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Postural Stability During Dual- and Triple-task Conditions: the Effect of Different Levels of Physical Fitness in Older Adults

Stabilité posturale en situation de double ou triple tâche: effet de différents niveaux de condition physique chez les personnes âgées

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Short title: Dual- and triple-tasks in sport activities

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Summary

Objectives: Postural stability is showed to decline with age and to be particularly challenging for older people during multitasking activities. However, the effect of different levels of physical fitness on postural stability performances during multitasking remains unclear. This cross-sectional study aimed to investigate the impact of dual-task (DT) and triple-task (TT) performances on postural stability among older adults with a different level of physical fitness (i.e., master cyclists and physically active), and to compare them with healthy Untrained older and young adults.

Equipment and methods: Seven master cyclists (mean age 70±3 years), 7 physically active older adults (mean age 73±1 year) 10 Untrained older adults (mean age 73±3 years) and 10 Untrained young adults (mean age 25±2 years) participated to the study. Data were recorded during: 1) a quiet upright stance task (single-task) and while performing an additional (dual-task) 2) manual, 3) cognitive task or 4) manual and cognitive task concurrently (triple-task). Area and Perimeter described by the center of pressure and mean velocity in anterior-posterior and medio-lateral directions were analyzed.

Results: Generally, a decrease in postural stability variables (Area, Perimeter, Mean Velocity in anterior-posterior and medio-lateral directions) was observed during dual and triple-task in all groups (all p values < 0.05). A general worse postural stability was observed in Untrained older adults compared to young adults in manual and cognitive DT. Moreover, Untrained older group showed worse values in Area, Perimeter, Mean Velocity in anterior-posterior and medio-lateral directions related to Untrained young group (percentage differences: 243.3, 76.4, 107.7 and 51.1 % respectively, all P values < 0.05) during triple-task performance. Additionally, the results showed a trend toward better postural stability of master cyclists and physically active older adults compared to Untrained older adults in single- rather than in dual- and triple-task performance.

Conclusion: The results underlined that to be a cyclist or to be physically active during aging are beneficial to maintain postural stability during multitasking activity and consequently to decrease the risk of falling observed in aging.

Keywords: multitasking; balance; sport; older adults.

Résumés

Objectifs : Il a été montré que la stabilité posturale diminue avec l'âge et constitue un défi particulier pour les personnes âgées lors d'activités multitâches en raison d'une demande importante du système nerveux central et des ressources cognitives. Cependant, l'effet de différents niveaux d'aptitude physique sur la stabilité posturale lors de performances multitâches reste inconnu. Le but de cette étude transversale était d'évaluer l'impact des performances à double et à triple tâche sur la stabilité posturale chez les personnes âgées avec différents niveaux de condition physique (c'est-à-dire des cyclistes séniors et des personnes physiquement actives), et de les comparer à des personnes âgées physiquement inactives et de jeunes adultes.

Matériel et méthodes : Sept cyclistes séniors (âge moyen: 70±3 ans), 7 adultes plus âgés physiquement actifs (âge moyen : 73±1 an), 10 adultes plus âgés physiquement inactifs (âge moyen: 73±3 ans) et 10 jeunes adultes physiquement inactifs (âge moyen: 25±2 ans) ont participé à l'étude. Les données ont été enregistrées lorsque: 1) le sujet se tient debout (tâche simple), 2) debout, il réalise une tâche manuelle qui est la prise d'un verre (double tâche), 3) debout, il réalise une tâche cognitive qui est celle d'un comptage, 4) debout, il réalise une tâche cognitive et manuelle (triple tâche). La zone et le périmètre décrits par le centre de pression et la vitesse moyenne dans les plans antéro-postérieurs et médio-latéraux ont été analysés.

Résultats : De manière générale, une diminution des variables de stabilité posturale (zone, périmètre, vitesse moyenne dans les plans antéro-postérieurs et médio-latéraux) a été observée lors de l'exécution de double et de triple tâche dans tous les groupes (toutes les valeurs de $p < 0,05$). De plus, un contrôle postural mineur a été observé chez les adultes âgés physiquement inactifs par rapport aux jeunes adultes physiquement inactifs tout en effectuant une tâche manuelle et cognitive supplémentaire. De surcroît, le groupe des personnes âgées physiquement inactives a montré des résultats moins performants pour ce qui est de la zone, du périmètre, de la vitesse moyenne dans les plans antéro-postérieurs et médio-latéraux par rapport au groupe de jeunes physiquement inactifs (différences en pourcentage : 243,3, 76,4, 107,7 et 51,1%, toutes valeurs $p < 0,05$) au cours de l'exécution de la triple tâche. En outre, les résultats ont montré une tendance à une meilleure stabilité posturale chez les cyclistes séniors et les adultes plus âgés physiquement actifs par rapport aux adultes plus âgés physiquement inactifs, pour les tâches simples ainsi que lors des performances à double et triple tâche.

Conclusion: Les résultats ont souligné que la pratique de sports et d'activités physiques au cours du vieillissement peut être bénéfique pour maintenir la stabilité posturale lors d'activités multitâches et, par conséquent, pour réduire le risque de chute observé lors du vieillissement.

Mots-clés : multitâche ; équilibre ; sport ; personnes âgées.

1. Introduction

Postural stability is a fundamental skill in humans, especially in old age. However, with aging, postural stability decreases because of changes in brain structure (i.e., gray and white matter), sensorimotor dysfunction and muscle weakness increasing body imbalance, risk of falls and subsequent injuries [1, 2]. Specifically, the maintenance of upright body posture depends on the integration of information provided by the visual, vestibular and somatosensory systems which decline with age [3]. Thus, in order to compensate, the attentional demands of postural balance control increase [4].

Typically, the dual-task (DT) paradigm has been used to investigate and examine the interaction between attentional resources and postural stability, and it consists in performing a primary static or dynamic task, while simultaneously carrying out an additional task that could be cognitive or manual [5, 6]. An example is the worst performance obtained during a cognitive task like a simple verbal assignment proposed during Romberg's position and this is more evident in elderly than in young adults [7]. The changes in postural stability under DT conditions are particularly pronounced and challenging for older adults [8], especially for those with a balance impairment and/or history of fall [4, 9]. It seems due to the interference, as the result of the interaction between two tasks (i.e., the stability and the additional task), leads to a competing demand for attentional resources. Therefore, older adults show postural instability due to a reduction of the available attentional resources [4] and the greater request of attention resources [4, 10].

Several studies showed that multicomponent and dual-task training [9, 11-15] may could improve physical function in older age. Moreover, it has been noted that master athletes (e.g., runners), after having unexpectedly moved backwards the standing platform, they were able to regain the imbalance faster and more frequently without stepping compared to sedentary older adults [16]. Master athletes presented similar postural sways such as middle-aged athletes, when standing upright [17], as well as young adults during one leg standing with open eyes, but not with closed eyes [18]. Indeed, both healthy older adults and master athletes showed similar trend when visual feedback was removed. Similarly, Lamoth and colleagues [19] investigated DT performance older ice-skaters and the authors found that the athletes were more stable than sedentary older adults and a similar stability to sedentary young adults. From this, the beneficial effect of a long-term sport activity has been noted. Indeed, older speed skaters showed levels of stability similar to young adults.

However, to our knowledge, few studies have investigated the effect of different levels of physical fitness on postural stability performances during DT and triple-tasks (TT) in older adults. A description of the difference in the role of physical activity on postural stability during DT and TT may be useful to better understand the aging process and the consequent impact of such a kind of exercises in everyday activities. Thus, the general purpose of this study was to investigate the impact of DT and TT performances on postural stability among older adults with a different level of physical fitness (i.e., master cyclists and physically active), and to compare them with healthy Untrained older and young adults. Therefore, the specific purposes of the study were to evaluate (1) posture changes occurring during a manual/cognitive DT and TT performance in comparison with the only single-task (ST) among the groups, and (2) to examine such difference among master cyclists, physically active older adults (i.e., older adults engaged in a low-impact fitness program), Untrained older adults, and Untrained young adults during manual/cognitive DT and TT conditions.

We expected to find a decreasing trend in postural stability during DT and TT in comparison with the ST performance. Moreover, according to previous research [19, 20] we expected to find better postural stability in master cyclists and physically active older adults than in Untrained older adults, as well as a worse performance in Untrained older adults compared to Untrained young ones.

2. Methods

2.1 Participants

A convenience sample of thirty-four healthy males were recruited from local senior social center of Torino and university campus (North Italy), including 7 master cyclists aged > 65 years (Master Cyclists; age=70±3 years; height=173±6 cm; weight=76±8 kg; BMI=25.1±2 kg/m^2); 7 physically active older adults aged > 65 years (Physically Active Older; age=73±1 years; height=168±6 cm; weight =74±5 kg; BMI=26 ±1 kg/m^2); 10 Untrained older adults aged > 65 years (Untrained Older; age=73±3 years, height=169±7 cm, weight=78±1 kg, BMI=27±2 kg/m^2); 10 Untrained young adults aged from 20 to 30 years (Untrained Young; age=25±2 years, height=178±7 cm, weight=69±5 kg, BMI=21±1 kg/m^2). Each subject filled a self-report questionnaire on current exercise activity. The

Master Cyclists group has been practicing cycling and training for more than 5 years four times a week for at least 60 min per session. They were regularly registered in a competitive sports club and participated in at least one competition during concurrent and previous seasons. The Physically Active Older group has been practicing fitness activities and training for more than 5 years, three times a week (at least 60 min per session) as previously defined [21]. Differently, the Older and Young groups were not enrolled in any exercise program and did not report any practice of regular moderate and vigorous physical activity or to improve physical fitness and general health in the last five years [22, 23]. The number of participants was defined considering the number of eligible Master Cyclists.

Participants were included if showed (1) a Mini-mental Status Examination [24] score ≥ 24 or higher, (2) no physical problems that could affect postural stability, (3) ability to walk without assistant device, (4) no history of previous falls, (5) comprehension of simple instructions, (6) ability to perform simple arithmetic exercises and to carry a glass of water, and (7) to be naïve to the study.

All the participants provided their written informed consent in accordance with Italian law and the ethical code of the American Psychological Association (APA) and according to the ethical standards stated in the 1964 Declaration of Helsinki. This study was approved by the local ethics committee.

2.2 Measurements

A stabilometric platform (TecnoBody PROKIN PK 214 P, Bergamo, Italy) with a diameter of 40 cm and housed three strain gauges placed at 120° has been used to quantify postural sways. These sensors had 0.48 N of maximal resolution, they were auto-calibrated and data were acquired with a frequency of 20 Hz. The stabilometric platform software provided the following postural stability parameters: the 90% ellipse area (Area; mm^2) and the sway path (Perimeter; mm) described by CoP, and the mean velocity in anterior-posterior (Mean $Velocity_{AP}$) and medio-lateral (Mean $Velocity_{ML}$) directions (mm/s) [25, 26]. The Area describes the area of the 95% confidence ellipse around the CoP trajectory. The Perimeter describes the length of the total CoP trajectory during the measurement. Mean $Velocity_{AP}$ and Mean $Velocity_{ML}$ were calculated as average velocity of CoP displacements in the sagittal and frontal planes, respectively. CoP measures have shown to be reliable [27, 28].

2.3 Procedures

All tests were performed in one day in the morning and each participant took 60 minutes approximately to complete them. The same investigator conducted all tests. Each participant completed the test session composed of the following four upright standing task conditions:

(1) simply maintaining an upright standing position (ST);

(2) maintaining an upright standing position and holding a glass of water (filled up to 10 mm from the rim) in their preferred hand (manual DT) [5];

(3) maintaining an upright standing position and counting backwards 7 from a randomly selected number included in a range of 100-200 (cognitive DT) [29-31];

(4) maintaining an upright standing position and simultaneously holding a glass of water and counting backwards from a randomly selected number included in a range of 100-200 (TT).

To minimize external disturbances, all measurements were carried out in a quiet, well-lit room suitable for such a purpose [25]. The participants were barefooted (with heels touching and metatarsal phalangeal joints in contact) and instructed to look straight ahead at a marked X on the wall [25, 32]. Each participant was tested in orthostatic position for a total time of 60 s [33], followed by a rest period of 5 minutes [7].

Before testing, trained researchers gave standardized verbal instructions regarding the procedure by means of a visual demonstration. Participants performed one not recorded trial to familiarize with the tasks. During DT and TT performances, participants did not receive any explicit instructions regarding task priority and trials order was randomized [29].

2.4 Statistical analysis

Means and standard deviations were calculated for all data. Data distribution was examined using the Shapiro-Wilk test. The assumption of normality for the outcome variables in the different groups was not satisfying for all group combinations (all p values < 0.05), thus non-parametric analyses were used.

To determine the within-subject difference in each condition (i.e., ST, manual DT, cognitive DT, and TT), a Friedman test was conducted among the different groups.

Separately Kruskal-Wallis tests were conducted to determine the differences among the groups (i.e., Master Cyclists, Physically Active Older, Untrained Older, and Untrained Young groups) in different task conditions (ST, manual DT, cognitive DT, and TT).

Subsequently, pairwise comparisons with a Bonferroni correction were computed to identify statistically significant differences between tasks and groups. Effect size for post-hoc comparison was calculated and reported according to the following effect ranges: small (0.1), medium (0.3) and large (0.5) [34].

The Statistical Package for Social Sciences (SPSS 24.0 for Windows) and the statistical software GraphPad Prism 6.0 (San Diego, California, USA) were used for all statistical analyses. The significance level was set at $p < 0.05$.

3. Results

All 34 participants completed the testing procedure. Figure 1 a-d displays the means and the standard deviations of the four centers of pressure parameters (i.e., Area, Perimeter, Mean $Velocity_{AP}$ and Mean $Velocity_{ML}$) in the different task conditions (i.e., ST, manual DT, cognitive DT, and TT) separately for Master Cyclists, Physically Active Older, Untrained Older and Young groups.

<Insert Figure 1 about here>

3.1 Within group differences

The results of Friedman test and the pairwise comparisons with a Bonferroni correction are provided in Table 1.

<Insert Table 1 about here>

A significant difference was observed for Master Cyclists group in Perimeter. Specifically, a higher value was observed in triple-task compared to manual DT performance (percentage increase: 29.7 %, $p < 0.05$). Considering Physically Active Older group, Friedman test yielded a significant difference in Perimeter and Mean $Velocity_{AP}$. A higher value in Perimeter was observed in cognitive DT compared to ST (percentage increase: 24.5 %, $p < 0.05$). Differently in Mean $Velocity_{AP}$, a higher value was observed in cognitive DT performance compared to manual DT performances (percentage increase: 66.0 %, $p < 0.05$). The Untrained Older group showed significant differences in Area and Mean $Velocity_{AP}$. A higher value in Area was observed in cognitive DT compared to ST (percentage increase: 23.9 %, p < 0.05), in triple-task compared to ST (percentage increase: 64.8 %, p < 0.05) and in triple-task compared to manual-task (63.6 %, p < 0.05). Concerning the Mean Velocity$_{AP}$, a higher value was observed in manual DT compared to cognitive DT (percentage increase: 42.0 %, p < 0.05) and in manual DT compared to TT (percentage increase: 35.0 %, p < 0.05). Finally, the Untrained Young group showed significant differences in Perimeter. Perimeter value was higher in cognitive DT compared to ST performance (percentage increase: 16.6 %, p < 0.05). For more details on p values and relative effect sizes (r) see Table 1.

3.2 Between group differences

Table 2 shows the Kruskal-Wallis Test outcomes during the different task conditions.

<Insert Table 2 about here>

During ST performance, a significant difference was observed on Area, Perimeter, Mean Velocity$_{AP}$, and Mean Velocity$_{ML}$ among the groups. Post hoc analysis revealed that Untrained Older group showed higher values in Area, Perimeter, Mean Velocity$_{AP}$, and Mean Velocity$_{ML}$ compared to Untrained Young group (percentage differences: 73.6, 71.0, 88.9 and 57.3 % respectively, all p values < 0.05). Additionally, a significant higher value in Area was observed in Master Cyclists group compared to Untrained Young group (percentage difference: 62.3 %, p < 0.05).

Concerning manual DT performance significant differences were observed in Perimeter, Mean Velocity$_{AP}$, and Mean Velocity$_{ML}$, but not in Area. Post hoc analyses revealed statistically significant higher values in Perimeter, Mean Velocity$_{AP}$, and Mean Velocity$_{ML}$ between the Untrained Older and Young groups (percentage difference: 63.0, 72.4 and 60.0 % respectively, all p values < 0.05).

Significant differences among groups were observed in Area, Perimeter, Mean Velocity$_{AP}$, and Mean Velocity$_{ML}$ during cognitive DT. Post hoc analyses revealed significant higher values in Area, Perimeter, Mean Velocity$_{AP}$, and Mean Velocity$_{ML}$ in Untrained Older group compared to Untrained Young group (percentage difference: 116.97, 68.4, 91.9 and 53.9 % respectively, all p values < 0.05). Additionally, a higher value in Mean Velocity$_{AP}$ was observed in Physically Active Older group compared to Untrained Young group (percentage difference: 69.9 %, p < 0.05).

Finally, considering the TT performance significant differences among groups were observed in Area, Perimeter, Mean Velocity$_{AP}$, and Mean Velocity$_{ML}$. Post hoc analyses revealed that Untrained Older group showed higher values in Area, Perimeter, Mean Velocity$_{AP}$, and Mean Velocity$_{ML}$ compared to Untrained Young group (percentage differences: 243.3, 76.4, 107.7 and 51.1 % respectively, all p value < 0.05). Moreover, Master Cyclists group showed higher value in Perimeter compared to Untrained Young group (percentage differences: 50.11 %, p < 0.05). For more details on p values and relative effect sizes (r) see Table 2.

4. Discussion

The purpose of this study was to assess the effect of different level of physical activity on postural stability among older adults in DT and TT conditions. To this purpose, postural stability (i.e., time course of CoP parameters) has been compared during quiet standing with an additional manual or cognitive task (DT conditions) or in combination with both tasks (TT condition).

In accordance with our hypothesis, it has been observed in older groups a general decrease of the performance in CoP parameters, during both DT and TT conditions. These results demonstrate that an additional task increases CoP parameters, due to the interference of the attentional resources [8, 35]. However, accordingly with previous studies [7, 36, 37] it has been observed a trend toward an improvement or similar results in the CoP parameter during DT and TT compared to ST in young adults. It might be possible that the external focus of the attention leads to greater automaticity in movement control and consequently to a reduction of the sways [7].

Considering the secondary aim of this study, emerged, during both manual and cognitive DT, and TT, CoP parameters of all older groups (i.e., Master Cyclists, Physically Active Older and Untrained Older) were higher during ST, DT, and TT if compared to the young group. Similarly, Unhjem and colleagues [20] found that young people compared to strength-trained master athletes, recreationally active older adults and Untrained older adults exhibited lower CoP velocity during 1-leg standing in association with a cognitive task. These findings may suggest that older people present a greater instability compared to young people [7], together with a poorer capability in attentional resources [4]. In contrast to our hypothesis, no significant differences were found between Master Cyclists or Physically Active Older and Untrained Older groups. However, the results of the study showed a trend toward better postural stability in Master Cyclists, Physically Active Older groups compared to Untrained ones. Generally, Master Cyclists, Physically Active Older groups showed better stability, not only in ST [16, 38], but also in DT and TT activities. Interesting, CoP variables were similar in Master Cyclists and Physically Active Older groups. Indeed, a larger difference was observed between Untrained Older and Untrained Young groups, in both ST, manual or cognitive task (DT conditions) and in combination with both tasks (TT condition). In an analogue way, Lamoth and colleagues[19] found that older adults, practicing a sport challenging the postural stability (i.e., ice speed-skating), presented similar results as young people. We might speculate that older adults, both cyclists and physically active, may counteract the age-related changes in postural stability corroborating the idea that physical and active exercises may lead to beneficial effects on postural stability [19, 39].

Some limitations of this study have to be underlined. First of all, we categorized our sample only based on the volume of exercise activity during the week and did not consider the intensity and the volume of the exercise activity performed by the Master Cyclists and the Physically Active Older group. Even if our definition to identify the group was in line with previous studies [19] this aspect should be considered when interpreting our results. Moreover, even if other studies [7, 38] suggested that anthropometric parameters do not influence posturography in static tasks we did not performed normalization data for height. This may be affect the results of the study [40]. Again, other anthropometric factors, such as body fat that slightly influenced posturography in static tasks [40-42], was not considered for the analysis. Thus, future studies are needed to better investigate this aspect and the effect of different levels of physical fitness in older adults during dual- and triple-task conditions. Finally, the relatively small sample size, the recruitment of males only and the selection of only cyclists as athletes, did not allow us to generalize the results to all older population. We only focused on postural stability and not on cognitive and manual performance during DT and TT tests. This limitation did not allow to investigate additional cognitive and manual task and the task prioritization which are actually goals not included in herein study. Further research is needed to generalize these findings and to investigate the differences related to the different sports activities in older adults.

5. Conclusions

In conclusion, the study demonstrated an inverse relationship between postural stability and DT and TT performance with a decrease of postural stability when the task difficulty is increased in master cyclists, physical active and Untrained older adults and in young Untrained. Moreover, the data suggested a trend in which Untrained older present worse postural stability if compared to master cyclists or physically active older adults during DT and TT demonstrating that that the practice of sports activities (e.g., master cyclists) and to be physically active may be beneficial to maintain postural stability during multitasking activities in older age.

Disclosure of interest

The authors declare that they have no competing interest.

References

[1] Borel L, Alescio-Lautier B. Posture and cognition in the elderly: interaction and contribution to the rehabilitation strategies. Neurophysiol Clin. 2014;44:95-107.

[2] Muir SW, Berg K, Chesworth B, Klar N, Speechley M. Quantifying the magnitude of risk for balance impairment on falls in community-dwelling older adults: a systematic review and meta-analysis. J Clin Epidemiol. 2010;63:389-406.

[3] Roman-Liu D. Age-related changes in the range and velocity of postural sway. Arch Gerontol Geriatr. 2018;77:68-80.

[4] Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. Gait Posture. 2002;16:1-14.

[5] Brustio PR, Magistro D, Zecca M, Rabaglietti E, Liubicich ME. Age-related decrements in dual-task performance: Comparison of different mobility and cognitive tasks. A cross sectional study. PLoS One. 2017;12:e0181698.

[6] Brustio PR, Magistro D, Rabaglietti E, Liubicich ME. Age-related differences in dual task performance: A cross-sectional study on women. Geriatr Gerontol Int. 2017;17:315-21.

[7] Bergamin M, Gobbo S, Zanotto T, Sieverdes JC, Alberton CL, Zaccaria M, et al. Influence of age on postural sway during different dual-task conditions. Front Aging Neurosci. 2014;6:271.

[8] Boisgontier MP, Beets IA, Duysens J, Nieuwboer A, Krampe RT, Swinnen SP. Age-related differences in attentional cost associated with postural dual tasks: increased recruitment of generic cognitive resources in older adults. Neurosci Biobehav Rev. 2013;37:1824-37.

[9] Ghai S, Ghai I, Effenberg AO. Effects of dual tasks and dual-task training on postural stability: a systematic review and meta-analysis. Clin Interv Aging. 2017;12:557-77.

[10] Chu YH, Tang PF, Peng YC, Chen HY. Meta-analysis of type and complexity of a secondary task during walking on the prediction of elderly falls. Geriatr Gerontol Int. 2013;13:289-97.

[11] Brustio PR, Liubicich ME, Chiabrero M, Rabaglietti E. Dancing in the golden age: a study on physical function, quality of life, and social engagement. Geriatr Nurs. 2018;39:635-9.

[12] Brustio PR, Magistro D, Ivaldi S, Caglio MM, Rabaglietti E, Liubicich ME. Neuromotor training in older women living in long-term care setting: a pilot study. Geriatr Nurs. 2015;36:361-6.

[13] Brustio PR, Rabaglietti E, Formica S, Liubicich ME. Dual-task training in older adults: The effect of additional motor tasks on mobility performance. Arch Gerontol Geriatr. 2018;75:119-24.
[14] Gobbo S, Bergamin M, Sieverdes JC, Ermolao A, Zaccaria M. Effects of exercise on dual-task ability and balance in older adults: a systematic review. Arch Gerontol Geriatr. 2014;58:177-87.
[15] Howe TE, Rochester L, Jackson A, Banks PM, Blair VA. Exercise for improving balance in older people. Cochrane Database Syst Rev. 2007:CD004963.
[16] Brauer SG, Neros C, Woollacott M. Balance control in the elderly: do Masters athletes show more efficient balance responses than healthy older adults? Aging Clin Exp Res. 2008;20:406-11.
[17] Feland JB, Hager R, Merrill RM. Sit to stand transfer: performance in rising power, transfer time and sway by age and sex in senior athletes. Br J Sports Med. 2005;39:e39.
[18] Leightley D, Yap MH, Coulson J, Piasecki M, Cameron J, Barnouin Y, et al. Postural Stability During Standing Balance and Sit-to-Stand in Master Athlete Runners Compared With Nonathletic Old and Young Adults. J Aging Phys Act. 2017;25:345-50.
[19] Lamoth CJ, van Heuvelen MJ. Sports activities are reflected in the local stability and regularity of body sway: older ice-skaters have better postural control than inactive elderly. Gait Posture. 2012;35:489-93.
[20] Unhjem R, van den Hoven LT, Nygard M, Hoff J, Wang E. Functional Performance With Age: The Role of Long-Term Strength Training. J Geriatr Phys Ther. 2017.
[21] Bulbulian R, Hargan ML. The effect of activity history and current activity on static and dynamic postural balance in older adults. Physiol Behav. 2000;70:319-25.
[22] Magistro D, Candela F, Brustio PR, Liubicich ME, Rabaglietti E. Longitudinal Study on the Relationship Between Aerobic Endurance and Lower Body Strength in Italian Sedentary Older Adults. J Aging Phys Act. 2015:444-51.
[23] Organization WH. Global recommendations on physical activity for health: World Health Organization; 2010.
[24] Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. Journal of Psychiatric Research. 1975;12:189-98.
[25] Pizzigalli L, Ahmaidi S, Rainoldi A. Effects of sedentary condition and longterm physical activity on postural balance and strength responses in elderly subjects. Sport Science for Health. 2014;10:135-41.

[26] Pizzigalli L, Cremasco MM, Cremona E, Rainoldi A. Human Postural Adaptation to Earthly and Atypical Gravitational Environment Effects of Sport Training on Stabilometric Parameters. Advances in Anthropology. 2013;3:229.
[27] Lafond D, Corriveau H, Hebert R, Prince F. Intrasession reliability of center of pressure measures of postural steadiness in healthy elderly people. Arch Phys Med Rehabil. 2004;85:896-901.
[28] Ruhe A, Fejer R, Walker B. The test-retest reliability of centre of pressure measures in bipedal static task conditions--a systematic review of the literature. Gait Posture. 2010;32:436-45.
[29] Brustio PR, Magistro D, Zecca M, Liubicich ME, Rabaglietti E. Fear of falling and activities of daily living function: mediation effect of dual-task ability. Aging Ment Health. 2018;22:856-61.
[30] Hauer K, Pfisterer M, Weber C, Wezler N, Kliegel M, Oster P. Cognitive impairment decreases postural control during dual tasks in geriatric patients with a history of severe falls. J Am Geriatr Soc. 2003;51:1638-44.
[31] Jamet M, Deviterne D, Gauchard GC, Vançon G, Perrin PP. Age-related part taken by attentional cognitive processes in standing postural control in a dual-task context. Gait Posture. 2007;25:179-84.
[32] Rogind H, Simonsen H, Era P, Bliddal H. Comparison of Kistler 9861A force platform and Chattecx Balance System for measurement of postural sway: correlation and test-retest reliability. Scand J Med Sci Sports. 2003;13:106-14.
[33] Raymakers JA, Samson MM, Verhaar HJ. The assessment of body sway and the choice of the stability parameter(s). Gait Posture. 2005;21:48-58.
[34] Cohen J. Statistical Power Analysis for the Behavioral Sciences: Taylor & Francis; 2013.
[35] Ruffieux J, Keller M, Lauber B, Taube W. Changes in Standing and Walking Performance Under Dual-Task Conditions Across the Lifespan. Sports Med. 2015:1-20.
[36] Swan L, Otani H, Loubert PV, Sheffert SM, Dunbar GL. Improving balance by performing a secondary cognitive task. Br J Psychol. 2004;95:31-40.
[37] Richer N, Saunders D, Polskaia N, Lajoie Y. The effects of attentional focus and cognitive tasks on postural sway may be the result of automaticity. Gait Posture. 2017;54:45-9.
[38] Bulbulian R, Hargan ML. The effect of activity history and current activity on static and dynamic postural balance in older adults. Physiol Behav. 2000;70:319-25.
[39] Paillard T. Plasticity of the postural function to sport and/or motor experience. Neurosci Biobehav Rev. 2017;72:129-52.

[40] Alonso AC, Luna NMS, Mochizuki L, Barbieri F, Santos S, Greve JMDA. The influence of anthropometric factors on postural balance: the relationship between body composition and posturographic measurements in young adults. Clinics. 2012;67:1433-41.
[41] Cieslinska-Swider JM, Blaszczyk JW. Posturographic characteristics of the standing posture and the effects of the treatment of obesity on obese young women. PLoS One. 2019;14:e0220962.
[42] Meng H, O'Connor DP, Lee BC, Layne CS, Gorniak SL. Effects of adiposity on postural control and cognition. Gait Posture. 2016;43:31-7.

Figure 1

Figure 1 (a-d) displays the mean and standard deviations of the four COP parameters in the different task conditions (ST, MDT, CDT and TT) for Master Cyclists, Physically Active Older Adults and Untrained Older and Younger Adults.
ST, single-task; MDT, manual dual-task; CDT, cognitive dual-task; TT, triple-task.

Notes: * denotes Bonferroni-adjusted p < 0.05, ** denotes Bonferroni-adjusted p < 0.01, *** denotes Bonferroni-adjusted p <0.01.

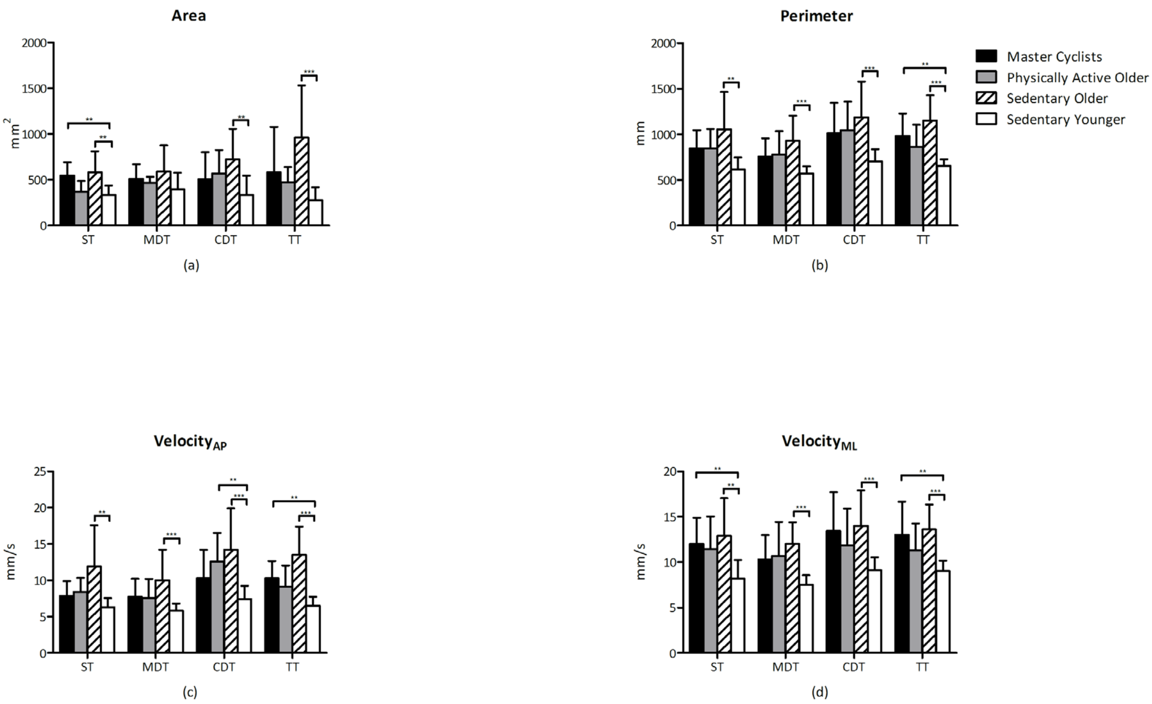

Table 1. Friedman Test and post hoc comparison for postural stability measures

Group	Variables	Task Effect			Significative values
		$\chi^2(3)$	Kendall's W test	p	
Master Cyclists	Area	3.857	0.18	0.277	
	Perimeter	7.971	0.38	0.047	Manual DT vs TT (p = 0.043; r = 0.89)
	Mean $Velocity_{AP}$	6.369	0.30	0.095	
	Mean $Velocity_{ML}$	7.147	0.34	0.067	
Physically Active Older	Area	3.514	0.17	0.319	
	Perimeter	9.000	0.43	0.029	ST vs Cognitive DT (p = 0.043; r = 0.89)
	Mean $Velocity_{AP}$	14.410	0.69	0.002	Manual DT vs Cognitive DT (p = 0.004; r = 0.62)
	Mean $Velocity_{ML}$	0.810	0.04	.847	
Untrained Older	Area	8.880	0.30	0.031	ST vs Cognitive DT (p = 0.038; r =0.53) ST vs TT (p = 0.015; r = 0.59) Manual DT vs TT (p = 0.038; r =0.85)
	Perimeter	6.960	0.23	0.073	
	Mean $Velocity_{AP}$	12.472	0.42	0.006	Manual DT vs Cognitive DT (p = 0.034; r =0.79) Manual DT vs TT (p = 0.019; r = 0.82)
	Mean $Velocity_{ML}$	1.915	0.06	0.590	
Untrained Younger	Area	5.640	0.19	0.131	
	Perimeter	0.160	0.27	0.043	Manual DT vs Cognitive DT (p = 0.034; r = 0.69)
	Mean $Velocity_{AP}$	7.410	0.25	0.060	
	Mean $Velocity_{ML}$	8.124	0.27	0.044	

Notes: ST, single task; DT, dual-task; TT, triple-task. Area indicated the 90% ellipse area (mm^2); perimeter indicated the sway path (mm); Mean $Velocity_{AP}$ indicated the mean velocity in anterior posterior direction (mm/s); Mean $Velocity_{ML}$ indicated mean velocity in medio-lateral direction (mm/s); *r*, effect size.

Table 2. Kruskal-Wallis Test and post hoc comparison for postural stability measures

Task	Variables	Group Effect			Significative values
		χ2(3)	*η²*	*P*	
ST	Area	14.670	0.44	0.002	Master Cyclists vs. Untrained Younger (*p* = 0.002; r = 0.71) Untrained Older vs. Untrained Younger (*p* = 0.002; r = 0.68)
	Perimeter	12.841	0.39	0.005	Untrained Older vs. Untrained Younger (*p* = 0.002; r = 0.68)
	Mean $Velocity_{AP}$	12.968	0.39	0.005	Untrained Older vs. Untrained Younger (*p* = 0.001; r =0.72)
	Mean $Velocity_{ML}$	10.929	0.33	0.012	Master Cyclists vs. Untrained Younger (*p* = 0.007; r =0.65) Untrained Older vs. Untrained Younger (*p* = 0.005; r =0.62)
Manual DT	Area	2.584	0.08	0.460	
	Perimeter	12.672	0.38	0.005	Untrained Older vs. Untrained Younger (*p* < 0.001; r =0.81)
	Mean $Velocity_{AP}$	10.182	0.30	0.017	Untrained Older vs. Untrained Younger (*p* < 0.001; r =0.73)
	Mean $Velocity_{ML}$	14.087	0.43	0.003	Untrained Older vs. Untrained Younger (*p* < 0.001; r =0.82)
Cognitive DT	Area	8.947	0.27	0.030	Untrained Older vs. Untrained Younger (*p* = 0.005; r =0.61)
	Perimeter	11.616	0.35	0.009	Untrained Older vs. Untrained Younger (*p* = 0.002; r =0.68)
	Mean $Velocity_{AP}$	12.426	0.38	0.006	Physically Active Older vs. Untrained Younger (*p* = 0.007; r = 0.64) Untrained Older vs. Untrained Younger (*p = 0*.002; r = 0.66)
	Mean $Velocity_{ML}$	10.887	0.33	0.012	Untrained Older vs. Untrained Younger (*p = 0*.002; r = 0.67)
TT	Area	14.434	0.43	0.002	Untrained Older vs. Untrained Younger (*p* < 0.001; r = 0.74)
	Perimeter	17.850	0.54	00.001	Master Cyclists vs. Untrained Younger (*p* = 0.001; r =0.73) Untrained Older vs. Untrained Younger (*p* < 0.001; r = 0.85)
	Mean $Velocity_{AP}$	18.565	0.56	00.001	Master Cyclists vs. Untrained Younger (*p* = 0.002; r =0.72) Untrained Older vs. Untrained Younger (*p* < 0.001; r =0.85)
	Mean $Velocity_{ML}$	13.011	0.39	0.005	Master Cyclists vs. Untrained Younger (*p* = 0.007; r =0.65) Untrained Older vs. Untrained Younger (*p* < 0.001; r =0.77)

Notes: ST, single task; DT, dual-task; TT, triple-task. Area indicated the 90% ellipse area (Area; mm^2); perimeter indicated the sway path (mm); Mean $Velocity_{AP}$ indicated the mean velocity in anterior-posterior direction (mm/s); Mean $Velocity_{ML}$ indicated mean velocity in medio-lateral direction (mm/s); *r*, effect size.