude (positive) Eye-hand coordination. Stereopsis.	Brock String. Base in/ base out prism Loose prism Virtual reality Play Station 4.	Brock String. Fusion vectograms
8	Vergence facility Fusional vergence amplitude (positive)	Base in/ base out prism Base in Prism + Step toe. Virtual reality Play Station 4.	Fusion and 3D -vectograms.
9	Vergence facility Fusional vergence amplitude (negative) Eye-hand coordination. Stereopsis.	Base in/ base out prism Loose prism + Marsden´s ball. Virtual reality. Play Station 4.	Modified Remy Separator Free space fusion cards
10	Vergence facility Eye-hand coordination. Stereopsis	Base in/ base out prism + Hart Chart. Virtual reality. Play Station 4.	

Source: Authors. * Optic trainer tests. ** taken from: https://eyecanlearn.com/tracking/peripheral/

The application of virtual reality as part of the visual training sessions was an innovative aspect of the study. A virtual reality game was incorporated using a Play Station 4 1TB HIT S4 8 Cores. The resolution was set to 1080p using a PS4 VR bundle virtual reality accessory. Using this, the older adult (personifying spider-man) had to test hand-eye coordination by shooting spider webs at initially fixed objects and then mobile ones. The last level of the game placed the participant on a highly unstable surface and thus stimulated balance in a safe environment (**Figure 1**).

Figure 1. a. Older adult using virtual reality equipment. **b.** Frame seen from inside the hull.

Results

A total of 52 older adults who met the established selection criteria and were active members of the physical conditioning program at the Bucaramanga Branch of the Universidad Santo Tomás were evaluated. Five adults under 60 were excluded, three because of pre-existing medical conditions, and two were not interested in participating.

The group that received only physical training had a higher median age; the difference not being recognized as statistically significant. In both groups, females presented the highest frequency. Regarding body composition, Body Mass Index (BMI) as measured by the SEEDO criteria (24), 36% (9) of participants in the experimental group were grade II overweight, while 33.33 % (9) were graded I overweight in the control group (Table 3).

Table 3. Demographic and clinical characteristics of participants.

Criteria	Physical training + Visual training (n = 25)	Physical training (n = 27)	P-Value
Age (years old)	66 (7)[a]	71 (10)	0.40[b]
Sex %(n)			
Femenine	88(22)[c]	96.3 (26)	0.34
Masculine	12 (3)	3.7 (1)	
BMI (Kg / mts)	27.7 (4.5)[b]	26.8 (5.4)	0.52
BMI SEEDO CRITERIA			
Normal weight	24 (6)[c]	25.93 (7)	
Obesity type I	20 (5)	18.52 (5)	0.64
Overweight I	20 (5)	33.33 (9)	
Overweight II	36 (9)	22.22 (6)	
Best vision acuity RE[d] %(n)			
20/20 – 20/40	91.3 (21)[b]	91.3 (21)	1.00
20/40 – 20/50	8.7 (2)	8.7 (2)	
Best vision acuity LE [d] %(n)			
20/20 – 20/40	91.3 (21)[b]	86.96 (20)	1.00
20/40 – 20/50	8.7 (2)	13.04 (3)	
SPH (Diopter)			
RIGHT EYE	-0.66 (-3.35 – 2.03)[e]	0.48 (-1.35 – 2.30)	0.46
LEFT EYE	-1.22 (-3.62 – 1.16)	-1.03(-4.03 – 1.6)	0.92
CYL (Diopter)			
Right eye	-0.77(- 1.24 - -0.31)[f]	-0.89 (-1.27 - -0.51)	0.67
Left eye	-0.5 (-0.77 - -0.23)	- 0,84 (-1.29 - -0.39)	0.18
Cover-un cover test % (n)			
Exophoria	48 (12)[b]	45.45 (10)	
Ortophoria	52 (13)	62.96 (17)	1.0
Pathological diagnosis % (n)			
Blepharitis			
Cataract	20 (5)[c]	22.22 (6)	0.84
Chorioretinitis	20 (5)	3.7 (1)	
Posterior vitreous	4 (1)	-------	
detachment	4 (1)	-------	
Gerontoxon		-------	
Optic neuritis	8 (2)	18.51 (5)	
Dry eye	4 (1)	-------	
Intraocular lens	4 (1)	11.1 (3)	
Narrow angles	24 (6)	7.41 (2)	
Epiretinal membrane	------	3.7 (1)	
Meibomitis	-------	33.33 (9)	
Healthy	4 (1)		
	8 (2)		

a. Median (interquartile range). b. Wilcoxon ranks test. c. Fisher's exact test. d. Experimental: No VA available data in two individuals Control: No available data in two individuals. e. T Student Test f. Average (95 % confidence interval).

Regarding the visual characteristics of the population being studied, 91.3% (21) of the participants had a level of visual acuity with optical correction at optimal levels, largely explained by low refractive errors. Pathologically, the ocular structures of the group that underwent only physical training are classified as healthy in 33.33% (9) of the participants, while in the group that additionally received visual training there was a greater presence of alterations, although these did not compromise visual function (Table 4).

When analyzing the effect of VT on the gait and balance functions evaluated through the Tinetti Scale, no considerable changes were achieved when comparing the pre-and post-treatment measurements. This result is likely due to the optimal state of these functions in the study population - 52% of the participants in the group that received the two training sessions were classified as without risk by the scale, and in the case of the group that received only physical training, 66.67% had minimal risk (Table 4).

Regarding depth perception, considered an important variable in the locomotion process, there was a slight improvement in the group intervention with VT, which was not, however, statistically significant. In the case of eye-hand coordination, on the other hand, the improvement over time in both groups was statistically significant.

Likewise, after carrying out both physical and visual training sessions, the data showed a positive effect on performance, with that of the group that received both being slightly better, and these results are statistically significant (Table 4).

No statistically significant improvements were evidenced in the performance of older adults on the (SFT) tests, except for Arm Curl Test (EXP) and chair stand test (CON) (Table 5).

There was evidence of a slight improvement in the four levels of the virtual reality game as well, where the best performance was graded with the letter A and the worst with the letter C. At the end of the five sessions, 20% (5) participants reached the maximum grade, a significant improvement in balance and eye-hand coordination for both static and moving objects.

Table 4. Post-intervention analysis

Criteria	**Physical training + Visual training (n=25)**		**P-Value**	**Physical training (n=27)**		**P-Value**
	Pre	**Post**		**Pre**	**Post**	
Tinetti Scale	23,86 (22,51 - 25,21)[a]	23,86 (22,45 - 25,27)	1,0	21,69 (19,41 - 23,97)	22,31 (19,36 - 25,26)	0,68
Tinetti Scale **Low risk** **Moderate** **High risk**	 52 (13) 55 (11) 50 (1)	 48 (12)[b] 45 (9) 50 (1)	1,0	 31,82 (7) 66,67 (14) 66,67 (4)	 68,18 (15) 33,33 (7) 33,33 (2)	0,05
Stereopsis (seconds of arc)	45,55 (28,99 - 62,11)	42,22 (28,73 - 55,71)	0,27	55,83 (27,10 - 84,56)	55,83 (27,10 - 84,56)	0,37
Plate Tapping. Eye -hand coordination (sec)	22,48 (7,32)	17,59 (5,95)	0,01[c]	26,69 (22,44 - 30,94)	22,69 (19,22 - 26,16)	0,00[d]
Number of obstacle collisions	2,33 (1,02 - 3,63)	1,35 (0,73 -1,98)	0,03	1,81 (1,06 - 2,57)	1,04 (0,57 - 1,52)	0,02
Obstacle collisions (completion time) (seconds)[g] CT	38,48 (17,13)	30,96 (7,3)	0,00[e]	40,55 (10,45)[f]	31,41 (12,05)	0,00[e]

a. Average (95% confidence interval). B. Three patients were not assessed. c. Sign test for paired samples. d. T-student test for paired samples and. Wilcoxon ranks test for paired samples. F. Median (interquartile range). g. Average (95% confidence interval). Consider the total time spent and compensation for collisions or omissions.

Table 5. Senior Fitness Test

Senior Fitness Test	Experimental Group (n = 25)		P[a] Value	Control Group (n = 27)		P[a] Value
	Pre	Post		Pre	Post	
Chair Stand	15,55 (13,17 - 17,92)	16,25 (13,70 - 18,79)	0,49	17,42 (14,22 - 20,62)	20,62 (16,82 - 24,42)	0,02
Arm Cur	21,4 (19,29 - 23,51)	22,6 (20,45 - 24,74)	0,03	22 (19,41 - 24,59)	23,61 (20,61 - 26,61)	0,14
Chair Sit & Reach	-1,33 (-5,91 - 3,24)	-1,19 (-5,98 - 3,60)	0,64	0,3 (-4,64 - 5,24)	1,73 (-3,29 - 6,76)	0,08
Back scratch	-29,4 (-66,34 - 7,50)	-28,34 (-61,75 - 5,08)	0,96	-4,42 (-9,05 - 0,21)	-4,5 (-9,29 - 0,29)	0,69
Stand Up Walk return	6,31 (5,71 - 6,9)	6,06 (5,54 - 6,58)	0,08	6,57 (6,0 - 7,14)	6,51 (5,94 - 7,07)	0,55
6 minutes' walk	518,46 (475,91 - 561,02)[a]	522,52 (480,88 - 564,16)	0,70	460,07 (392,07 - 528,09)	488,98 (441,03 - 536,94)	0,20

a. t-Student for paired samples.

Discussion

The impact of visual training on physical abilities and visual function in a group of older adults was studied. A total of 92.3% of the population were women, which coincides with other studies carried out in Colombia (Bucaramanga and its metropolitan area[25], Manizales, Puerto Salgar, Colombia[26], where most of the participants were also women. They show greater adherence to training and physical activity programs, as they feel these spaces are places where they can share with their friends, improve their physical condition, and better their quality of life[23,26]. Nevertheless, BMI results showed normal weight in a few people. However, other studies carried out in the same city show similar results[20,25], possibly due to the type of diet of older adults or the hormonal and morphological changes that occur at this stage of life, such as alterations in body sizes, vertebrae, and curvature of the spine.

To overcome obstacles and be able to move safely, older adults not only need to be in good physical condition, but also require optimal processing of the visual image. The most relevant finding is data revealed from the obstacle course test, as the evaluation goes beyond the physical condition and provides an overview of body control mediated by visual information. The decrease in travel times, especially from those who received the two pieces of training, supports the hypothesis that VT improves obstacle avoidance, data comparable to those presented by Reed-Jones. VT also impacts dynamic balance, allowing the elderly to have greater frequency, amplitude, and quality of step and body control during walking, thus, avoiding the need to seek support on a nearby object to maintain stability and reduce the risk of falling[27].

Although both groups of older adults experienced fewer collisions in the last development of the obstacle course, the decrease was greater in the group that received VT, data that agree with those of Reed-Jones, who designed the circuit, and with Ooijen et al.[28]. VT with virtual reality can contribute to the somatosensory integration of older adults by providing "very real" visual stimuli and tasks with a progressive increase in difficulty (motor response) in otherwise unsafe environments may explain this finding. This result can also be explained by the fact that it also provides interactive cognitive-motor training since gross motor control and complex information processing is required to carry out the game, thereby, causing a positive impact on reducing the risk of falls[29].

Although a PlayStation 4 was used for these tests, any virtual reality tool can be adjusted to improve specific visual skills, according to the requirements of the participant, such as eye-foot coordination with soccer games or less severe postural demands. Enhancement of hand-eye coordination and balanced visual skills have a positive impact on the avoidance of obstacle. This was also confirmed in the study carried out in Chile, where there were improvements in balance and posture after the implementation of virtual reality therapies through use of a Nintendo Wii[30].

Visual training could be incorporated into older adult health programs, since there is evidence that multifactorial interventions are associated with a reduction in the risk of falls in this group[3,31,32].

Conclusions

Visual training has a positive effect on eye-hand coordination, reaction speed, vision-mediated locomotion, and balance in older adults.

Results show a positive impact of the treatment with older adults in a short period of only 10 VT sessions. Future research should verify or contradict these data.

Weaknesses of the research process to be recognized include the failure to follow-up in the group that received the two training sessions, which reached 7.69% (4 people), and the frequency of attendance at the physical training sessions, which was close to 70% in the group that only received that therapy.

Ethical considerations

This paper follows the foundations outlined in the Declaration of Helsinki. Approval for the study was obtained from the ethics committee of Santo Tomás University number 00162019-114022019 and all participants signed informed consent before the start.

References

1. World Health Organization. WHO global report on falls prevention in older age. Geneva, Switzerland: World Health Organization; 2018. 47 p. Retrieved from https://www.who.int/ageing/projects/falls_prevention_older_age/en/
2. Cameron ID, Dyer SM, Panagoda CE, Murray GR, Hill KD, Cumming RG, et al. Interventions for preventing falls in older people in care facilities and hospitals. Cochrane Bone, Joint and Muscle Trauma Group, editor. Cochrane Database Syst Rev [Internet]. 7 de septiembre de 2018 [citado 12 de enero de 2022]. Disponible en: https://doi.wiley.com/10.1002/14651858.CD005465.pub4
3. Guirguis-Blake JM, Michael YL, Perdue LA, Coppola EL, Beil TL. Interventions to prevent falls in older adults: Updated evidence report and systematic review for the US preventive services task force. JAMA. 2018; 319(16):1705. doi:10.1001/jama.2017.21962.
4. Saftari LN, Kwon OS. Ageing vision and falls: a review. J Physiol Anthropol. 2018; 37(1):11. doi: 10.1186/s40101-018-0170-1
5. Patla AE. Understanding the roles of vision in the control of human locomotion. Gait Posture. 1997; 5(1): 54-69. doi: 10.1016/S0966-6362(96)01109-5
6. Lord SR, Dayhew J, Sc BA, Howland A. Multifocal glasses impair edge-contrast sensitivity and depth perception and increase the risk of falls in older people. J Am Geriatr Soc. Noviembre de 2002; 50(11): 1760-1766. doi: 10.1046/j.1532-5415.2002.50502.x.
7. Abdelhafiz AH. Visual factors should be assessed in older people presenting with falls or hip fracture. Age Ageing. 2003; 32(1): 26-30. doi: 10.1093/ageing/32.1.26.
8. Ferraz DD. Nintendo Wii training on postural balance and mobility rehabilitation of adults with Parkinson's disease: a systematic review. Fisioter Em Mov. 2017; 30(Supp 1): 383-93. doi: 10.1590/1980-5918.030.s01.ar07.
9. Yu RWL, Chan AHS. Meta-analysis of the effects of game types and devices on older adults-video game interaction: Implications for video game training on cognition. Appl Ergon. 2021; 96: 103477. doi: 10.1016/j.apergo.2021.103477
10. Po-Jung Chena, Penn IW, Shun-HW, Long RC, Wen HS. Augmented reality-assisted training with selected Tai-Chi movements improves balance control and increases lower limb muscle strength in older adults: A prospective randomized trial. J Exerc Sci Fitness. 2020; 18(3): 142-147. doi: 10.1016/j.jesf.2020.05.003
11. Reed-Jones RJ. Vision and agility training in community dwelling older adults: incorporating visual training into programs for fall prevention. Gait Posture. 2012; 35(4): 585–589. doi: 10.1016/j.gaitpost.2011.11.029
12. Schoene D, Valenzuela T, Toson B, Delbaere K, Severino C, Garcia J, et al. Interactive cognitive-motor step training improves cognitive risk factors of falling in older adults - a randomized controlled trial. PLoS One. 2015; 10(12: e0145161). doi: 10.1371/journal.pone.0145161
13. Buccello-Stout RR, Bloomberg JJ, Cohen HS, Whorton EB, Weaver GD, Cromwell RL. Effects of sensorimotor adaptation training on functional mobility in older adults. J Gerontol B Psychol Sci Soc Sci. 2008; 63(5): P295-300.
14. Hatzitaki VV. Visual feedback training improves postural adjustments associated with moving obstacle avoidance in elderly women. Gait Posture. 2009; 29(2): 296–299. https://doi.org/10.1016/j.gaitpost.2008.09.011
15. McGee JS, van der Zaag C, Buckwalter JG, Thiebaux M, Van Rooyen A, Neumann U, et al. Issues for the assessment of visuospatial skills in older adults using virtual environment technology.

Cyberpsychol Behav. 2000; 3(3): 469-482. doi: 10.1089/10949310050078931.
16. Rikli RE, Jones CJ. Senior fitness test manual. 2nd ed. Champaign, IL: Human Kinetics; 2013. 176 p.
17. Sandoval Cuellar C, Cobo-Mejía EA, Ochoa-Gonzalez ME, Ruiz- Castillo L, Vargas-Niño DM, Sanchez-Pacheco AM. Confiabilidad del senior fitness test versión en español, para población adulta mayor en Tunja-Colombia. Arc Med Deporte. 2016; 33: 382-386.
18. Terra Jonas LV. (2014). Evaluación del riesgo de caídas en las personas mayores: ¿cómo hacerlo?. Gerokomos. 25(1), 13-1. doi: 10.4321/S1134-928X2014000100004
19. Rodríguez Guevara C, Lugo LH. Validez y confiabilidad de la Escala de Tinetti para población colombiana. Rev Col Reumatol. 2012; 19(4): 218-233.
20. Villamarin Orejuela M, López Veloza JJ, Aguirre Rueda DM. Valoración del equilibrio dinámico y estático en la población de adultos mayores pertenecientes al grupo adulto mayor «Estrellitas mañaneras y Gimnasia al parque» del municipio de Girón-Santander. Tesis de grado. Repositorio Universidad Santo Tomás. 2019. Obtenido de https://repository.usta.edu.co/handle/11634/15990.
21. Marigold DS. Role of Peripheral Visual Cues in Online Visual guidance of locomotion. Exerc Sport Sci Rev. Julio de 2008; 36(3): 145-151 doi: 10.1097/JES.0b013e31817bff72
22. Graci V, Elliott DB, Buckley JG. Utility of peripheral visual cues in planning and controlling adaptive gait. Optom Vis Sci. 2010; 87(1): 21-27. doi: 10.1097/OPX.0b013e3181c1d547
23. Castellanos J, Gómez D, Guerrero C. Condición física funcional de adultos mayores de centros día, vida, promoción y protección integral, Manizales. Hacia Prom Salud. 2017; 22(2): 84-98. doi: 10.17151/hpsal.2017.22.2.7
24. Salas-Salvadó JG. (2007). Consenso SEEDO 2007 para la evaluación del sobrepeso y la obesidad y el establecimiento de criterios de intervención terapéutica. 128. Med Clin. 2007; 128: 184-196. doi: 10.1016/S0025-7753(07)72531-9
25. Rodríguez Calderón, CM, & Velandia Calderón G. Niveles de la condición física funcional de los adultos mayores de los Centros Vida, Bucaramanga, 2018-I. Tesis de grado. Bucaramanga: Repositorio Universidad Santo Tomás; 2018. Obtenido de https://repository.usta.edu.co/handle/11634/21294
26. Quiroga J, De La Cruz M, Ramos C, Urueta C. Condición física de los adultos mayores del programa años de plenitud del municipio de Puerto Colombia y Salgar. Rev Salud Mov. 2010; 2(2): 10-15.
27. Lee J, Yoo HN, Lee BH. Effects of augmented reality-based Otago exercise on balance, gait, and physical factors in elderly women to prevent falls: a randomized controlled trial. J Phys Ther Sci. 2017; 29(9): 1586-1589. doi: https://doi.org/10.1589/jpts.29.1586
28. van Ooijen MW, Roerdink M, Trekop, M. et al. The efficacy of treadmill training with and without projected visual context for improving walking ability and reducing fall incidence and fear of falling in older adults with fall-related hip fracture: a randomized controlled trial. BMC Geriatr 16, 215 (2016). doi: https://doi.org/10.1186/s12877-016-0388-x
29. van Helvoort D, Stobbe E, Benning R, Otgaar H., van de Ven V. Physical exploration of a virtual reality environment: Effects on spatiotemporal associative recognition of episodic memory. Mem Cognition. 2020; 48(5), 691–703. doi: 10.3758/s13421-020-01024-6
30. Gatica Rojas VE, Vidal Silva C, Cantin López M. Impacto del Entrenamiento del Balance a través de Realidad Virtual en una Población de Adultos Mayores. Int J Morphol. 2010; 28(1): 303-308. doi: 10.4067/S0717-95022010000100044
31. Gillespie LD, Robertson MC, Gillespie WJ, Sherrington C, Gates S, Clemson L, et al. Interventions for preventing falls in older people living in the community. Cochrane Bone, Joint and Muscle Trauma Group, editor. Cochrane Database Syst Rev [Internet]. 12 de septiembre de 2012 [citado 13 de enero de 2022]; 2021. doi: 10.1002/14651858.CD007146.pub
32. Tricco AC, Thomas SM, Veroniki AA, Hamid JS, Cogo E, Strifler L, et al. Comparisons of Interventions for Preventing Falls in Older Adults: A Systematic Review and Meta-analysis. JAMA. 2017;318(17):1687. doi: 10.1001/jama.2017.15006