The influence of physical activity on gait parameters during dual-task activities in the older people

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Abstract

Objective: To analyze the possible differences in the kinematic variables of gait between physically active and physically inactive older people while performing dual-task activities. *Method*: Older individuals, aged between 60 and 75 years, participated, divided into two groups: physically inactive (PI) (n=20) and physically active (PA) (n=20). Participants were equally grouped into ten female and male individuals, classified using the International Physical Activity Questionnaire (IPAQ). Participants initially performed simple tasks (arithmetic, verbal fluency, and gait) and then performed dual task activities, associating gait with the two cognitive activities (arithmetic and verbal fluency). The variables velocity, cadence, stride length, step width, stride time and double support were analyzed. To compare variables according to task and group, the Generalized Estimating Equations (GEE) model complemented by the Bonferroni test was used. *Results*: In the intragroup analysis both groups showed significant decreases in velocity, cadence, step width, stride time and double support, both in the arithmetic dual task and in the verbal fluency dual task. However, in the comparisons between the groups, there were no statistically significant differences in any kinematic parameter analyzed, both in the single gait analysis and in the dual tasks. *Conclusion*: The dual tasks had a negative influence on the kinematic gait parameters in both groups. However, the level of physical activity can not be considered a factor that minimizes the effects of the dual task on gait in the older people.

Keywords: Physical Activity. Aging. Gait. Cognition.

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INTRODUCTION

The aging process is related to the impairment of physical and cognitive functions[1]. Among the physical changes in older people, alterations on gait and mobility can be highlighted. Gait is a complex motor task for the older people, whose execution is considered automatic in healthy adults and with absence of this automatism in old age[2]. However, it is common for people to walk while they are performing another task.

Dual tasking involves the performance of a motor and a cognitive task simultaneously, requiring attentional and cognitive resources and it is involved in many daily activities[3]. Independent of the age, when the execution of a task intervenes in the performance of another, there is a negative interaction between the tasks, exceeding the capacity of the available resource[4]. As result of exceed capacity, a lower gait performance can occur and it has been highly related to increases in falls risk, especially in the older people[5]. Also, aging is linked to low performance in cognitive function, such as attention and executive functions, as it may be linked to increased risk of falls[6]. Due to the high cost that falls may incur to individuals and the society, it is essential to devise ways to improve physical and cognitive performance in older adults[7].

The updated WHO guidelines on physical activity confirmed the importance in regular physical activity to accomplish health benefits, especially in older adults. This helps prevent falls and injuries from falls[8]. For the maintenance of health, independence and quality of life, the practice of physical activity has beneficial effects for a better longevity and well-being of the older people, through multiple mechanisms and physiological pathways[9]. Some studies have already demonstrated that physical activities are interventions capable of reducing cognitive decline, showing favorable effects on the brain; in addition to promoting the maintenance of physical function during advancing age[10]. As you age, the importance of staying active and practicing physical exercise becomes fundamental to having a longer life[11]. Despite the knowledge that physical activity influences musculoskeletal and cognitive systems, few studies evaluated the influence of physical activity levels on gait parameters in the older population during dual-tasking[12,13]. In view of the above, the main objective of this study was to analyze the possible differences in the kinematic variables of gait between physically active and physically inactive older people while performing dual-task activities. The main hypothesis of the present study is that dual tasking would influence the gait parameters in physically active less than older people that are physically inactive.

METHOD

This is an observational, analytical, and quasi-experimental study. The study was carried out at the Laboratory of Analysis of Biomechanics of Human Movement of the Clinical Center of the University of Caxias do Sul (CECLIN-UCS), located in Block 70, of the University of Caxias do Sul (UCS). The data was collected between May and July 2022.

The sample consisted of 40 older participants, recruited through posters from the community of University of Caxias do Sul, divided into two groups: physically inactive group (PI): 20 older people of both genders (ten females and ten males), who do not practice physical exercise on a regular basis and physically active group (PA): 20 older people of both sexes (ten females and ten males), who practice physical exercises on a regular basis. The sample size was calculated using the statistical program G*Power 3.1, based on gait velocity as the primary parameter for analysis. With a sample size of 20 per group, the Generalized Estimating Equations (GEE) model (interactions between tasks and between groups) will have a statistical power of 80% and an effect size of 0.30.

For the beginning of data collection, first, a telephone contact was made with the possible participants of the research for invitation and explanations about the research. Those who agreed to participate in the study, and who met the inclusion and exclusion criteria, were invited to attend the Laboratory of Biomechanical Analysis of Human Movement on predetermined days and times. The participants were included if they were aged 60–75 years. Participants were excluded if they experienced an acute illness during the last 3 months; had unstable cardiovascular, neurological or musculoskeletal conditions that could interfere with independent ambulation and/or limit safe performance of the experimental protocol; had taken medication that could affect memory and cognitive function; had cognitive impairment or lacked Portuguese fluency that could interfere with informed consent, questionnaires or following study instructions.

On the day scheduled for the evaluation, the participants were received in the laboratory by the researchers and immediately received explanations about the study procedures and the Informed Consent Form (ICF). Once in agreement, anthropometric data were measured [body mass, height, body mass index (BMI)] and then a questionnaire was applied with questions about personal data (name and age), history of past and current pathologies, use of medication, physiotherapy treatment. Then, the participants answered the questionnaires about the levels of physical activity and cognition. For the assessment of physical activity, the International Physical Activity Questionnaire (IPAQ) was used. This questionnaire consists of 27 items comprising different domains (related to work, transport, domestic and leisure activities) and different intensities (moderate vigorous) and requires participants to estimate the time spent in various levels of physical activity during the previous week[14]. IPAQ uses an overall physical activity level of participants based on their Metabolic Equivalent Task minutes (MET-min) per week and classified the participants into five categories: very active, active, irregularly active A, irregularly active B and sedentary. Participants classified as very active and active were included in PA group and participants classified as irregularly active A, irregularly active B and sedentary were included in PI group. It has strong psychometric characteristics for monitoring the physical activity levels of adults aged 18 to 85 years[15]. For the cognitive assessment, two questionnaires were used, the Mini Mental State Examination (MMSE) and the Montreal Cognitive Assessment (MoCA). Each questionnaire lasts approximately ten minutes, is easy to apply and does not require any specific material. The MMSE is considered a standardized, simplified, and quick assessment, with wide acceptance in the scientific and clinical community, already validated and adapted for the Brazilian population[16]. The MMSE evaluates cognitive functions such as spatial and temporal orientation, immediate and evocation memory, calculation, language-naming, repetition, comprehension, writing and drawing copy; the maximum score is 30 points and scores lower than 23 can be interpreted as cognitive impairment[17]. The MoCA assesses similar tributes to the MMSE, but also assesses visuospatial skills and executive function[18].

Subsequently, simple tasks were performed. First, the two simple cognitive tasks and then the simple motor task of walking. To perform simple cognitive tasks, study participants were invited to sit in a comfortable chair, in a quiet room, and performed the following tests: 1) subtraction arithmetic task: consisted of participants performing for one minute the subtraction of five by five, starting from the number 400[19]; 2) verbal fluency task: consisted of the older people speaking the maximum number of words in 1 minute that began with the letter "P" or "B"[20].

Afterwards, the simple gait task was performed. The procedures for gait data collection were based on the protocol by Laroche et al.[21]. The self-selected velocity was used for the evaluation. In order to adapt the participants to the evaluation protocol, they were first asked to walk for eight meters in a straight line at the self-selected velocity in the place destined for gait collection in the laboratory. The participants were instructed to memorize the number of steps and the pace needed to be able to make contact with the platform, sometimes with the entire right foot, sometimes with the entire left foot. After familiarization, retroreflective markers (VICON MX systems, Oxford Metrics Group, United Kingdom) were affixed following the Plug-in gait lower body model (Motion Capture Systems, VICON MX systems, Oxford Metrics Group, United Kingdom) at the following anatomical points, to the right and left: anterior superior iliac spine, posterior superior iliac spine -superior, medial-lateral portion of the femur, medial and lateral portion of the knee, medial-lateral portion of the tibia, medial and lateral portion of the ankle, central-posterior portion of the calcaneus and dorsal surface of the second metatarsal. The gait protocol consisted of taking steps on the platform, and in all attempts the participant took the same route as in the adaptation session. Attempts were made until eight steps were fully captured[21]. During the walking evaluation protocol, kinematic and kinetic data were collected simultaneously. To capture the three-dimensional trajectory of the markers positioned on the participants' bodies during gait, a kinemetric system with seven integrated cameras (VICON MX systems, Oxford Metrics Group, United Kingdom) was used. Kinematic data were collected at a sampling rate of 100Hz.

After performing each of the simple tasks, both the two cognitive tasks and the motor task of walking, the dual task activities were performed. Dual tasks consisted of performing the motor gait task simultaneously with each of the two cognitive tasks. This means that walking at a self-selected velocity was performed at the same time as each of the two cognitive tasks. It is noteworthy that the participants first performed all the simple tasks, both cognitive and motor, prior to the dual task activities. Both the execution order of the simple and dual task cognitive activities was defined at random, through a raffle carried out by the researchers before the arrival of the participant to carry out the research.

The project complies with Resolution 466/2012, which approves the regulatory guidelines and standards for research involving human beings. This project was approved by the Research Ethics Committee (REC) of the University of Caxias do Sul, under CAAE number 97497518.1.0000.5341.

The statistical treatment of the data was carried out using the statistical program Statistical Package for Social Sciences version 21.0 (SPSS Inc., Chicago, USA) for Windows, and initially the data were organized in an electronic spreadsheet in the Microsoft Excel® program. The gait variables analyzed were velocity (velocity of the center of mass measured in meters per second); cadence (walking rate measured in steps per minute), stride length (distance from initial contact of one foot to the following initial contact of the same foot measured in meters), step width (the side-to-side distance between the feet measured in meters), stride time (period of time from initial contact of one foot to the following initial contact of the same foot measured in seconds), double support (period of time when both feet are in contact with the ground measured in seconds). The data was filtered with a Butterworth 4th order recursive digital filter with a cut-off of 6 Hz. In addition, the cognitive tasks of arithmetic and verbal fluency were analyzed. Quantitative variables were described as mean and standard deviation/standard error, and categorical variables as absolute and relative frequencies. Shapiro-Wilk test was used to check normal distribution. To compare means between groups, the t-student test was used. When comparing proportions, Pearson's chi-square test or Fisher's exact test was used. To compare variables according to task and group, the Generalized Estimating Equations (GEE) model complemented by the Bonferroni test was used. As a decision criterion, the significance level adopted was 5% ($p<0.05$).

RESULTS

The presented results refer to a sample of 40 research participants, divided into physically inactive group (n=20) and physically active group (n=20), with no sample losses. The general characterization of the sample was stratified by the two groups and the anthropometric and questionnaire characteristics (MMSE, MoCA and IPAQ) are presented in Table 1. It can be observed that no statistically significant difference was observed between the groups, both in terms of analysis of the characteristics of the participants and the results of the cognitive questionnaires. Regarding BMI values, both groups had average values that classify them as overweight, according to the World Health Organization[22]. However, in the PI, three (15%) as normal weight (between 18.5 Kg/m² and 24.9 Kg/m²), eight (40%) as overweight (between 25 Kg/m² and 29.9 Kg/m²), seven (35%) as grade I obesity (between 30 kg/m² and 34.9 kg/m²) and two (10%) as grade II obesity (between 35 kg/m² and 39.9 kg/m²); while PA had seven (35%) with normal weight, seven (35%) with overweight, four (20%) with grade I obesity and two (10%) with grade II obesity. The IPAQ was used to classify the sample where all of the PI were shown to be irregularly active, that is, they perform physical activities, but insufficient to be classified as active because they do not meet the recommendations regarding frequency or duration. Of these, seven (35%) were considered irregularly active A (35%) and thirteen (65%) irregularly active B. In PA, two (10%) were categorized as very active and eighteen (90%) as active.

Regarding gait kinematic variables during single and dual tasks, the results are presented in Table 2. In the comparisons between the groups, there were no statistically significant differences in any kinematic parameter analyzed, both in the single gait analysis and in the dual tasks.

In the intragroup analysis, where the effect of dual tasks on gait parameters was verified by comparing the results of dual tasks with the simple gait task, both groups showed significant decreases in velocity, cadence, step width, stride time and double support, both in the arithmetic dual task and in the verbal fluency dual task.

Table 1. Characteristics of participants and results of cognitive questionnaires (N=40). Caxias do Sul, RS, 2022.

	PI (n=20)	PA (n=20)	
Characteristics of individuals	Mean ± SD		*P*
Mean age (years)	65.95 ± 3.87	64.80 ± 3.94	0.36
Mean body mass (Kg)	79.47 ± 12.29	78.11 ± 15.07	0.75
Mean height (m)	1.64 ± 0.10	1.66 ± 0.07	0.47
BMI (Kg/m²)	29.70 ± 3.94	28.37 ± 4.37	0.32
MEEM	26.30 ± 2.73	27.50 ± 1.67	0.09
MoCA	22.70 ± 3.78	23.85 ± 3.56	0.33
IPAQ	Absolute Frequency		
Very active	-	2 (10%)	
Active	-	18 (90%)	
Irregularly active A	7 (35%)	-	
Irregularly active B	13 (65%)	-	
Sedentary	0 (0%)	-	
Total	20 (100%)	20 (100%)	

The test used was the t-Student test for independent data (not paired); PI = Physically inactive group; PA = Physically active group; SD = Standard Deviation; Kg = Kilograms; m = meters; BMI = Body Mass Index; Kg/m² = Kilogram per square meter; MMSE = Mini Mental State Examination; MoCA = Montreal Cognitive Assessment; IPAQ = International Physical Activity Questionnaire.

Table 2. Results of the analysis of gait kinematic parameters during the performance of cognitive tasks performed in isolation (simple task) and performed in association with gait (dual task) (N=40). Caxias do Sul, RS, 2022.

	PI (n=20)	PA (n=20)			
Kinematic Parameters	Mean ± SD		Group	Effects * Task	Group x Task
Velocity (m/s)			p=0.057	p<0.001	p=0.602
Simple – gait	1.04 ± 0.04[B,a]	1.11 ± 0.03[B,a]			
DT – arithmetic	0.82 ± 0.04[A,a]	0.94 ± 0.04[A,a]			
DT – verbal fluency	0.83 ± 0.05[A,a]	0.93 ± 0.03[A,a]			
Cadence (steps/min)			p=0.106	p<0.001	p=0.772
Simple – gait	105.02 ± 2.43[B,a]	109.76 ± 2.74[B,a]			
DT – arithmetic	87.51 ± 4.62[A,a]	95.74 ± 3.28[A,a]			
DT – verbal Fluency	90.01 ± 4.49[A,a]	97.97 ± 3.36[A,a]			
Stride length (m)			p=0.215	p=0.776	p=0.978
Simple – gait	1.17 ± 0.03[A,a]	1.21 ± 0.02[A,a]			
DT – arithmetic	1.15 ± 0.04[A,a]	1.19 ± 0.02[A,a]			
DT – verbal fluency	1.15 ± 0.04[A,a]	1.19 ± 0.02[A,a]			
Step width (m)			p=0.164	p=0.014	p=0.877
Simple – gait	0.18 ± 0.01 [B,a]	0.17 ± 0.01 [B,a]			
DT – arithmetic	0.20 ± 0.01[A,a]	0.19 ± 0.01[A,a]			
DT – verbal fluency	0.19 ± 0.01[A,a]	0.17 ± 0.01[A,a]			
Stride time (s)			p=0.153	p<0.001	p=0.527
Simple – gait	1.17 ± 0.03[B,a]	1.11 ± 0.03[B,a]			
DT – arithmetic	1.41 ± 0.06[A,a]	1.29 ± 0.05[A,a]			
DT – verbal fluency	1.32 ± 0.05[A,a]	1.27 ± 0.04[A,a]			
Double support (s)			p=0.175	p<0.001	p=0.645
Simple – gait	0.30 ± 0.02[B,a]	0.25 ± 0.02[B,a]			
DT – arithmetic	0.35 ± 0.04[A,a]	0.33 ± 0.02[A,a]			
DT – verbal fluency	0.39 ± 0.05[A,a]	0.33 ± 0.02[A,a]			

*through the Generalized Estimating Equations (GEE) model; Capital letters (A,B): intragroup comparison, equal letters do not differ by the Bonferroni test at 5% significance; Lowercase letters (a, b): intergroup comparison, equal letters do not differ by the Bonferroni test at 5% significance. PI = Physically inactive group; PA = Physically active group; SD = Standard Deviation; DT = Dual Task; m/s = meters per second; steps/min = steps per minute; m = meters; s = seconds.

DISCUSSION

The analyzed results demonstrated that in the comparison between the PI and the PA groups, there were no statistically significant differences, despite the PI having presented lower performances in the analysis of the kinematic parameters, both in the simple gait task and during the dual tasks. However, when the effect of the dual task is related to the single task, there are significant differences in both groups and in both cognitive tasks in the velocity, cadence, stride time, step width and double support of gait. Gait is one of the keys to functional independence and presents several changes resulting from the aging process. However, the gait parameter was evaluated while participants walked in combination with a cognitive task. This presented the strongest relevance for everyday life in the older people[23]. Also, the analysis of dual-task walking can be used for monitoring gait deteriorations in aging in order to identify older adults[24]. In this direction, the present study aimed to analyze the possible differences in the kinematic variables of gait between physically inactive and physically active older people while performing dual-task activities.

In both groups, the analysis of the MEEM and MoCA cognitive tests revealed that the MEEM average values were above the 23 points. They were considered as a threshold to differ healthy subjects from subjects that already presented cognitive damage[17]. The comparison between the average MoCA values and the normative ones revealed that both groups presented values below the 26 points that were considered as the cutoff for the Brazilian population[25]. This is because MoCA presents a greater complexity regarding its subtests. It features more complex approaches on attention, executive functions, and language and visuo-spatial abilities[25].

Regarding the influence of dual tasking on gait parameters in both groups, previous studies have shown that dual task activities reduced the gait velocity of healthy older people[26]. Other research also supports this statement with frail older people and older people with mild cognitive impairment[27]. The other kinematic gait parameters are also influenced by dual activities in both groups, with the exception of stride length. Previous studies have also demonstrated significant changes in cadence, stride length, increased stride variability, double support time and step width in older people[27,28]. The effect of the additional cognitive task with increased prefrontal and motor cortex activation, relating that we use different strategies to maintain dynamic stability and that this depends on the demands of the task and the individual capabilities of each person[28]. Changes resulting from walking followed by a secondary task are considered a predictor of falls[27]. In addition, studies show that the association of two or more tasks can affect balance, promoting higher rates of falls, which contributes to a worse quality of life in the older people[29].

Related to the influence of physical activity on gait parameters, the present study did not observe significant differences between physically active and physically inactive participants, both in the assessment of single gait and during dual tasks. However, unlike the present results, better levels of physical activity are associated with better mobility in older adults[8]. Also, other kinematic parameters such as variability of step length, step time, double support ratio[30], shorter step length, shorter step time, shorter swing time, and higher cadence were associated with physical activity level[31]. When we compared the influence of the dual task between active and inactive older people, no significant differences were observed either. Muhaidat et al.[12] evaluated 120 women older people and also identified no relationship between physical activity level and better gait parameters during dual tasking. However, Gomes et al.[13] highlight that inactive older people are more likely to present compromised gait performance during dual-task activities. Since mobility averages with dual motor task, with dual cognitive task, the worst performance being associated with physically inactive lifestyle. In this way, as is well established in several literatures, the regular practice of physical exercises provides the older people with greater security in activities of daily living, better balance, and greater walking velocity, reducing the risk of falls[9]. In addition, the importance of physical activity in older people is essential to improve quality of life and prevent age-related diseases[9,10].

It is well known that regular physical activity is an important component of healthy aging[31]. Despite the importance of physical activity in the older people already being very well described in the scientific literature; the present study was not able to verify the interference of physical activity in the kinematic parameters of gait during dual tasks.

However, some limitations need to be highlighted. First, the presente study had a quasi-experiental approach, which presents a lower level of evidence compared to a longitudinal study design. Secondly, the fact that, even though there is a lot of research related to dual tasking, the way in which these activities are evaluated is quite heterogeneous, which makes it difficult to analyze and compare data. Another aspect that may have influenced the results is that the older subjects were classified using the IPAQ, one of the most used instruments in research. This is a self-administered questionnaire in which participants reported their levels of physical activity during the previous week.

CONCLUSION

This research demonstrated that dual tasks had a negative influence on gait parameters of older individuals. However, the results did not support the hypothesis that dual tasking influences the gait parameters in physically active older people less then physically inactive ones. Although active older people show smaller declines in gait kinematic parameters compared to inactive older people, the practice of physical activity could not be considered a factor that minimizes the effects of the dual task on gait in the older in our study. We believe that this occurred due to the average age of the participants, who, despite being older people, are considered young older and also due to the degree of difficulty of the cognitive tasks used, since the complexity of cognitive interference involves greater concurrent demands.

The importance of the present study is highlighted due to the high number of studies that currently have investigated the effects of the dual task on gait performance, which reflects its importance from the research area and its potential clinical applications. In future perspectives, more studies are needed that relate the practice of physical activity with walking associated with the dual task, to provide more scientific evidence. In view of how rapidly the older population has been growing, it is hoped that the results of this research can broaden the understanding of the dual task, in order to qualify professionals, as well as assist researchers in creating strategies that allow minimizing the effects of aging.

AUTHORSHIP

- Verônica Filter de Andrade - conception, analysis and interpretation of results and writing of the article.
- Laura Buzin Zapparoli - analysis and interpretation of results.
- Pedro Henrique Farneda - analysis and interpretation of results.
- Fernanda Cechetti - design and critical review.
- Raquel Saccani - design and critical review.
- Leandro Viçosa Bonetti - conception, design, critical review and approval of the version to be published.

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REFERENCES

1. Demnitz N, Esser P, Dawes H, Valkanova V, Johansen-Berg H, Ebmeier KP, et al. A systematic review and meta-analysis of cross-sectional studies examining the relationship between mobility and cognition in healthy older adults. Gait Posture. 2016;50:164–74. Available at: https://doi.org/10.1016/j.gaitpost.2016.08.028
2. Ronthal M. Gait disorders and falls in the elderly. Med Clin North Am. 2019;103(2):203–13. Available at: https://doi.org/10.1016/j.mcna.2018.10.010
3. Piche E, Gerus P, Chorin F, Jaafar A, Guerin O, Zory R. The effect of different dual tasks conditions on gait kinematics and spatio-temporal walking parameters in older adults. Gait Posture. 2022;95:631–69. Available at: https://doi.org/10.1016/j.gaitpost.2022.04.006
4. Clouston SA, Brewster P, Kuh D, Richards M, Cooper R, Hardy R, et al. The dynamic relationship between physical function and cognition in longitudinal aging cohorts. Epidemiol Rev. 2013;35(1):33–50. Available at: https://doi.org/10.1093/epirev/mxs004
5. Bayot M, Dujardin K, Dissaux L, Tard C, Defebvre L, Bonnet CT, et al. Can dual-task paradigms predict falls better than single task? - A systematic literature review. Neurophysiol Clin. 2020;50(6):401–40. Available at: https://doi.org/10.1016/j.neucli.2020.10.008
6. Montero-Odasso M, Speechley M. Falls in cognitively impaired older adults: implications for risk assessment and prevention. J Am Geriatr Soc. 2018;66(2):367–75. Available at: https://doi.org/10.1111/jgs.15219

7. Chaparro GN, Stine-Morrow EAL, Hernandez ME. Effects of aerobic fitness on cognitive performance as a function of dual-task demands in older adults. Exp Gerontol. 2019;118: 99–105. Available at: https://doi.org/10.1016/j.exger.2019.01.013

8. 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. Available at: http://dx.doi.org/10.1136/bjsports-2020-102955

9. Hayes L, Burtscher M, Elliott B. Editorial: Exercise as a countermeasure to human aging, volume II. Front Physiol. 2022;13:1–3. Available at: https://doi.org/10.3389/fphys.2022.878983

10. Stillman CM, Esteban-Cornejo I, Brown B, Bender CM, Erickson KI. Effects of exercise on brain and cognition across age groups and health states. Trends Neurosc. 2020;43(7):533–43. Available at: https://doi.org/10.1016/j.tins.2020.04.010

11. Kivimäki M, Singh-Manoux A. Prevention of dementia by targeting risk factors. Lancet. 2018;391(10130):1575–76. Available at: https://doi.org/10.1016/S0140-6736(18)30578-6

12. Muhaidat J, Al-Yahya E, Mohammad MT, Qutishat D, Okasheh R, Al-Khlaifat L, et al. Dual-tasking in older women: physical activity or else? J Women Aging. 2022;34(1):101–11. Available at: https://doi.org/10.1080/08952841.2020.1819177

13. Gomes CS, Carvalho MT, Coelho VHM, de Walsh IAP, Martins LJP, Nogueira CM, et al. Relações entre sedentarismo e mobilidade com e sem dupla tarefa em idosos usuários da atenção básica em saúde. Estud Interdiscip Envelhec. 2021; 26(1):217–23. Available at: https://doi.org/10.22456/2316-2171.96876

14. Saglam M, Vardar-Yagli N, Savci S, Inal-Ince D, Calik-Kutukcu E, Arikan H, et al. Functional capacity, physical activity, and quality of life in hypoxemic patients with chronic obstructive pulmonary disease. Int J Chron Obstruct Pulmon Dis. 2015;26(10):423–8. Available at: https://doi.org/10.2147/COPD.S78937

15. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381–95. Available at: https://doi.org/10.1249/01.MSS.0000078924.61453.FB

16. Melo DM, Barbosa AJG. O uso do Mini-Exame do Estado Mental em pesquisas no Brasil: uma revisão sistemática. Cien Saude Col. 2015;20(1):3865–76. Available at: https://doi.org/10.1590/1413-812320152012.06032015

17. BruckI S, Nitrini R, Caramelli P, Bertolucci P, Okamoto I. Sugestões para o uso do mini-exame do estado mental no Brasil. Arq Neuropsiquiatr. 2003;61:777–81. Available at: https://doi.org/10.1590/S0004-282X2003000500014

18. Nasreddine ZS, Phillips NA, Bédirian V, Charbonneau S, Whitehead V, Collin I, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. J Am Geriatr Soc. 2005;53(4):695–9. Available at:

19. Mirelman A, Maidan I, Bernad-Elazari H, Nieuwhof F, Reelick M, Giladi N, et al. Increased frontal brain activation during walking while dual tasking: an fNIRS study in healthy young adults. J Neuroeng Rehabil. 2014;11:1–7. Available at: https://doi.org/10.1111/j.1532-5415.2005.53221.x

20. Yogev-Seligmann G, Rotem-Galili Y, Mirelman A, Dickstein R, Giladi N, Hausdorff JM. How does explicit prioritization alter walking during dual-task performance? Effects of age and sex on gait speed and variability. Phys Ther. 2010;90(2):177–86. Available at: https://doi.org/10.2522/ptj.20090043

21. Laroche D, Duval A, Morisset C, Beis JN, d'Athis P, Maillefert JF, et al. Test–retest reliability of 3D kinematic gait variables in hip osteoarthritis patients. Osteoarthr Cartil. 2011;19(2):194–9. Available at: https://doi.org/10.1016/j.joca.2010.10.024

22. World Health Organization. Obesity: preventing and managing the global epidemic. Report of a World Health Organization Consultation. Geneva: World Health Organization, 2000;284:256. Available at: https://apps.who.int/iris/handle/10665/42330

23. Metzger FG, Ehlis AC, Haeussinger FB, Schneeweiss P, Hudak J, Fallgatter AJ, et al. Functional brain imaging of walking while talking - An fNIRS study. Neuroscience. 2017;343:85–93. Available at: https://doi.org/10.1016/j.neuroscience.2016.11.032

24. Ko SU, Jerome GJ, Simonsick EM, Studenski S, Hausdorff JM, Ferrucci L. Differential associations between dual-task walking abilities and usual gait patterns in healthy older adults - Results from the Baltimore Longitudinal Study of Aging. Gait Posture. 2018;63:63–7. Available at: https://doi.org/10.1016/j.gaitpost.2018.04.039

25. Memória CM, Yassuda MS, Nakano EY, Forlenza O. Brief screening for mild cognitive impairment: validation of the Brazilian version of the Montreal cognitive assessment. Int J Geriatr Psychiatry. 2013;28(1):34–40. Available at: https://doi.org/10.1002/gps.3787

26. Simoni D, Rubbieri G, Baccini M, Rinaldi L, Becheri D, Forconi T, et al. Different motor tasks impact differently on cognitive performance of older persons during dual task tests. Clin Biomech. 2013;28(6):692–6. Available at: https://doi.org/10.1016/j.clinbiomech.2013.05.011

27. Beauchet O, Dubost V, Herrmann F, Rabilloud M, Gonthier R, Kressig RW. Relationship between dual-task related gait changes and intrinsic risk factors for falls among transitional frail older adults. Aging Clin Exp Res. 2005;17(4):270–5. Available at: https://doi.org/10.1007/BF03324609

28. Al-Yahya E, Mahmoud W, Meester D, Esser P, Dawes H. Neural substrates of cognitive motor interference during walking; peripheral and central mechanisms. Front Hum Neurosci. 2019;12(1):536–48. Available at: https://doi.org/10.3389/fnhum.2018.00536

29. Hall CD, Echt KV, Wolf SL, Rogers WA. Cognitive and motor mechanisms underlying older adults' ability to divide attention while walking. Phys Ther. 2011;91(7):1039–50. Available at: https://doi.org/10.2522/ptj.20100114

30. Kovács É, Simon A, Petridisz NA, Erdős RL, Rozs F, Virág A. Gait parameters in physically active and inactive elderly as well as young community-living people. J Sports Med Phys Fitness. 2019;59(7):1162–7. Available at: https://doi.org/10.23736/S0022-4707.18.09205-8

31. Eckstrom E, Neukam S, Kalin L, Wright J. Physical activity and healthy aging. Clin Geriatr Med. 2020;36(4):671–83. Available at: https://doi.org/10.1016/j.cger.2020.06.009