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Effects of Age and Task Difficulty on Postural Sway, Variability and Complexity

Abstract

This study aimed to examine the effects of age and the task difficulty on postural sway, variability and complexity. The participants were 90 able-bodied individuals from children (n = 39; age: 5.89 ± 0.94 years), young adults (n = 30; age: 23.23 ± 1.61 years) and older adults (n = 21; age: 64.59 ± 5.24 years) that took part in different balance tasks that were had different levels of cognitive and physical challenges. The main dependent variables were postural sway area, postural variability and postural complexity. The participants stood on a standard force plate for 10 seconds in each task condition, and the centre of pressure displacement was collected at 100 sampling frequency. The results of this study showed that children and older adults, in the more difficult tasks, had greater sway area and complexity and less postural variability. In addition, there was a linear trend in the stability measures as the difficulty of the task was increased. In conclusion, special populations, such as children and older adults, were more sensitive to the balance changes and used active control mechanisms to minimise the risk of losing balance in more challenging conditions.

Keywords: control mechanisms; postural challenges; stability; complexity

Introduction

The ability to control posture is one of the fundamental movement skills in humans during the motor development process. The postural stability that is acquired in early infancy is necessary for performing the activity of daily living (ADL) in later years (Era et al., 2006) and has a crucial role in the prevention of falls in older adults (Gadkaree et al., 2016). The postural stability requires sensory-motor integrations in the nervous system and multi-segment coordination in the active limbs, including head, torso and legs (Błaszczyk & Michalski, 2006; Horak, 2006).

Postural stability refers to the ability to maintain an upright stance and to constantly monitor and adapt to the centre of mass (COM) of the body (Hilbun & Karsai, 2017). One valid and reliable method to assess the postural stability that is preferred to behavioural methods (e.g., Berg Balance Scale) is measuring the postural sway, that is the position of the centre of pressure (COP) within the base of support (Błaszczyk, Hansen, & Lowe, 1993). The position of the COP (e.g., the size of area and shape) that is quantified in the anterior–posterior (AP) and mediolateral (ML) directions suggests the degrees of ability to regain the balance and indicates different postural strategies (Melzer, Benjuya, & Kaplanski, 2004). For example, the ankle strategy is responsible for stability in the AP direction, whereas the hip strategy mainly controls the stability in the ML direction (Winter, 1995).

The COP displacement is not sufficiently sensitive to the postural strategies that are required for prevention of postural instability (Nashner, Shumway-Cook, & Marin, 1983). Some mathematical methods have been proposed to gain an insight into the functionality/adaptability of the motor system in postural stability, and as clinical measures that are sensitive to fall and neuromusculoskeletal diseases. Some of the adaptability measures are time-to-boundary (TtB), COP variability and COP complexity. The COP variability is a postural stability measure that has been used for understanding the control mechanisms that decline due to the ageing process (Howcroft, Lemaire, Kofman, & McIlroy, 2017). For example, lower COP variability in younger adults and decreased COP variability in the more challenging balance tasks have been interpreted as adaptive mechanisms in the nervous system to prevent the loss of balance. This function declines in older adults that show a greater COP variability in balance tasks (Merlo et al., 2012; Van Wegen, Van Emmerik, & Riccio, 2002). COP complexity is another stability measure that indicates the dynamic interactions between and within elements of the motor systems, which give more flexibility to the system to meet the needs of environments (Busa & van Emmerik, 2016). According to the loss of complexity hypothesis, deteriorations in a healthy system arise from a reduced capacity of the system to produce an adaptable set of solutions (Lipsitz & Goldberger, 1992). Hence, the complexity index has been used as a clinical measure in balance tasks and is sensitive to balance declines due to ageing or pain (Duarte & Sternad, 2008; Hilbun, Karsai, & Perry, 2019; Kang et al., 2009).

The quality of postural stability is affected by organismic constraints such as ageing and motor disabilities and environmental constraints such as the type of surface (Amoud et al., 2007). For example, the postural stability in older adults relative to young adults shows more decline in AP and ML directions (Borg, Laxaback, & Bjorkgren, 2013; Merlo et al., 2012). The decline in postural stability is more apparent in the tasks that require bodyweight transfer, such as walking and turning (Nyberg & Gustafson, 1997). These findings could suggest the important interactions between organismic, environment and type of task on postural stability according to the motor control theories (K. Newell, 1986).

The adaptability of the motor system has been studied extensively through increasing the task difficulty by adding physical or cognitive challenges to a postural stability task. The examples of challenges were removing vision (Donker, Roerdink, Greven, & Beek, 2007), standing on one leg (Oliveira et al., 2018), standing on an uneven surface (Gosselin & Fagan, 2015), reducing the base of support (Gebel, Lüder, & Granacher, 2019) and adding a secondary task (Petrigna et al., 2019). Because of the cyclic interactions between organismic, environment and task constraints, the adaptability of different groups of people (e.g., age groups, gender and motor disabilities) might depend on the difficulty of the task. For example, older adults with falls experience showed greater COP variability in the ML direction than non-fallers in the eyes-closed balance task, which suggests a higher risk of fall in environmental conditions with low lights (Howcroft et al., 2017; Piirtola & Era, 2006). In addition, the effects of the task difficulty on stability might depend on the type of stability measure (postural sway, variability or complexity). Kang et al. (2009) showed an increase in COP variability and a decrease in COP complexity in older adults under the cognitive dual-task condition. The differences in the task also were greater in the fallers group relative to non-fallers.

Despite different ways to measure the postural adaptations to the difficulty of the stability tasks through postural sway, variability and complexity, there is not any classification system on the task difficulty that is sensitive to different age groups. For example, in a study on the postural stability in different age groups (20–80+ years), it was shown that by increasing the task difficulty from two legs to one leg stand, the age in which the 50% of participants could complete the task successfully and stand for 30 seconds was 72.5 (Riis et al., 2020). Another hypothetical relationship between postural stability and task difficulty was the U-shaped pattern between age groups and dual-tasking. In fact, the debilitative effects of adding a secondary task during balance (dual-task cost) were greater in children and older adults than younger adults (Ruffieux, Keller, Lauber, & Taube, 2015). However, these studies only used a few stability tasks and cannot be regarded as comprehensive stability task with special attention to the task difficulty. Devising a graded postural stability assessment task could be beneficial for the screening of children and older adults who might have limitations in cognitive processing ability. Furthermore, as was shown in previous studies, the graded postural assessment should collectively consider the motor system adaptive responses and be sensitive to all stability measures such as postural sway, postural variability and complexity.

This study aimed to examine the effects of age and the task difficulty on postural sway, variability and complexity. It was hypothesised that:

- By increasing in the task difficulty, postural sway, variability and complexity will be increased.
- Children will demonstrate greater postural sway, variability and complexity than young and older adults.
- The age effects on postural sway, variability and complexity depend on the task difficulty.

Methods

Participants

Ninety participants from three different age groups including 39 children (5.89 ± 0.94 years), 30 young adults (23.23 ± 1.61 years) and 21 older adults (64.59 ± 5.24 years) were recruited voluntarily for this study. Permission for child participants was sought from their parents or guardians. All participants were healthy and free of any musculoskeletal problems, neurological diseases or sensory/visual problems, only took part in light physical activities and without any experience in sports and the older adults were non-frail according to Frailty Index in Older People (Tocchi, Dixon, Naylor, Jeon, & McCorkle, 2014). The local ethics committee at the university approved all stages of the study.

Procedure

The main variable of this study was the COP, which was measured by a standard force plate (Kistler, UK; L:60 × W:50 × H:5 cm) at 100 Hz sampling frequency. The participants were asked to stand on the force plate whilst they were focusing on an external target that was placed 2 meters away and in front of them. They had to keep their balance for 10 seconds under different conditions: two-leg standing, one leg standing (dominant leg) and two leg standing on an inflatable balance cushion. Each balance task condition was also repeated in simple and dual-task conditions. In the simple condition, they were asked to keep their balance only, whereas, in the dual-task condition, they should perform a cognitive dual-task while keeping their balance. The cognitive dual-task for adults was subtracting three numbers from a randomly given number between 70 and 100. The cognitive task in the children group was backward counting numbers from 30. All tasks were practised once before the actual data collection in the familiarisation phase that was accompanied by verbal instructions and demonstrations. The participants also practised the cognitive task separately before the balance tasks in the familiarisation phase. Each participant completed six 10-s balance tasks with their difficulty determined in this order: (1) two leg-simple, (2) two leg-dual, (3) one leg-simple, (4) one leg-dual, (5) cushion-simple and (6) cushion-dual. Tasks 1 to 6 were theoretically defined as easy to difficult tasks in this study as the rate of postural and cognitive challenges were added systematically by changing the base of support (wide to narrow and uneven). The order of tasks in the six conditions was counterbalanced between participants so that all participants tried the balance tasks in different random orders (e.g. 123456; 231564; 632451, etc.).

Data analysis

The dependent variables of this study were sway area, COP variability and COP complexity. The first typical measure that expresses the total amount of sway for each participant was the sway area that is the COP displacement in both AP and ML directions during the 10-s task. The raw data were filtered at 10 Hz by means of 2nd order Butterworth filter before calculation of postural sway, variability and complexity. The postural sway is the position of the COP relative to the base of support in both AP and ML directions that was calculated by the area of the COP displacement within a 10-s trial. The wider area indicates the greater displacement of the COP during the trial. The COP variability was calculated by the root-mean-square errors (RMSE) of COP in both AP and ML directions. The complexity of the COP time series was quantified using the Multiscale Entropy (MSE) method (Costa, Goldberger, & Peng, 2005). MSE is the degree of irregularity of a time series over multiple timescales. Time series that are highly irregular over a wide range of timescales are considered as more complex time series than the time series that show irregular behaviour at only a single timescale. The method to calculate the MSE is explained in the supplementary material section. A Matlab code (Mathwork 2019) was written to calculate the sway area, RMSE and MSE.

The independent variables of this study were age groups and task difficulty. A 3 (age group) × 6 (task difficulty) within-between (mixed) analysis of variance (ANOVA) with repeated measures on the last factor was used to test the effects of age group and task on each dependent variable. If the ANOVA was significant, the Tukey's post hoc test was used as a follow-up test. We also used eta-squared (η^2) to determine the strength of the relationship between independent and dependent variables after the trend analysis (ANOVA contrast tests). The eta-squared is analogous to the coefficient of variance (R^2) and it ranges between 0 and 1 (Pierce, Block, & Aguinis, 2004). The effect size magnitude was classified to trivial (η^2 = <0.10), small (η^2 = 0.10–0.30), medium (η^2 = 0.30–0.50) and large (η^2 = >0.050) (Cohen, 1992).

Results

The cognitive performance of different groups was calcuated as the number of correct responses during the actual balance tasks. The children's group demonstrated almost the same accuracy (98% ± 1.2) as the adults (99% ± 1.1) and older adults (97% ± 1.3) in different dual-task conditions.

The performance of different age groups in different stability tasks are presented in Figures 1–3 for COP area, COP variability and COP complexity, respectively (see the supplementary material for numerical information of dependent variables).

COP area

There were a significant age and task interactions ($F_{10,435}$ = 3.94, p <0.05) on the COP area. The main effects of the task ($F_{5,435}$ = 19.23, p <0.05) and age groups were also significant ($F_{2,87}$ = 12.18, p <0.05). The results of the post hoc test showed that the children's group in the cushion-dual (68.44), cushion-simple (53.44), one leg-simple (42.74) and older adults in cushion-dual (44.68) and cushion-simple (43.82) had a greater COP area than other groups and conditions. The children also had a significantly greater COP area than other groups. The trend of task difficulty showed a significant linear trend (η^2 = 0.31, $F_{1,87}$ = 38.15, p <0.05) on COP area.

COP variability

Only the effect of task difficulty on the COP_{ML} variability was significant ($F_{10,435}$ = 4.01, p <0.05). The main effect of group and interaction between age and task were not significant (p >0.05). The post hoc results showed that the one leg-dual task (3.09) had significantly greater variability in ML direction than the two-leg stand-simple (2.37) and dual tasks (2.17). The trend of task difficulty showed a significant linear trend (η^2 = 0.05, $F_{1,87}$ = 4.47, p <0.05) on COP_{ML} variability.

There were a significant age and task interaction ($F_{10,435}$ = 2.78, p <0.05) on COP_{AP} variability. The main effects of the task ($F_{5,435}$ = 20.24, p <0.05) and age groups were also significant ($F_{2,87}$ = 12.91, p <0.05). The results of the post hoc test showed that the children's group in the two leg-simple (5.42), two leg-dual (5.44) and young adults in two leg-dual (4.17) had greater COP_{AP} variability than other groups and conditions. The children also had a significantly greater COP_{AP} variability than other groups. The trend of task difficulty showed a significant linear trend (η^2 = 0.31, $F_{1,87}$ = 38.60, p <0.05) on COP_{AP} variability.

COP complexity

There were a significant age and task interaction ($F_{10,435}$ = 1.87, p <0.05) on COP_{ML} complexity. The main effects of the task ($F_{5,435}$ = 23.33, p <0.05) and age groups were also significant ($F_{2,87}$ = 107.3, p <0.05). The results of the post hoc test showed that the children's group in all task conditions had significantly greater COP_{ML} complexity. The older adults also had high COP_{ML} complexity in the cushion-simple, cushion-dual, one leg-simple and one leg-dual. The young adults also had high COP_{ML} complexity in the cushion-simple and cushion-dual. The children also had a significantly greater COP_{ML} complexity than other groups. The trend of task difficulty showed a significant linear trend (η^2 = 0.41, $F_{1,87}$ = 61.27, p <0.05) on COP_{ML} complexity.

The main effects of the task ($F_{5,435}$ = 44.82, p <0.05) and age groups were significant ($F_{2,87}$ = 102.4, p <0.05) on COP_{AP} complexity. The interaction of age and task was not significant. The children had significantly greater COP_{AP} complexity than other groups. The cushion-simple and dual and one leg-simple and dual had greater COP_{AP} complexity than the two-leg standing tasks. The trend of task difficulty showed a significant linear trend (η^2 = 0.56, $F_{1,87}$ = 112.9, p <0.05) on COP_{AP} complexity.

Discussion

The aims of the current study were to examine the effects of age and the task difficulty on postural sway, variability and complexity. Our findings showed that there was a significant and linear positive trend by increasing task difficulty on all stability measures that support our first hypothesis. In addition, children relative to young and older adults had greater postural sway, variability and complexity, whereas there was not a significant difference between young and older adults. Thus, our second hypothesis was supported in this study. The findings also showed that in the majority of stability measures such as sway, COP variability in AP and COP complexity in ML, the effects of age were affected by task difficulty that supported our third hypothesis. More specifically, the postural sway area was greater in children and older adults and in more challenging tasks that required more cognitive attention or perturbations. The increased postural sway also was accompanied by a decrease in COP variability in AP direction and an increase in COP complexity in ML direction in children and older adults in more challenging tasks such as the one-leg stand and cushion stand.
The main findings of this study are explained in the following sections.

Age-related changes in balance are specific to the task difficulty

The dependency of age differences on task difficulty suggests that the age-related differences on the ability to stabilise the posture is specific to the task difficulty and was evident in more challenging postural tasks. We found such interactions in sway area, COP_{AP} variability and COP_{ML} complexity. Previous studies have also shown that the age differences were related to the type of stability tasks (Condron, Hill, & Physio, 2002; Schaefer, Krampe, Lindenberger, & Baltes, 2008). For example, older adults above age 72.5 years, relative to younger age groups, had difficulty to control their balance when the task difficulty was increased from two legs to the one-leg stand (Riis et al., 2020). In addition, the age group difference was apparent in the dual-task condition relative to the simple-task condition (Ruffieux et al., 2015).

The reason for the age differences on the balance task was attributed to a limited attentional capacity in both children and older adults due to the task interference (Boisgontier et al., 2013; Schaefer, 2014). For example, the ability to focus on both the secondary task and the balance task simultaneously deteriorates after 60 years of age (Clapp, Rubens, Sabharwal, & Gazzaley, 2011; Iwasaki & Yamasoba, 2015). Furthermore, in the contexts requiring quick reactions to the sensory environments, children and older adults have difficulty to re-weight the sensory inputs quickly and may lose their balance (Doumas & Krampe, 2010).

The classification of the balance task difficulty in the current study was not limited to cognitive interference; other task constraints, such as reducing the base of support in one leg standing and standing on a balance cushion also have been used that increased the postural challenges. Thus, other control mechanisms such as muscle synergies might be involved that increased postural sway and related control strategies (e.g.. reduced COP variability and increased COP complexity) in children and older adults (Nashner et al., 1983; Wang, Asaka, & Watanabe, 2013). For example, Wang et al. (2013) showed that ageing was associated with diminished multi-muscle synergies between leg and trunk muscles in the anticipatory postural adjustments tasks, such as reactive stepping. Our results (see Figure 4) also supported the U-shape pattern that was suggested for postural stability in different age groups (Ruffieux et al., 2015), but the U-shape pattern could be extended to more than cognitive tasks and be regarded as task difficulty. In other words, increased postural instability in children and older adults relative to younger adults is related to the task difficulty generally and not only the dual-tasking.

The decreased complexity due to ageing was not supported in this study and partially supported our last hypothesis. More specifically, our results showed that older adults were not different from younger adults, and they showed higher complexity in more challenging stability tasks. This finding contradicts with the loss of complexity hypothesis (Lipsitz & Goldberger, 1992) or ageing effects on the complexity–performance relationship (Newell, Vaillancourt, & Sosnoff, 2006). A previous study also showed that movement complexity is not different between young and older adults (Duarte & Sternad, 2008). One plausible explanation is that the level of frailty might be a mediating factor and losing movement complexity is only evident in the frail and pre-frail older adults and not in healthy older adults (Kang et al., 2009). We only recruited healthy older adults and non-frail in this study.

The motor system adaptation is a strategy against losing balance

The motor system is adaptive to postural instability and uses some strategies to minimise the risk of losing balance. The two main strategies that are usually used to minimise the postural oscillation after perturbations are ankle and hip strategies. The former is effective for postural stability in the AP direction, whereas the latter is used in the ML direction (Winter, 1995). The adaptations of the motor system in this study were quantified by COP variability and complexity. The motor system adaptations when the postural stability was destabilised more in the difficult tasks were reductions in the COP variability and increasing the COP complexity. The motor system strategy of reducing the COP variability, and specifically in the more challenging tasks, has been recognised as an effective control mechanism against losing balance (Van Wegen et al., 2002) and has been effective in all age groups despite some evidence that showed older adults had a greater COP variability in balance tasks (Merlo et al., 2012). We found a stronger age and task interaction in the COP_{AP} variability that might indicate the contribution of an active ankle strategy to minimise the forward–backward oscillations in more difficult tasks such as standing on the cushion.

The increased COP complexity was accompanied by increases in the postural sway when the task difficulty was increased (see Figures 1 and 3); this postural strategy was more apparent in the children. The increased complexity is attributed to the dynamic and highly adaptable network of neuromuscular connections that are responsible for controlling the posture (Lipsitz & Goldberger, 1992). This interactive network works at different time scales to stabilise the posture in different environmental conditions. In fact, there are interactions at different levels of movement so that changes at the lower level (e.g., tissues, muscules) have cascading effects on the higher levels (e.g., joints, bones). Due to organismic (e.g., ageing, diseases) and task constraints (e.g., challenging tasks) the network of interactions is strengthened, leading to the increased complexity (Busa & van Emmerik, 2016). It seems that with postural complexity, the young children have highly adaptive capacity to activate the network of interactions in the neuromusculoskeletal system to mitigate the postural perturbations that occurred in the system. In summary, the motor system utilises different strategies to stabilise the posture that, to some extent, depends on the task difficulty. Kang et al. (2009) also showed an increase in COP variability and a decrease in COP complexity in older adults under the cognitive dual-task condition.

The graded balance assessment is sensitive to the postural strategies

The findings of the trend analysis showed that the increased task difficulty was linearly associated with changes in postural stability. The magnitude of effects ranged from trivial (COP_{ML} variability) to medium (sway area, COP_{AP} variability and COP_{ML} complexity), and large (COP_{AP} complexity). The smallest effect size of task difficulty in COP_{ML} variability might suggest that the motor system behaves consistently regardless of the amount of the challenges, due to the nature of the task (physical or cognitive perturbations) in order to minimise the COP fluctuations for postural stability. Therefore, the graded balance assessment, which included different levels of physical and cognitive challenges, was sensitive to the type of postural stability measures and was stronger in COP complexity and might not be effective to be used for COP variability in ML direction. The stability-task difficulty relationship was also reported in previous studies, but the range of tasks was very limited (Riis et al., 2020; Ruffieux et al., 2015). In this study, we examined the effectiveness of a graded assessment system for balance testing that was sensitive to the age differences and the postural adaptive strategies such as variability and complexity. This is the first study that evaluated a range of tasks for assessment of postural stability at different levels. For example, the simple metric is postural sway, which could be easily compared between different populations. At the higher level, the postural strategies could be investigated for a deeper understanding of the postural adaptations due to ageing, development and neuromusculoskeletal problems. As was explained, the COP variability and COP complexity are valid metrics that indicate the motor systems changes due to organismic and environmental constraints (Busa & van Emmerik, 2016), however, the clinical applications of such a graded assessment system should be examined in future studies.

We acknowledge some limitations in this study. The selected balance tests and types of cognitive and physical challenge might have low ecological validity and do not completely represent the ADLs. Future studies can use the tasks that are usually used in our daily living situations, such as reaching for the objects and simple stepping, and then naturally interfere with the attentional capacity. We have not tested the physical fitness factors of the participants that might affect postural stability, such as leg strength. Future studies can investigate postural stability based on the graded assessment system with special focus on the physical fitness components.

In conclusion, the findings of this study showed that postural sway, as a stability measure, is greater in children and older adults and depends on the task difficulty. These age groups use active control strategies such as decreased variability and increased complexity to minimise the postural perturbations due to increased task difficulty. The graded balance assessment system is a sensitive measure to age differences and has potential clinical applications in special populations such as children and older adults. The finding of these studies on the relationship between postural stability and task difficulty in different age groups is a novel that enhances our insights regarding the matching the tasks with the age groups to understand the underlying mechanisms that are changed due to natural motor development processes such as variability and complexity.

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Supplementary information:

MSE analysis

The MSE analysis consists of three steps: (1) coarse-graining the original time series to derive multiple signals, each of which captures the system dynamics on a given scale; (2) calculating a Sample entropy (SampEn) suitable for finite time series and (3) integrating the entropy values over a predefined range of scales to obtain an index of complexity (C_I). SampEn quantifies the likelihood that if a vector with *m* data points matches, within a tolerance *r*, a template of the same length, then the vector and the template will still match when their length increases from *m* to *m + 1* data points. The MSE curve is obtained by plotting SampEn for each coarse-grained time series (ordinate) as a function of scale. The C_I is the area under the MSE curve. The length of the original time series, *N*, determines the largest scale factor, *n*, analysed (Costa et al., 2005). In this study, we used n = 10, m = 2 and r = 20% of the standard deviation of the original signal. The high C_I, indicate high complexity and vice versa.

Numerical reports

	Two leg-simple	Two leg-dual	One leg-simple	One leg-dual	Cushion-simple	Cushion-dual
Area						
Children	21.16 ± 10.71	23.43 ± 9.71	42.74 ± 0.09	34.73 ± 16.98	53.44 ± 17.3	68.47 ± 12.52
Young adults	9.93 ± 3.7	24.4 ± 17.9	16.22 ± 11.66	12.46 ± 6.24	35.56 ± 14.7	29.23 ± 15.5
Older adults	34.37 ± 7.74	11.86 ± 6.53	18.11 ± 12.16	18.69 ± 8.34	43.82 ± 23.64	44.68 ± 27.42
RMS-ML						
Children	2.04 ± 0.9	2.05 ± 0.87	2.77 ± 0.98	3.19 ± 1.22	2.94 ± 1.14	2.89 ± 1.22
Young adults	2.27 ± 0.97	2.76 ± 3.02	2.75 ± 1.78	3.46 ± 1.94	2.67 ± 1.29	2.61 ± 1.28
Older adults	2.81 ± 3.2	1.68 ± 0.83	2.66 ± 0.85	2.62 ± 0.89	2.89 ± 1.58	2.25 ± 0.85
RMS-AP						
Children	5.42 ± 2.62	5.44 ± 2.23	3.41 ± 1.81	3.34 ± 1.72	3.25 ± 1.02	3 ± 1.2
Young adults	3.37 ± 1.54	4.17 ± 2.03	2.76 ± 1.4	2.97 ± 1.64	2.67 ± 0.95	2.37 ± 0.91
Older adults	2.98 ± 1.75	3.52 ± 2.12	2.48 ± 1.27	2.43 ± 1.17	2.89 ± 1.18	2.32 ± 0.96
MSE-ML						
Children	13.54 ± 1.9	13.77 ± 1.9	15.12 ± 2.04	15.27 ± 1.9	15.58 ± 1.95	16.25 ± 2.56
Young adults	8.08 ± 2.29	7.46 ± 2.7	9.66 ± 3.2	8.86 ± 2.8	9.85 ± 2.2	9.92 ± 2.2
Older adults	9.1 ± 3.69	8.33 ± 2.99	9.91 ± 2.18	10.74 ± 2	10.05 ± 2.61	9.84 ± 2.36
MSE-AP						
Children	10.75 ± 1.8	10.98 ± 1.77	12.93 ± 2.01	12.85 ± 2.29	13.39 ± 2.52	14.07 ± 2.99
Young adults	5.43 ± 2.22	5.36 ± 2.4	8.05 ± 3.31	7.23 ± 2.1	8.09 ± 1.63	8.69 ± 1.7
Older adults	6.48 ± 3.51	5.63 ± 2.59	7.58 ± 2.6	8.14 ± 2.34	8.54 ± 2.19	9 ± 2.57

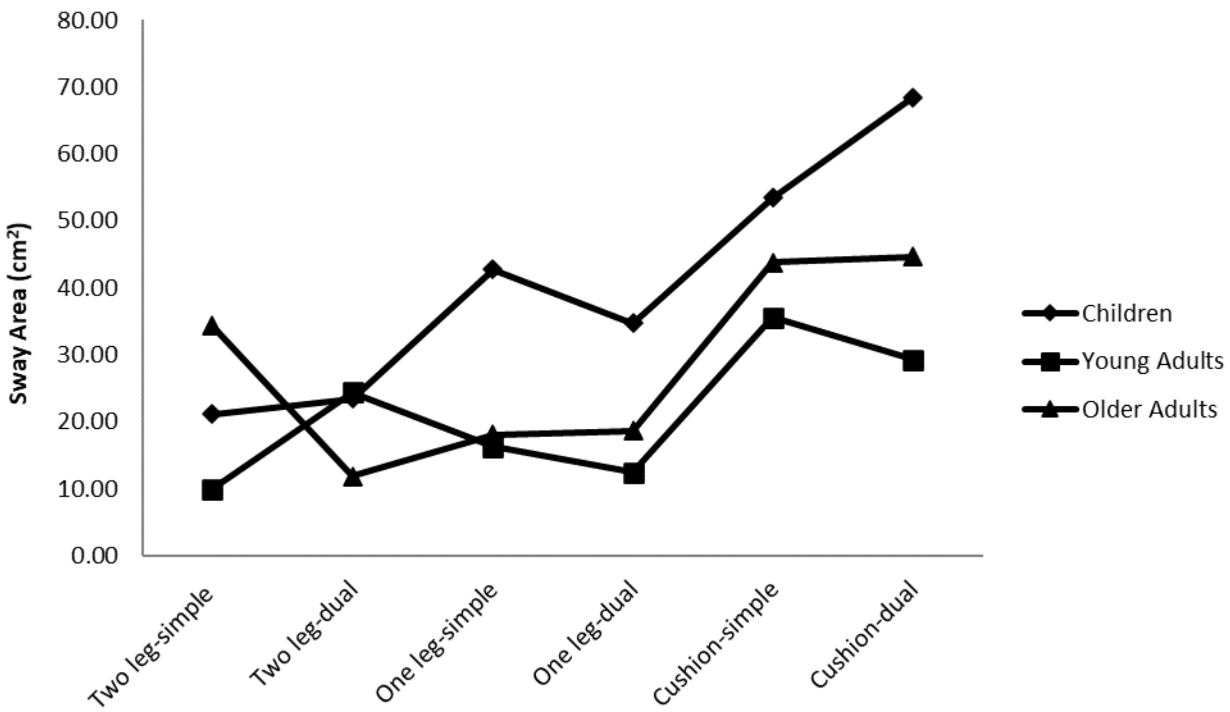
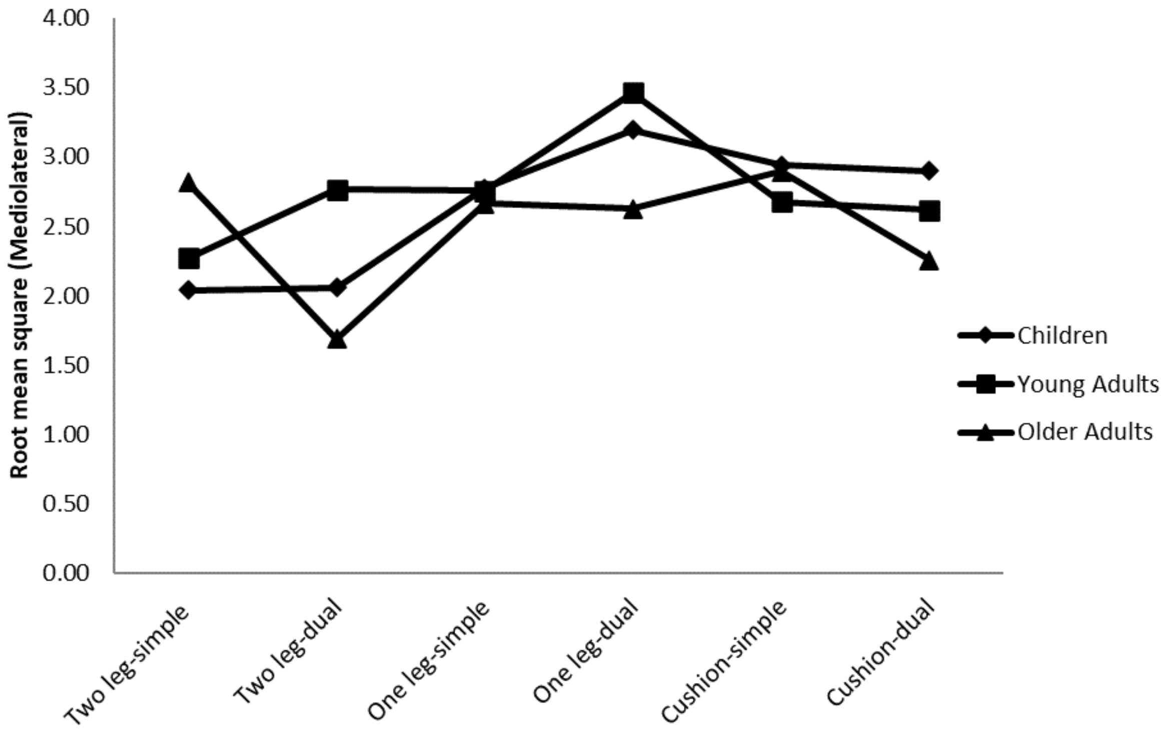

80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Sway Area (cm²)
Two leg-simple
Two leg-dual
One leg-simple
One leg-dual
Cushion-simple
Cushion-dual
Children
Young Adults
Older Adults

Figure 1- COP area in different age groups and stability tasks.



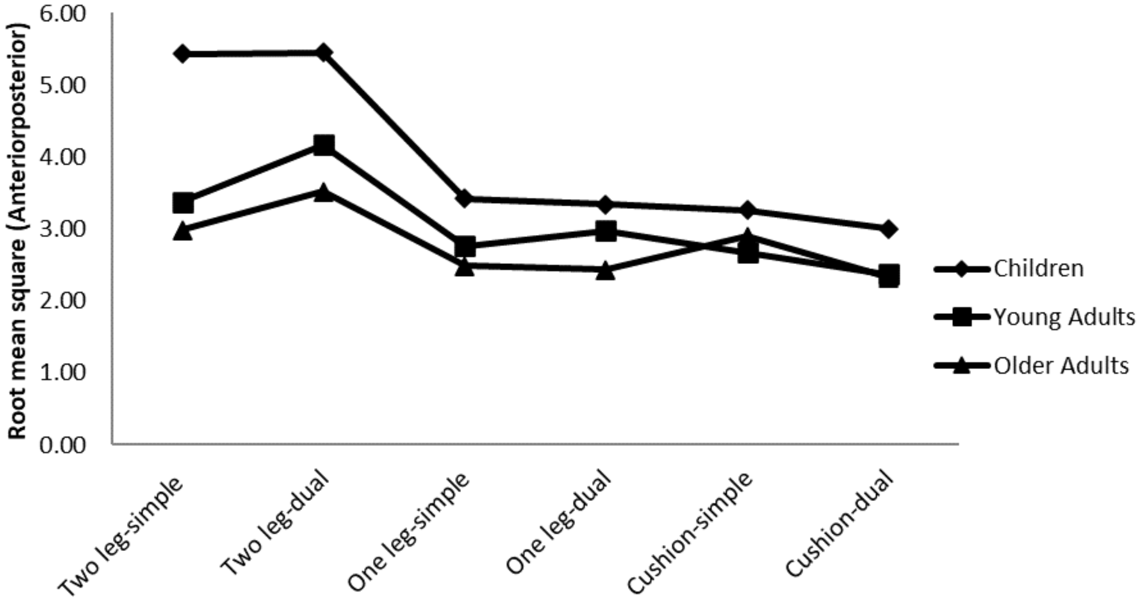
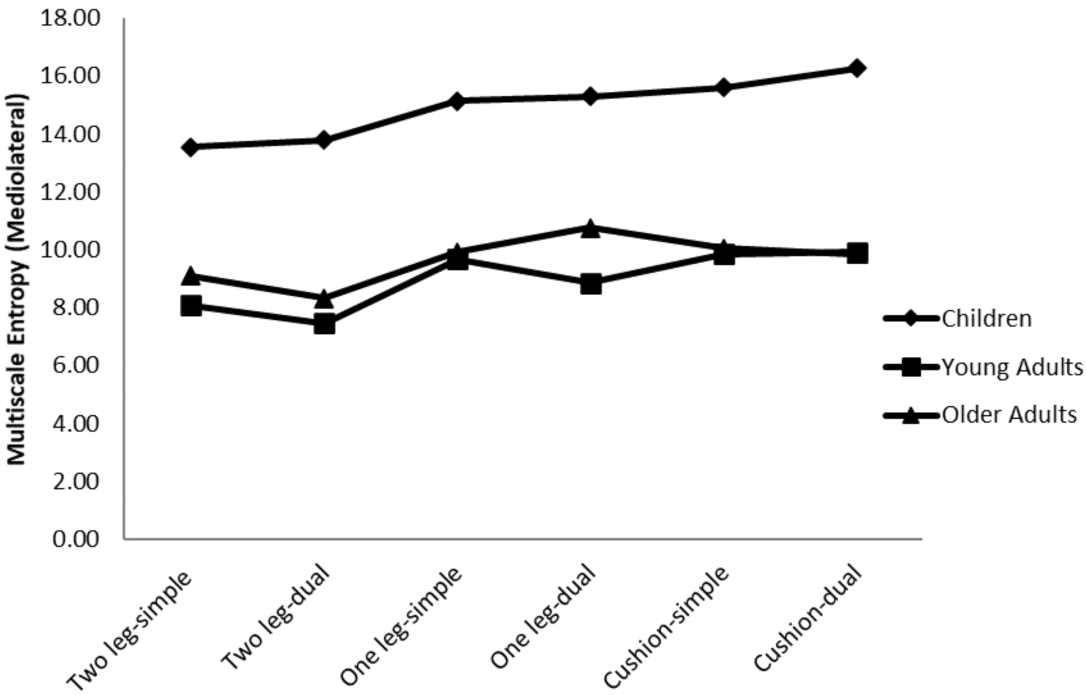


Figure 2- COP variability in different age groups and stability tasks.



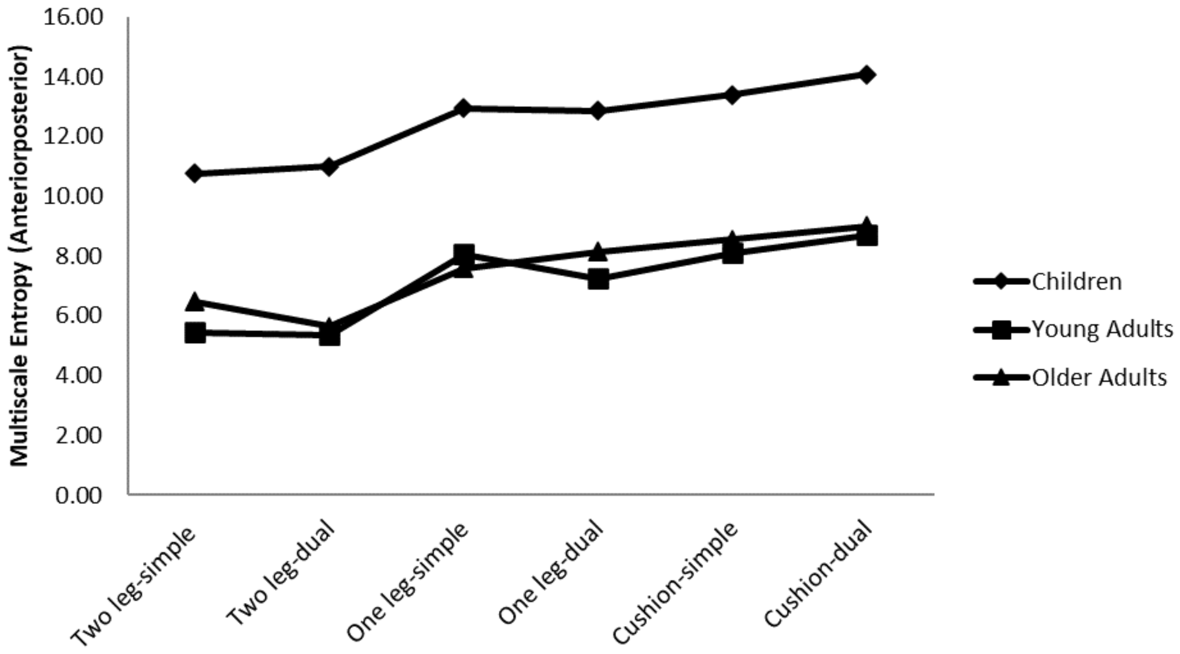


Figure 3- COP complexity in different age groups and stability tasks.

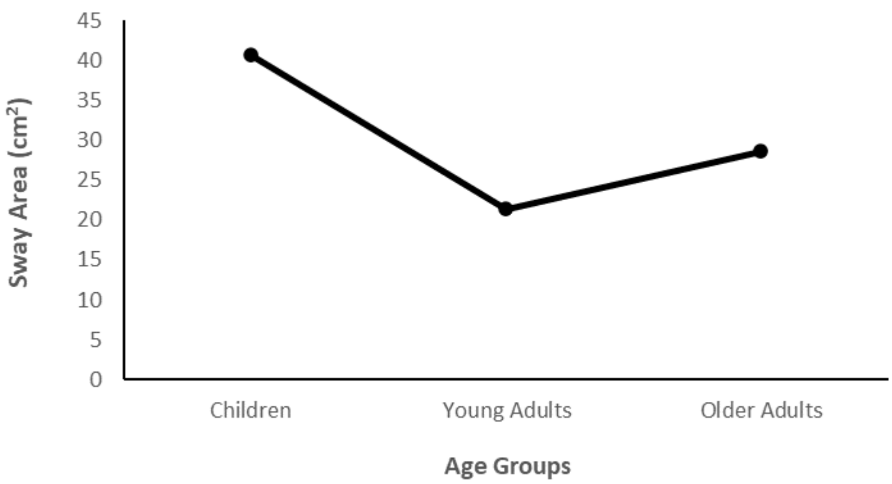


Figure 4- The pattern of age effects on postural sway.