

Original Article

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**Postural stability during standing balance and sit-to-stand in  
master athlete runners compared with non-athletic old and  
young adults**

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Key Words: ageing, mobility, frailty, sarcopenia, masters athlete

Running title: Postural stability during standing balance and sit-to-stand

1     **Postural stability during standing balance and sit-to-stand in**  
2     **master athlete runners compared with non-athletic old and**  
3                     **young adults**

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8

1 **Abstract**

2 The aim of this study was to compare postural sway during a series of static  
3 balancing tasks and during five chair rises between healthy young (mean (SEM)  
4 age 26(1) yrs), healthy old (age 67(1) yrs) and master athlete runners (age 67(1)  
5 yrs; competing and training for the previous 51(5) yrs) using the Microsoft Kinect  
6 One. The healthy old had more sway than young in all balance tasks. The master  
7 athletes had similar sway to young during two-leg balancing and one leg standing  
8 with eyes open. When balancing on one-leg with eyes closed, both the healthy old  
9 and the master athletes had around 17-fold more sway than young. The healthy  
10 old and master athletes also had less antero-posterior movement during chair  
11 rising compared with young. These results suggest that masters runners are not  
12 spared from the age-associated decline in postural stability and may benefit from  
13 specific balance training.

1 **Introduction**

2 Older adults have unstable balance compared with young and the amount of body  
3 sway increases with more challenging foot positions that reduce the base of  
4 support, and with removal of vision (Gill et al., 2001). The altered posture control  
5 in older people is also evident during the gait cycle and transitions from sit-to-  
6 stand, which increases the risk of falls (Rubenstein, 2006). The reduced postural  
7 control and mobility may occur in part due to the increased tendency for older  
8 people to be sedentary (McPhee et al., 2016). Relatively short-term exercise  
9 training lasting just a few weeks and including different components of resistance  
10 or endurance activities can improve muscle function, mobility and balance  
11 (McPhee et al., 2016; Sherrington et al., 2011). It may therefore be expected that  
12 very athletic older people (masters athletes) who have been active for the  
13 majority of their adult lives would maintain good postural stability when standing  
14 and during transition from sit-to-stand, but there is little evidence currently  
15 available to this effect. Studying masters athletes may also help to distinguish  
16 between effects of ageing per se, and effects occurring due to the combination of  
17 sedentary living and ageing (Hawkins et al., 2003). While there is no doubt that  
18 masters athletes maintain high physical capability (Rittweger et al., 2009), athletic  
19 performance nevertheless declines with advancing age alongside loss of muscle  
20 power and cardiopulmonary function (Degens et al., 2013; Michaelis et al., 2008;  
21 Runge et al., 2004), so it is possible that balance and performance of common  
22 movements such as sit-to-stand transitions in masters athletes also decline with  
23 increasing age.

24 Research into postural control of masters athletes has focused mainly on the  
25 ability to recover balance after perturbation. Masters runners with exceptionally

1 high performance (recent world championship competition winners) regained a  
2 stable centre of pressure more quickly and required fewer steps to prevent falls  
3 compared with non-athletes after moving the standing platform unexpectedly  
4 backwards (Brauer et al., 2008). Another study of 173 people attending a mixed-  
5 sports event showed that men aged >65 years produced less power during  
6 repeated sit-to-stand transitions than those aged 50-64 years (Feland et al., 2005).  
7 Postural stability during the movements was not assessed, so it remains unknown  
8 whether the older athletes adapted a different rise strategy than healthy old  
9 during the sit-to-stand. The older sports participants had similar postural sway to  
10 the middle aged when standing upright (Feland et al., 2005), unlike people from  
11 the general population where postural sway increases with advancing old age (Gill  
12 et al., 2001). However, the sway during standing was assessed for just 5 s  
13 immediately following the sit-to-stand transition (Feland et al., 2005), which is  
14 more reflective of recovery of stability after whole-body movement than a test of  
15 postural sway during quiet standing.

16 Recent research showed the incidence of falls to be around 10% in athletic older  
17 people and associated with shorter time achieved during a single leg stand and  
18 slow chair-rise time (Jordre et al., 2016), although postural stability was not  
19 measured in this study. Knowing the extent to which athletic older people are  
20 unstable during challenging balance tasks and other common movements (such  
21 as sit-to-stand) may highlight physiological age-associated declines that are not  
22 necessarily halted by specific training of one type (such as running) and instead  
23 require targeted intervention. Thus, the aim of this study was to compare postural  
24 sway during a series of static balancing tasks and during five chair rises between  
25 young, old and master athlete runners.

1 **Methods**

2 **Participants and ethical approval**

3 The Local Research Ethics Committee at Manchester Metropolitan University  
4 approved the study and all participants provided written, informed consent. The  
5 young men and women were recruited from amongst the university student and  
6 staff population. The healthy older participants were all living independently and  
7 were recruited from the local community, but were excluded if they reported any  
8 cognitive, musculoskeletal or cardiovascular disease or other disability that  
9 affected their mobility levels. Master runners were recruited as part of ongoing  
10 studies (*details added after acceptance*). They were exceptionally physically active  
11 for their age, the majority were endurance runners (73%) and the remainder were  
12 sprinters (27%). All were free from injury at the time of testing and they had a  
13 mean 51.1 (SEM: 5.5) yrs history of competing in athletics. Participants reported  
14 training on average 5.5 (SEM: 2.5) hrs per week over the previous 10 yrs and all  
15 achieved British Masters Athletics Federation standards for their age group within  
16 the past two years. All assessments were completed over a four-month period  
17 during 2015 in the research laboratory at (*details added after acceptance*).

18 **Postural sway and motion analysis data capture**

19 The balance and sit-to-stand assessments (described in more detail below) were  
20 selected because they form core parts of the short physical performance test  
21 battery commonly used to assess mobility impairments in older people, with  
22 additional single-leg stance tests that are well validated and predictive of falls risk  
23 (Guralnik et al., 1994; Macrae et al., 1992; Franchignoni et al., 1998). The  
24 participant performance was recorded by a Kinect One depth sensor coupled with  
25 the Microsoft Windows Software Development Kit (Kinect for Windows Software

1 Development Kit, 2014). The Kinect One accurately tracks human motion and  
2 provides temporal-spatial features such as speed, distance travelled and time  
3 taken. For example, in Parkinson's disease patients the Kinect One had very low  
4 bias and very high accuracy when compared with the gold-standard VICON  
5 motion capture system when tracking whole-body movements, such as sit-to-  
6 stand (intraclass correlation coefficient = 0.989) (Galna et al., 2014). It is highly  
7 accurate and repeatable during standardized balance and sit-to-stand  
8 assessments (Clark et al., 2012; Clark et al., 2015; Vernadakis et al., 2014; Ejupi et  
9 al., 2015). A detailed description of the data collection techniques and algorithms  
10 used in this study has been published previously (*details added after acceptance*).  
11 Briefly, the sensor was fixed horizontally to a tripod at a height of 0.70 metres to  
12 synchronise capture of depth and skeleton streams at 30 Hz. Motion capture data  
13 (MoCap) was extracted in real time using the technique of Shotton *et al.* (2012).  
14 Following validated protocols (Clark et al., 2015; Ejupi et al., 2015; Mentiplay et  
15 al., 2015), participants wore tight-fitting shorts and a tight-fitting upper body  
16 garment that allowed for unrestricted free movement. The MoCap was composed  
17 of 25 joints and the raw axes coordinates ( $x, y, z$  orthogonal coordinates) were  
18 analysed using purpose-designed algorithms (*Reference details added after*  
19 *acceptance*) that tracked participant movements from over 116,500 frames of  
20 skeleton data (Matlab 2014a; MathWorks Inc, USA).

## 21 **Standing balance**

22 Balance was assessed with arms extended horizontally, parallel to the ground, and  
23 participants were given three attempts, separated by rest intervals lasting 30 s, to  
24 achieve 10 s without taking any steps or touching external supports in the  
25 following foot-placements: 1) side-by-side; 2) semi-tandem; 3) full-tandem; 4)

1 one-leg standing; 5) one-leg standing with eyes closed. Total time was defined as  
2 the absolute time taken to perform a test (measured in s). The Centre-of-Mass  
3 (CoM) was identified in each frame as the centre of the hip joint, the shoulders and  
4 the spine (Gonzalez et al., 2014). The change in position between consecutive  
5 frames was considered as the directional change in medio-lateral (ML) and  
6 antero-posterior (AP) movements.

### 7 **Five-times sit-to-stand**

8 After completing the balance assessments, participants were asked to perform  
9 five chair rises as quickly as possible and to keep their arms folded across their  
10 chest. A chair with seat height 44 cm and secure back rest, without arm rests, was  
11 used and positioned against a wall to prevent it from slipping backwards during  
12 the test. The number of chair stands and the estimated time taken to complete  
13 each of the five chair stands was determined using spectral analysis techniques  
14 (*details added after acceptance*). For each test, the number of local peaks (i.e.  
15 reaching the highest point in the vertical-plane (y-axis) when fully standing) in the  
16 data was extracted based on a threshold reached when standing fully upright. It  
17 was determined by a minimum distance of 20 frames or greater than the overall  
18 sequence mean (the sequence mean occurs at around half-way between sitting  
19 and standing). An inversion of this process was undertaken to define the starting  
20 and end point of each rise (indicative of a seated position).

21

### 22 **Statistical analysis**

23 Analysis of Kinect data was performed using a customized script in Matlab 2014a  
24 (MathWorks Inc, USA) and statistical analysis of the results was completed using  
25 SPSS (IBM Corporation, USA). The ML and AP movements were presented as



1 absolute values (cm). Comparison of results between genders using independent  
2 samples t-tests showed no significant differences between men and women for  
3 assessments of balance or sit to stand, so results from the two genders were  
4 combined for further analyses. Participant group data (young; healthy old and  
5 master runners) were compared using one-way ANOVA and where significant  
6 differences were detected between groups a tukey's post-hoc test was performed.  
7 A two condition (eyes open vs eyes closed) Repeated Measures ANOVA was used  
8 to assess within-group differences between the single leg eyes open and the single  
9 leg eyes closed balance assessments. Where a significant condition-by-group  
10 interaction was found, separate dependent samples t-tests were performed to  
11 determine individual group effects. Significance was accepted as  $p < 0.05$ .

12

### 13 **Results**

14 The balance and sit to stand results are summarized in Table 1.

15 ***Two-leg stance balance tests:*** During the side-by-side stance, AP movements did  
16 not differ between groups ( $p = 0.667$ ). The young and master runners had similar  
17 ML sway ( $p = 0.299$ ), but healthy old had significantly more ML sway than both  
18 young ( $p = 0.001$ ) and master runners ( $p < 0.0005$ ). During the semi-tandem stance,  
19 the young and master runners did not differ for ML ( $p = 0.835$ ) or AP ( $p = 0.094$ )  
20 sway. The healthy old had significantly more ML and AP sway than both the young  
21 and master runners (all  $p < 0.01$ ). During the tandem stance, ML sway did not differ  
22 between groups ( $p = 0.117$ ). Master runners had similar AP movements to the  
23 young ( $p = 0.917$ ) during tandem stance, but the healthy old had more movement  
24 than the master runners ( $p = 0.011$ ) and the young ( $p = 0.009$ ).

25

1 ***One-leg stance balance tests:*** When eyes were open, two young and four healthy  
2 old could not achieve the full 10 seconds standing on one leg, but all masters  
3 runners completed the test. The postural sway during one-leg standing with eyes  
4 open was similar between the young and the master runners, but healthy old had  
5 more ML ( $p=0.001$ ) and more AP sway ( $p=0.001$ ) than young. When standing on  
6 one leg with eyes closed, three young and five master runners could not achieve  
7 the full 10 seconds and all of the healthy old failed to reach 10 seconds. Master  
8 runners ( $p=0.048$ ) and healthy old ( $p<0.0005$ ) were not able to stand on one leg  
9 with eyes closed for as long as the young, and healthy old performed worse than  
10 master runners ( $p=0.009$ ). Master runners ( $p=0.006$ ) and healthy old ( $p=0.009$ )  
11 had more ML sway than young; there was no difference between master runners  
12 and healthy old ( $p=0.929$ ). Master runners ( $p=0.045$ ) and healthy old ( $p=0.012$ )  
13 had more AP sway than young, with no difference between master runners and  
14 healthy old ( $p=0.462$ ).

15 ***Comparison of performance during one leg stance with eyes open and eyes***  
16 ***closed.*** When eyes were closed, participants achieved significantly less time  
17 ( $p<0.0005$ ) standing on one leg compared with eyes open. A significant condition-  
18 by-group interaction for total time ( $p<0.0005$ ) was due to the young adults  
19 ( $p=0.193$ ) maintaining similar total balance time with eyes open and eyes closed,  
20 while the masters runners ( $p=0.043$ ) and the healthy old ( $p<0.0005$ ) had shorter  
21 balance time with eyes closed compared with eyes open.

22 Although all groups had more ML and AP sway (both  $p<0.0005$ ) during the eyes  
23 closed condition compared with eyes open, there were significant condition-by-  
24 group interactions for ML ( $p=0.009$ ) and AP sway ( $p=0.003$ ). The young showed  
25 over 5-fold more ML sway ( $0.020$ ) and 3.5-fold more AP sway ( $p=0.005$ ) with eyes

1 closed compared with eyes open. The healthy old showed 3.2-fold more ML sway  
2 (0.009) and 4-fold more AP sway ( $p=0.005$ ) with eyes closed compared with eyes  
3 open. The masters runners showed 37-fold more ML sway (0.002) and 8-fold  
4 more AP sway ( $p<0.0005$ ) with eyes closed compared with eyes open.

5

6 ***Five-times chair rise:*** There was no difference between the groups in the total  
7 time taken to perform five chair rises ( $p=0.361$ ), but the healthy old had higher  
8 standard deviation of the time between stands than young ( $p=0.001$ ) and higher  
9 than master runners ( $p=0.004$ ). There were no significant differences between  
10 groups for ML movements of the upper body ( $p=0.102$ ). Compared with the young,  
11 both master runners and healthy old had significantly less AP movements  
12 ( $p<0.0005$ ), but the master runners and healthy old did not differ significantly.  
13 The AP movements during the chair rise correlated inversely with both AP and ML  
14 sway when balancing with eyes closed ( $r=-0.327$ ,  $p=0.045$ ; and  $r=-0.422$ ,  $p=0.008$ ,  
15 respectively).

16

## 17 **Discussion**

18 There is little doubt that regular physical activity helps to preserve health and  
19 physical function into older age and reduce risks of falling, which is the basis of  
20 the physical activity recommendations from the UK Chief Medical Officer  
21 (Department of Health, 2011). Our results show that competitive masters runners  
22 performed better than non-athletic old and similar to young in moderately  
23 challenging balance tasks. However, during more challenging and less familiar  
24 conditions when standing on one leg with visual feedback removed, the masters

1 runners were very unstable and they also demonstrated a restricted, possibly  
2 more cautious, upper body movement during the chair stand, similar to non-  
3 athletic old (Table 1).

#### 4 ***Balance Performance***

5 As the balance assessments increased in difficulty, all the participants tended to  
6 show more postural sway (Table 1). Masters runners showed similar postural  
7 sway to the young during side-by-side stance, semi-tandem, full tandem and one-  
8 leg eyes open stance. Conversely, compared to the young, the non-athletic old had  
9 around 40% more postural sway during side-by-side, 70% more during semi-  
10 tandem, over 4.5-fold more during tandem and over 8-fold more during one-leg  
11 standing with eyes open (Table 1). The results from the balance trials that were  
12 completed with eyes open suggest some cross-over benefit of regular running  
13 training when visual feedback was available. These findings may help to explain  
14 why masters athletes have a lower risk of falling than the non-athletic population  
15 (Jordre et al., 2016). The results also support those from two previous studies  
16 showing that masters athletes recovered balance more quickly after perturbation  
17 compared with non-athletic old (Brauer et al., 2008) and old athletes had similar  
18 postural sway to middle-aged athletes (Feland et al., 2005). They also add to a  
19 large body of evidence suggesting exercise training in old age is beneficial for  
20 balance and falls prevention (Orr et al., 2006; Perrin et al., 1999; Glenn et al., 2015;  
21 Sherrington et al., 2011).

22 During balance trials performed on one leg with eyes closed, the extent of  
23 underlying age-related deterioration was clearly apparent both in the old and the  
24 masters runners. A previous study of masters cyclists showed that they were often  
25 unable to balance on one leg with eyes closed for more than ten seconds (Pollock

1 et al., 2015), which is similar to the performance we previously reported for non-  
2 athletic older people and substantially worse than younger adults (*details added*  
3 *after acceptance*), again indicating poor postural control in older athletes. Running  
4 and cycling both require the majority of work to be completed by the legs, but the  
5 loads and eccentric contractions during cycling are lower than when running  
6 (Millet et al., 2009). Any comparison of balance performance between these two  
7 modes of training is beyond the scope of this study.

8 Results in Table 1 indicate that the young had around 4-fold more sway (5-fold ML  
9 and 3.5-fold AP) when standing on one leg with eyes closed compared to one-leg  
10 with eyes open. Master runners showed 17-fold more sway (37-fold ML and 8-fold  
11 AP) when standing on one-leg with eyes closed compared with one-leg with eyes  
12 open, going from reasonable stability with their eyes open to finding the task very  
13 difficult and performing almost as badly as the non-athletic old with their eyes  
14 closed. The non-athletic old showed around 3.5-fold more sway (3.2-fold ML and  
15 4-fold AP) with eyes closed compared with eyes open. This value might seem  
16 modest compared to the 17-fold change for master runners, but the old were  
17 already very unstable on one leg with their eyes open. Indeed, when eyes were  
18 closed, all of the old and around a third of the master runners failed to stand on  
19 one leg for 10 sec.

20 Overall, our results indicate that long-term, regular intense running is associated  
21 with better balance during standing tasks completed with the eyes open compared  
22 with age-matched non-athletic old. However, long-term training did not attenuate  
23 the declines in postural sway during static balancing with eyes closed. These  
24 results might appear to conflict with advice that training can improve balance in  
25 older people (Sherrington et al., 2011), but the available evidence shows that the

1 training-induced improvements to balance are most pronounced for ‘vulnerable’  
2 populations at high risk of falling and they rarely or never return to levels seen in  
3 young (Sherrington et al., 2011). Our methodology cannot elucidate the sensory-  
4 motor control mechanisms differentially affecting balance performance with eyes  
5 open compared with eyes closed. Removing the visual feedback increases reliance  
6 upon the nervous-system components of motor control including central  
7 processing, vestibular function, proprioception and efferent motor-unit  
8 recruitment. Age-related declines in these systems are well documented  
9 (Campbell et al., 1973; Piasecki et al., 2016; Li et al., 2014; Lopez et al., 1997;  
10 Wiesmeier et al., 2015) although few previous studies included master athletes.  
11 The poor balance of masters runners with their eyes closed suggests that even  
12 competitive masters athletes might benefit from regular balance training.

### 13 ***Five times sit-to-stand***

14 The five times sit to stand is a commonly used test of physical function in older  
15 people and patient groups and a part of the Short Physical Performance Battery  
16 (Guralnik et al., 1994). Recently, Ejupi *et al.* (2015) used the Kinect One to detect  
17 differences between older fallers compared with non-fallers in the five-times-sit-  
18 to-stand in the laboratory and the unsupervised home setting. In the present  
19 study, similar methodology with the Kinect One was used to show that young,  
20 healthy old and athletic old complete five chair rises in similar overall time.  
21 However, both the athletic and non-athletic old had less AP movement of the  
22 upper body throughout the task, which was principally due to the older adults and  
23 masters runners restricting the forwards lean of the upper body in the early stages  
24 of the sit-to-stand transition. The healthy old had more variability in time taken  
25 between chair rises due to slowing of movements during the task. The inverse

1 correlation between AP movement during the chair stand test and sway during  
2 balancing with eyes closed might reflect an awareness of limitations of postural  
3 stability during functional tasks, causing older people to be more cautious, or less  
4 confident, during the transition from sit-to-stand. This caution when standing is  
5 thought to protect against leaning the centre of gravity too far forward and  
6 consequently losing balance (Binda et al., 2003).

### 7 ***Limitations and further work***

8 The main limitation of using the Kinect One to track movements is that the data  
9 collection area is restricted to within 4m of the depth sensor. This is sufficient for  
10 analysis of sit-to-stand and static balance and although we have previously shown  
11 that spatio-temporal characteristics of gait can be analysed (*details added after*  
12 *acceptance*), we considered 4m to be too limiting to compare gait results between  
13 groups. Future studies could consider using a treadmill during analysis of gait with  
14 the Kinect One. In this study we recruited masters runners to complete the  
15 assessments as a model of active ageing. It is possible that masters athletes  
16 competing in different weight-bearing events that have a greater emphasis on  
17 balance control, agility or strength, or indeed non-weight-bearing activities (such  
18 as swimming or cycling), may produce different results. All of the assessments  
19 were completed in a research laboratory and it will be important to determine  
20 how the differences that we identified between groups translate to mobility in a  
21 real-world setting.

### 22 ***Summary and conclusion***

23 These results indicate that masters runners display greater postural stability than  
24 non-athletic old when balancing with visual feedback intact. However, during the  
25 more challenging condition when visual feedback was removed while standing on

1 one leg, the masters runners were just as unstable as non-athletes, both being  
2 considerably less stable than young adults. The masters runners and healthy old  
3 restricted their upper body forwards lean during transitions from sit to stand,  
4 which was associated with the higher postural sway when balancing with eyes  
5 closed. These results suggest that masters runners are not spared from the age-  
6 associated decline in postural stability and are likely to benefit from the inclusion  
7 of specific challenging balance exercises into their weekly training programme to  
8 try to halt any further decline and reduce the risks of injurious falls.

### 9 **Conflict of interest**

10 None declared.

### 11 **Acknowledgements**

12

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1 **Tables**

2

Measurement	Young	Healthy Old	Masters runners	p-value
<b>Participant Characteristics</b>				
N (% male)	15 (68)	13 (65)	15 (47)	
Age (years)	25.5 (6.4) <sup>b,c</sup>	67.6 (3.9)	67.2 (5.2)	0.000
Height	173.2 (8.5)	170.9 (6.1)	165.7 (10.1)	0.058
Body mass	77.1 (16.3)	77.5 (17.0)	61.0 (9.5) <sup>a,b</sup>	0.005
BMI	25.0 (5.2)	26.4 (5.8)	22.1 (2.2)	0.051
<b>Two-leg (Open Eyes)</b>				
ML-CoM Sway (cm)	0.27 (0.11)	0.44 (0.15) <sup>a,c</sup>	0.22 (0.09)	0.001
AP-CoM Sway (cm)	0.32 (0.2)	0.36 (0.21)	0.38 (0.17)	0.667
<b>Semi Tandem (Open Eyes)</b>				
ML-CoM Sway (cm)	0.29 (0.08)	0.49 (0.16) <sup>a,c</sup>	0.29 (0.11)	0.001
AP-CoM Sway (cm)	0.21 (0.07)	0.36 (0.14) <sup>a,c</sup>	0.28 (0.14)	0.009
<b>Tandem (Open Eyes)</b>				
ML-CoM Sway (cm)	0.41 (0.2)	1.87 (3.86) <sup>a,c</sup>	0.30 (0.12)	0.117
AP-CoM Sway (cm)	0.27 (0.11)	1.33 (1.86) <sup>a,c</sup>	0.30 (0.16)	0.016
<b>One Leg (Open Eyes)</b>				
Total Time (s)	9.74 (0.72)	8.47 (2.42)	10.00 (0.00)	0.165
ML-CoM Sway (cm)	0.28 (0.09)	3.85 (4.62) <sup>a</sup>	0.32 (0.12)	0.001
AP-CoM Sway (cm)	0.41 (0.21)	1.78 (2.13) <sup>a</sup>	0.68 (0.46)	0.012
<b>One Leg (Closed Eyes)</b>				
Total Time (s)	9.47 (1.24)	5.09 (1.70) <sup>a,c</sup>	8.12 (2.96) <sup>a,b</sup>	0.001
ML-CoM Sway (cm)	1.5 (1.78)	12.66 (9.1) <sup>a</sup>	11.93 (14.86) <sup>a</sup>	0.010
AP-CoM Sway (cm)	1.47 (1.16)	7.07 (5.57) <sup>a</sup>	5.48 (7.68) <sup>a</sup>	0.036
<b>Chair Stand</b>				
Total Time (s)	9.42 (1.94)	10.09 (1.64)	9.38 (1.75)	0.597
ML CoM Sway (cm)	1.35 (0.58)	1.67 (0.90)	1.15 (0.3)	0.102
AP CoM Sway (cm)	17.07 (4.6)	10.83 (3.57) <sup>a</sup>	8.97 (3.08) <sup>a</sup>	0.001
Time Rise (s)	1.43 (0.27)	1.55 (0.27)	1.54 (0.23)	0.361
Time Rise SD (s)	0.53 (0.11)	0.79 (0.16) <sup>a,c</sup>	0.58 (0.42)	0.002

3 **Table 1. Comparison between young, master athletes and old for balance**  
4 **and chair rise performance.** ML: Medial Lateral; AP: Anterior-Posterior; CoM:  
5 Centre-of-Mass. Data shown as mean (SD). The p-value represents the main effect  
6 of group from the ANOVA. Results from the post-hoc between-groups  
7 comparisons are indicated as <sup>a</sup>: significantly different from Young; <sup>b</sup>: significantly  
8 different from healthy old; <sup>c</sup>: significantly different from masters runners (actual  
9 p-values are reported in the main text).