Original article (short paper)

Can functional exercise capacity discriminate older individuals with poor postural control?

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Abstract—Postural instability can be related to functional limitations as a result of the aging process. This study aimed to compare functional exercise capacity and postural control in older adults. Participants were allocated into three groups according to their functional exercise capacity based on the six minute walking test (6MWT): 1) Low performance group (LP: distance walked ≤ 80% of the predicted value $n = 19$), 2) Normal performance group (NP: distance walked 81-100% of the predicted value $n = 21$) and, 3) High performance group (HP: distance walked >100% of the predicted value $n = 23$). All groups performed three trials of a one-leg stance for 30s on a force platform. LP showed worse postural control in comparison to NP and HP, and significant differences ($p < .05$) were found between groups for area, velocity antero-posterior of center of pressure and time limit variables during the one-leg stance task. These results have implications for rehabilitation management with regard to exercise, balance assessment and intervention in older adults.

Keywords: postural control, exercise, performance, aging

Resumo—"A capacidade funcional de exercício pode discriminar idosos com pior controle postural?" Instabilidade postural pode estar relacionada com as limitações funcionais, como um resultado do processo de envelhecimento. Este estudo teve como objetivo comparar a capacidade funcional de exercício e o controle postural em indivíduos idosos. Os participantes foram separados em três grupos de acordo com sua capacidade funcional de exercício baseada no teste de caminhada de seis minutos (TC6min): 1) grupo baixo desempenho (BD: distância caminhada ≤ 80% do valor predito $n = 19$), 2) grupo normal desempenho (ND : distância caminhada 81-100% do valor predito $n = 21$) e, 3) grupo alto desempenho (AD: distância caminhada >100% do valor predito $n = 23$). Todos os grupos realizaram três testes com apoio unipodal permanecendo por 30s sobre a plataforma de força. BD apresentou pior equilíbrio postural em comparação com ND e AD; com diferenças significativas ($p < 0,05$) encontradas entre os grupos para os parâmetros de área e velocidade antero-posterior do centro de pressão e a variável tempo-limite durante a posição unipodal. Estes resultados têm implicações para estratégias de reabilitação no que diz respeito ao exercício, avaliação do equilíbrio e intervenção em idosos.

Palavras-chave: controle postural, exercício, desempenho, envelhecimento

Resumen—"La capacidad funcional de ejercicio puede discriminar ancianos con mal control postural?" Inestabilidad postural puede estar relacionada con las limitaciones funcionales como resultado del proceso de envejecimiento. Este estudio tuvo como objetivo evaluar la comparación entre la capacidad funcional del ejercicio en el control postural de las personas de edad avanzada. Los participantes fueron divididos en tres grupos de acuerdo a su capacidad de ejercicio funcional basado en la Prueba de Caminada de seis minutos (PC6M): 1) grupo Bajo Rendimiento (BR: distancia recorrida ≤ 80% del valor predijo, $n = 19$), 2) grupo Normal Rendimiento (NR: distancia recorrida 81-100% del valor predijo, $n = 21$) y 3) grupo Alto Rendimiento (AR: distancia recorrida >100% del valor predijo, $n = 23$). Todos los grupos realizaron tres pruebas sobre un solo pie por 30s en la plataforma de fuerza. BR presentó un mal equilibrio postural en comparación con NR y AR; con diferencias significativas ($p < 0,05$) encontrado entre los grupos de los parámetros área y velocidad antero-posterior del centro de presión y el límite de tiempo para la postura de una sola pierna. Estos resultados tienen implicaciones para las estrategias de rehabilitación en relación con el ejercicio, la evaluación del equilibrio y la intervención en los ancianos.

Palabras claves: control postural, ejercicio, rendimento, envejecimiento

Introduction

Aging is often associated with functional and histomorphological alterations that progressively change the organism, and in turn increase internal and external disorders in the body system (Ferrucci, Giallauria, & Guralnik, 2008). Physical inactivity during the aging process also contributes to an increase of chronic diseases and consequently disabilities (Romeiro-Lopes *et al*., 2014). A decline in muscular capacity, such as reduction of strength, negatively impacts functional exercise capacity in older adults (Broskey *et al*., 2014).

Different clinical and laboratory methods have been developed to assess physical capacity in older individuals. The six minute walking test (6MWT) is often used to determine the functional exercise capacity that is required during a sub-maximal task in different populations (healthy, obese, adults with chronic diseases) by using the most common movement of daily life: walking (ATS, 2002; Iwama *et al*., 2009). Furthermore, this measurement tool is capable of identifying changes in functional exercise capacity related to distance walking during the test (Hovington, Nadeau, & Leroux, 2009; Troosters, Gosselink, & Decramer, 1999). In general, functional tests such as the 6MWT (distance walking measure) or time limit variables (mobility timed-up-and-go or one-leg balance) can help health professionals to better objectively assess the physical capacity of an individual and in turn, identify those with balance problems and, consequently, increased risks of falls (Ansai, Aurichio, & Rebelatto, 2015).

Hayashi *et al*. (2012) reported that older adults with more preserved exercise capacity than those with poor capacity, measured by a maximal exercise test namely Incremental Shuttle Walking Test - ISWT, present better postural control measured by COP sway variables of a force platform (Area and velocity of COP). Also, these authors presented that this better exercise capacity present higher levels of physical activity in daily life than those with poor exercise capacity measured by subjective questionnaire modified of Baecke for older people and objectively by pedometer. The ISWT is a simple and inexpensive test, which evaluates maximal exercise capacity based on the distance walked around a 10 m course according to different speeds dictated by an audio signal (Probst *et al*., 2012). The Baczkowicz *et al*. (2008) also observed a moderate relationship (r = - .63) between postural control measured by the area of COP sway using a force platform and distance/velocity walking measured by the 6MWT in older adults. However, these two studies used different experimental protocols for balance tasks: unipodal (Hayashi *et al*., 2012) versus bipedal standing (Baczkowicz *et al*., 2008), and for exercise capacity tests: maximal (Hayashi *et al*., 2012) versus sub-maximal activity effort (Baczkowicz *et al*., 2008).

The interaction between balance and functional exercise capacity would be better related to a sub-maximal contraction effort since both balance performance and activities of daily living are used with low to moderate force level contraction. Although it is not totally defined in the literature, balance tends to be more associated with 6MWT classification (r = - .63; Baczkowicz *et al*., 2008) than with the Shuttle maximal test (r = - .28; Hayashi *et al*., 2012) in older adults. However, even the bipedal quiet standing task has been proven to be sensitive in discriminating balance in the older adults, as employed by Baczkowicz *et al*. (2008), this condition is also not a major challenge in our balance control system, which also limits the clinical usefulness of data obtained from it (Clifford & Holder-Powell, 2010) and its conclusions. The one-legged stance may be a better condition (Hayashi *et al*., 2012), since it provides a more challenging balance-control task, which may be more predictive of balance problems and consequently a better indicator of falls (Michikawa *et al*., 2009).

Thus, our research team, motivated by Hayashi's results (2012), integrated again a new investigational study design including both unipodal balance performance and functional exercise capacity based on sub-maximal effort with the 6MWT test. The purpose was to: 1) compare three experimental groups of older adults with different levels of functional exercise capacity (low, normal, high) in postural control measured by COP sway variables computed by a force platform; and 2) assess the relationship between all these measures (6MWT with balance). We hypothesized that a better functional exercise capacity can lead to better balance results during sub-maximal performance. However, the relation between these variables still stay weak to moderate because balance linked to postural control system is multifaceted (Nguyen *et al*., 2012).

Methods

Design and participants

This cross-sectional study was conducted from September 2009 to December 2010, with a convenience sample of older adults who participated in an interdisciplinary project (EELO Project - study on ageing and longevity). The EELO Project is a thematic project that was developed at the Universidade Norte do Paraná (UNOPAR), which aimed to evaluate socio-demographic factors and indicators of health conditions of older adults in Londrina, a city of the Northern State of Paraná, Brazil. Information can be found at: http://www2.unopar.br/sites/eelo/. The older population of this city represents today 12% of the total population, which is similar to means from other countries (IBGE, 2010; Lutz & KC, 2010). The total sample of the EELO project consisted of 508 individuals, which was representative of the 43,610 older citizens over 60 years old living in Londrina. In the present study, 244 individuals were not included in the analysis because they did not perform one of the two tests. 201 participants were excluded with regard to exclusion criteria. Finally, only 63 older adults (43 women and 20 men) participated in this analysis. The participants included were individuals over 60 years old, who lived physically independent according to the classification proposed by the Functional Status Spirduso (levels 3 and 4) (Spirduso, 1995); no falls in the past year and a cognitive status of >21 on the Mini-Mental State Examination (Hughes *et al*., 1996). Individuals with severe heart disease or neuro-musculo-skeletal or mental limitations that would impair understanding and performance of the tests involved in the study were excluded. All participants agreed to participate in this study and signed a written informed consent. This research project was approved by the Ethics Committee of the Universidade Norte do Paraná (PP0070/09).

Assessments

Two sessions of approximately two hours duration in total (taking into consideration rest periods), separated by a maximum of 72 hours were necessary. The investigators performed the procedures and tasks with all participants in the same laboratory environment to ensure uniformity in the balance test. The physical tests were applied on two different days: (1) session one: functional exercise capacity with the six-minute walking test (6MWT); (2) session two: balance test during a one-leg stance on a force platform. The order of the tests on the two separate days was according to the experimental design conducted in the EELO project.

Exercise capacity

The 6MWT was used to assess functional exercise capacity, according to the standards of the American Thoracic Society (ATS, 2002; Singh *et al*., 2014). Two tests were performed with at least 30 minutes of rest between them. Participants were asked to walk as fast as they could down a 30 meter corridor, however running was not allowed. They could also rest and stop during the test, if necessary. Verbal encouragement was given following standard protocols (ATS, 2002). Physiological variables such as heart rate and hemoglobin saturation were assessed using a transcutaneous pulse oximetry system (GE OhmedaTuffsat Handheld Pulse Oximeter®) before and after each test. In addition, perceived exertion, such as dyspnea (Borg D) and leg fatigue (Borg F), was assessed using the modified Borg scale (Kendrick, Baxi, & Smith, 2000), also before and after each test. All of these physiological parameters were assessed as a protocol in order to control and follow the physiological responses during the test and hence to guarantee a safe test.

When the test was finished, the researcher recorded the covered distance. The greatest distance between the first and second trial was utilized for analysis. The older adults were separated into three groups according to physical performance on the 6MWT, using the percentage of the predicted value for group division. The predicted values were calculated for each individual using the prediction equation proposed by Iwama and colleagues (2009) (six minute walking distance (6MWD) meters= 622.461 – (1.846 x age years) + (61.503 x gender males=1; females=2), which is applicable for individuals 13-84 years old. The first group (LP) included older adults with low performance (≤80% of the predicted value; $n = 19$). The second group (NP) included older adults with normal performance (81-100% of the predicted value; $n = 21$). The third group (HP) included older adults with high performance (>100% of the predicted value; $n = 23$).

Postural balance

All participants were familiarized with the equipment and protocol until they were comfortable with the testing. Balance assessment was performed with a standardized protocol: barefoot with their arms at their sides or parallel to their trunk. The preferred leg for one-leg stand was indicated by each participant. During testing with eyes open, the participant would look at a target (black cross = 14.5 cm height x 14.5 cm wide x 4 cm thick) placed on a wall at eye level 2 m away. Three trials of 30 s with 30 s rest intervals were performed and the mean was retained for analysis (Oliveira *et al*., 2014). Time limit test in the present study was defined as the maximum time that the older person remained until abandoning the position due to loss of balance, i.e., when the lifted foot touched the force platform, and was evaluated in the protocol described above (da Silva *et al*., 2013).

The vertical ground reaction force data from the force platform (BIOMEC400, EMG System do Brasil, Ltda., SP) was sampled at 100 Hz. All force signals were filtered with a 35-Hz low-pass second- order Butterworth filter and converted into COP data using proper software, which was compiled with MATLAB routines (The Mathworks, Natick, MA). Stabilographic analysis of COP sway data led to the calculation of the four main balance parameters: (1) 95% confidence ellipse area of COP (A-COP in cm^2), and (2) mean velocity (Vel in cm/s) of COP for both antero-posterior (A/P) and medio-lateral (M/L) directions (da Silva *et al*., 2013). For tasks, these balance parameters were calculated for the total duration of the trial for each participant.

Statistical analysis

For data analysis, the older adults were separated into three groups according to the functional exercise capacity level assessed using the 6MWT, using the percentage of the predicted value for group division (Iwama *et al*., 2009) as described above. Descriptive analyses were presented as median and interquartile ranges with regard to non-parametric tests used for force platform variables. First, MANOVAs analyses were performed to compare the three groups by anthropometric characteristics such as age, height, weight and body mass index (as dependent variables). Second, MANOVAs were performed again to compare the three groups (LP, NP and HP) in time-limit balance performance during one-leg stance task, the 6MWT distance in meters and in percentage of the predicted value of 6MWT. When necessary a *post hoc* Tukey test was used to identify differences between the groups.

For main analysis of study, Kruskal-Wallis test with Dunn *post hoc*, when necessary, was performed to compare the three groups in each COP sway variable (A-COP, VEL A/P and VEL M/L). Spearman correlation coefficient was used in the end to assess the relationship between all COP balance variables and the scores of exercise capacity by 6MWT. All statistical analysis was performed with SPSS software (v20, SPSS Inc., Chicago, IL) and significance was set at $p < .05$.

Results

The characteristics of participants are described in Table 1. The groups were similar with regard to age, height, weight and body mass index ($F = 1.01$, $p = .442$). However, the groups were different with regard to time limit, 6MWT in meters and percentage of the predicted variables ($F = 2.74$, $p = .001$). The LP presented decreased time-limit in balance one-leg stance task (LP 12 ± 5, NP 17 ± 5 and HP 18 ± 6) as well as poor exercise capacity performance absolute distance in meters (LP 371 ± 41, NP 436 ± 50 and HP 454 ± 44) and predicted in % (LP 74 ± 6, NP 88 ± 4 and 103 ± 2) when compared to the NP and HP groups.

Significant differences were found between the three groups for the two main COP balance sway variables (Table 2). The LP group presented more balance instability (higher COP values) than NP and HP groups. These significant differences were related to A-COP variable ($p = .027$, effect size = - .61, LP < NP; $p = .027$, effect size= -.60 LP < HP) and VEL A/P variable ($p = .016$, effect size= - .47 LP < HP). None significant difference was reported for VEL M/L variable.

Overall, the correlations between COP balance sway variables and scores of functional exercise capacity were weak and not significant. The results for relation with absolute score of 6MWT in meters were: A-COP = - .22 ($p = .076$), VEL A/P = - .10 ($p = .407$), and VEL M/L = .00 ($p = .963$); while for predicted value: A-COP = .05 ($p = .644$), VEL A/P = - .02 ($p = .877$), and VEL M/L = .02 ($p = .866$). Finally, the relationship between the percentage of the predicted value and absolute value in meters with the time limit of balance performance were weak ($r = .36$, $p = .003$; $r = .23$, $p = .069$, respectively).

Table 1. Results of characteristics of participants and tests performance.

	LP (*n* = 19) 9 M /10 W	**NP (*n* = 21) 4 M /17 W**	**HP (*n* = 23) 7 M /16 W**	***p***
Age (yrs)	68 ± 6	64 ± 6	66 ± 4	.442
Height (cm)	161 ± 9	157 ± 8	156 ± 3	.442
Weight (Kg)	71 ± 21	68 ± 11	64 ± 9	.442
BMI (Kg/cm²)	27 ± 6	27 ± 4	26 ± 4	.442
Time limit (s)	12 ± 5	17 ± 5	18 ± 6	.001*
6MWT (m)	371 ± 41	436 ± 50	454 ± 44	.001**
6MWT (%)	74 ± 6	88 ± 4	103 ± 2	.001***

Values are presented as mean and standard deviation (±).

BMI: body mass index; 6MWT: six minute walking test.

Groups: (LP): low performance group; (NP): normal performance group and (HP): high performance group. M: men; W: women.

* Significant differences between groups (LP and NP Tukey *post hoc* $p = .024$; LP and HP Tukey *post hoc* $p = .002$).

** Significant differences between groups (LP and NP Tukey *post hoc* $p < .001$; LP and HP Tukey *post hoc* $p < .001$).

*** Significant differences between groups (LP and NP Tukey *post hoc* $p < .001$; NP and HP Tukey *post hoc* $p < .001$; LP and HP Tukey *post hoc* $p < .001$).

Table 2. Comparison of postural control between groups.

	LP (*n = 19*) 9 M /10 W	**NP (*n = 21*) 4 M /17 W**	**HP (*n = 23*) 7 M /16 W**	***Kruskal-Wallis* (*p value*)**
A-COP (cm²)	9,95 [3-5]	7,85 [2-3]	8,49 [6-8]	.041 ‡
VEL A/P (cm/s)	3,25 [3-5]	2,86 [2-3]	2,74 [2-3]	.048 †
VEL M/L (cm/s)	3,62 [3-6]	3,06 [3-4]	3,54 [2-4]	.199

Values are presented as median and interquatile range [25-75] Condition ONE: one-legged stand.

Balance parameters: A-COP (cm^2): area of center of pressure; VEL-A/P (cm/s): sway mean velocity of COP in anteroposterior direction; VEL-M/L (cm/s): sway mean velocity of COP in medio-lateral direction.

Groups: (LP): Low performance group, (NP): Normal performance group and (HP): High performance group. M: Men; W: Women.

‡ Significant differences in A-COP variable ($p \leq .05$) between groups (LP versus NP, Dunn *post hoc P* 0.027 and LP versus HP Dunn *post hoc* $p = .027$)

† Significant differences in VEL A/P variable ($p \leq .05$) between groups (LP versus HP, Dunn *post hoc* $p = .016$)

Discussion

This study aimed to investigate the impact of functional exercise capacity on postural control, and the relationship between these measures among older adults. Our hypotheses were confirmed: older adults with low functional exercise capacity (LP group) also presented poor balance results during a one-leg stance, while the relationship between all measures (COP sway versus exercise capacity variables) was weak. Our findings are in agreement with previous works. Hayashi *et al*. (2012), showed that physically independent older adults with more preserved exercise capacity have better postural control and higher levels of physical activity in their daily life. Although Hayashi *et al*. (2012), evaluated maximum exercise capacity using the incremental shuttle walking test, while in the present study a sub-maximal exercise capacity was assessed with the 6MWT.

It is well known that the decline in muscular capacity, such as a reduction in strength due to physical inactivity or the aging process, negatively impacts the functional capacity of older adults and hence their balance (Broskey *et al*., 2014; Papegaaij *et al*., 2014). Schrager *et al*. (2008), demonstrated with spatial-temporal parameters of gait (peak velocity, displacement, stride velocity and step length) that older adults with decreased speed gait and smaller step length have poor dynamic postural stability during a walking task, which supports the current findings. The same authors suggested that quantification of control during gait may improve the identification of older persons at an increased risk of falls related to a more dynamic context (Vieira *et al*., 2015; Schager *et al*., 2013) and that the decline in gait speed can slow 2.4% per year after 70 years old (Write *et al*., 2013). This could thus support, at least, the negative balance results from low exercise capacity group when compared to other groups.

On the other hand, factors regulating balance are multi-faceted because the integration of different systems (Hughes *et al*., 1996; Lindmark *et al*., 1999; Tang *et al*., 1998), which could explain the weak correlations seen between our measurements compared with the study reported by Baczkowicz *et al*. (2008). Furthermore, the difference on age factor can have influenced our results of correlation, as evidenced in the study of Baczkowicz *et al*. (2008), in which the average age of the participants was 78 years old, whereas in ours it was 68 years old. It must be remembered that, any cognitive, proprioceptive (sensory), muscular strength or motor coordination impairment could result in postural control deficits, and clinical balance assessment tools (such as time, distance performance or COP parameters) can provide some information on a variety of dimensions of postural control deficits (Hughes *et al*., 1996; Mancini & Horak, 2010; Pollock *et al*., 2000). This is further supported by a recent study (Nguyen *et al*., 2012) that suggest clinical functional tests such as 6MWT and laboratory-based measures from COP parameters may capture different aspects of balance and likely complement each other.

Finally, some limitations of this study should be mentioned. The first limitation is that dynamic postural control on force platforms should be used to better determine the relationship with a dynamic functional exercise capacity test with walking activity. Another limitation is that gender factor was not analyzed in this study because the number of male and female in each group was not equal. Finally, an objective assessment of the level of physical activity in daily life of the older adults could help explain the results presented.

Conclusion

The results of this study indicate that older adults with a low functional exercise capacity, based on a sub-maximal walking test (6MWT), also present poor balance performance during a one-leg stance task. This information could be useful for an objective evaluation of functional exercise capacity and balance performance in rehabilitation or exercise programs for older people.

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