Anticipatory Postural Adjustments in the Frail Older Adults When Postural Stability is Manipulated

Bianca Callegari (callegari@ufpa.br)
Universidade Federal do Para https://orcid.org/0000-0001-9151-3896
Alexandre Kubicki
Universite de Bourgogne
Ghislain Saunier
Universidade Federal do Para
Manuela Brito Duarte
Universidade Federal do Para
Gizele Cristina da Silva Almeida
Universidade Federal do Para
Bruno Mazziotti Oliveira Alves
Universidade Cidade de Sao Paulo
César Ferreira Amorim
Florida International University North Miami Campus Official Bookstore
Daniela Rosa Garcez
Universidade Federal do Para
Givago da Silva Souza
Universidade Federal do Para
France Mourey
Universite de Bourgogne

Research article

Keywords: Standing, Sitting, Anticipatory postural adjutments, Frailty, Aging, Stability, Posture, Surface electromyography

Posted Date: November 20th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-107332/v1

Abstract

Background: Anticipatory Postural Adjustments (APAs) are importantly affected by age and may represent restrictions for functional independence. Previous studies have already highlighted some delayed APAs during self-generated rapid arm movements in aged adults, as well as in cases of non-optimal aging, such as in frail older adults. In young (Y) adults, it was also previously demonstrated that changing the postural stability (i.e. seated vs. upright posture) affects the motor planning and APAs. Considering the clinical relevance of these balance tasks in the functional independence in frail older adults (FOA), and the lack of literature about this task, the present study aimed to investigate the impact of these different conditions of postural stability on APAs in FOA.

Methods: In this paper, participants executed an arm-pointing task to reach a diode immediately after it turned on, under different conditions of stability (seated with and without feet support and in upright posture).

Results: The main finding of this study is that the adopted posture and body stabilization in FOA did not reflect differences in APAs or kinematic features. In addition, they did not present an optimal APA, since postural muscles are recruited simultaneously with the deltoid.

Conclusion: Thus, FOA seem to use a single non-optimal motor plan to assist the task performance and counterbalance perturbation forces, in which they present similar APAs and do not modify their kinematics features according to the body stabilization (i.e. less challenging task present greater finger velocity).

Background

During arm movements, self-induced body perturbations are expected by the central nervous system (CNS) and anticipatory strategies are generated[1, 2]both to counteract these perturbations and maintain dynamic balance but also to create necessary momentums to initiate movements toward the target[3–5].These strategies are known as anticipatory postural adjustments (APAs) and are programmed as a feedforward control mechanism, consisting in changes in the activity of postural muscles, 100 to 150 ms prior to the focal muscle[1].

APAs are importantly affected by age[6–8]and may represent an important restriction for functional independence in older adults. It was previously described that the amplitude of APAs are comparable between young and older adult, but aged adults have delayed APAs (even later than the onset of prime mover muscles)[6, 9–11]. APAs investigation including pathological aging (frailty) in comparison with normal aging are rare and mostly focused on the Center of Pressure (COP) displacement[12, 13]. Frail older adults (FOA) present slowed down reaching movements and APAs were delayed and reduced[12, 14]. The posture adopted while performing various types of pointing movements also affect APAs behavior[15, 16]. Recently, we have demonstrated that when the postural stability is manipulated, young adults modify their motor planning, changing both the focal movement and the APA features. We modified the degrees of postural stability, using two seated postures (with and without feet support) and a standing posture while subjects performed an arm pointing task. We found an increase of the reaction time and movement duration when the body was less stabilized (standing posture), which reflects a more challenging task and complex motor plan. APAs were present even with the body stable (seated with feet support), what suggests an additional APA role, independently of the postural stability, beyond the feedforward control of the other body parts (i.e., to accelerate, or to facilitate the pointing movement)[4]. Therefore, young adults adopt APAs to improve the task performance and kinematic features even with stabilized body.

Accordingly, the present study is the first to investigate if the postural stability manipulation (standing and sitting) affects APAs in FOA subjects in the same manner as it was previously demonstrated for healthy subject. FOA are people with increased risk of fall[12, 14], which is linked, among other things, with the balance function including the management of self-paced perturbations [17]. It is then interesting to investigate their APA programing, manipulating de body stability, to understand how this population control of the balance in advance to a predictive perturbation. To address this issue, we utilized an arm-pointing task paradigm where we instructed the participants to execute the task to reach a diode immediately after it turned on, under different conditions of stability. We evaluated the sequence of muscle activation adopted by FOA, among the different positions and body stability context.

We hypothesized that FOA would conserve the same pattern of muscle activation (i.e. sequence of activation) among the different positions, maintaining the motor plans for the task execution and the body balance during the movement performed in different equilibrium context. However, we expect that under stable posture (i.e. seated with feet support) they present less, or no anticipation in the onset of the postural muscles, related to the focal muscle (deltoids).

Methods

Subjects

A total of 10 FOA (mean ± standard deviation [SD]: 72.8 ± 1.2years; 167.2 ± 6.3 cm; 68.3 ± 6.5 kg) participated in the present study after giving their written consent. Participants were all males with no vision, neurological or muscle disorders, and right-handed. FOA were submitted to a geriatrician diagnosis according to the clinical features of this syndrome [18]. Frailty was defined as a clinical syndrome in which three or more of the following criteria were present: unintentional weight loss, self-reported exhaustion, weakness, slow walking speed, and low physical activity[18]. The exclusion criteria were suffering from any neurological syndrome, or peripheral neuropathy, having recent orthopedic or traumatic injuries (1 year) and/ or cognitive impairments with loss in intellectual capacity that compromised the understanding and execution of the task. The study was approved by the Ethics Committee XXX (report #1384907). The subjects were informed about the procedures and have the written informed consent form agreeing with their participation. All experiments were performed in accordance with the tenets of Helsinki declaration.

Experimental set up and Protocol

Three postures were employed aim manipulate the postural stability: (i) Barefooted Upright position; (ii) seated with their feet on a force platform (Sit Sup); and (iii) seated without their feet support (SitUnsup). For seated postures, subjects kept 30% of their thigh length in contact to the seat (i.e. from the head of their femurs to the intra-articular line of their knees). We adjusted the height of the seat to make sure their feet would not touch the ground in SitUnsup posture and to standardize the ground reaction force (Fz) in Sit Sup posture (Fig. 1).

Subjects were instructed to point to a central diode attached to a horizontal bar fixed in their front, with their index fingers, as soon as it turned on. Protocol followed previous recommendation[4]. Subjects carried out ten-trial randomized blocks in each posture, with a 5-minute interval between them.

Kinematic and electromyographic recording

Eight reflective markers were attached to their right upper and lower main joints (i.e. index, wrist, elbow, shoulder, fifth metatarsal, ankle, knee, and hip) and kinematic data was recorded using a three-dimensional motion analysis system (Simi Motion) by using three cameras at a 120 Hz sampling frequency.

The study assessed surface electromyographic (EMG) data, from their dominant-side leg muscles using disposable self-adhesive electrodes (Medtrace® 200 – Kendall, Canada): tibialis anterior (TA), soleus (SOL), rectus femoris (RF), semitendinosus (ST) and Deltoids anterior (DEL). Lower limb muscles were chosen due to its role in the ankle and knee control, especially during sitting without feet support and previously demonstrated to be related to APAs [4]. Such data were obtained by using two EMG equipment (EMG System ®, EMG System do Brasil, Brazil), using a sampling rate of 2 KHzper channel and a pass-band ranging from 20 to 500 Hz. EMG signals were amplified (4.000) and digitized with a 16-bit resolution. Instrumentation and sensor location followed the international guidelines of the Surface Electromyography for Non Invasive Assessment of Muscles [19].

Data analysis

All kinematic and EMG analysis were previously described in by the authors[4] and are summarized bellow.

Kinematic characteristics

Kinematic data referring to axis x, y and z were filtered by a 10-Hz low-pass, second order Butterworth filter. Tzero was defined on the finger trajectory and corresponded as the moment when the tangential velocity of this marker reached 5% of the maximum velocity [5]. The total movement duration (MD) was considered the time interval between the Tzero moment and the trial end, when the index finger stopped pointing to the LED. Movement velocity (MV) and reaction time (RT) were also evaluated. The differences of index tangential velocity profile in function of participant postures were also calculated. To do so, we considered the fraction of movement time required to reach peak velocity, which is known as the ratio of acceleration time to total movement duration (ACC/MD).

We also evaluated the ankle displacement (AD) by measuring the linear displacement of the ankle marker in the antero-posterior plane. This was measured to analyze the temporal organization and verify if there is any kinematic strategy of anticipation of lower limb motion related to the finger.

EMG data

By using MatLab programs, we synchronized and analyzed data off-line. Every EMG signals were rectified (RMS) and filtered by a 100-Hz low-pass, second-order Butterworth filter. Individual trials were displayed off-line on a monitor screen.

All data were aligned related to Tzero and EMG signals were integrated from − 150 with respect to Tzero (∫EMG150) in order to quantify anticipatory changes in muscle activity prior movement – what was later corrected for background activity, defined as the integral from − 500 to -450 ms with respect to Tzero (∫EMG50) as the following:

∫EMG = ∫EMG 150- 3*∫EMG 50

To allow comparisons, integrated EMG (EMGi) data were normalized by the peak muscle activity across all postures within an experiment for each muscle for each subject [15, 20]. As a result of the normalization all EMGi data are within the range from + 100 to -100, with the positive values indicating an activation of the muscle and negative values indicating inhibition. Finally, we calculated the average of data obtained in each subject’s trials within a series of postures.

We detected muscle latency in a time window ranging from − 450 ms to + 200 ms in relation to Tzero by using a combination of computer algorithm and visual inspection of the averaged trials. Timing of activation or deactivation for a specific muscle was considered the moment after which, for at least 50 ms, its EMG amplitude was greater (activation) or smaller (deactivation) than the mean of its baseline value, measured from − 500 to -450 ms, plus or minus 2 SD [15, 20]. After having the onset of each trial, we calculated the timing of each muscle activation with reference to DEL onset[12]. This EMG synergy allowed us to clearly identify the muscles involved mainly in APA within each group, without misinterpreting factors associated with electro-mechanical delays.

Statistical analysis

Statistical procedures were carried out in RStudio (R version 3.3.2, R Core Team (2016). Shapiro-Wilk test was performed to test the data normality. A repeated-measures ANOVA was performed with body posture (sitting with support, sitting without support and standing) as factor. Post-hoc analyses were done with Tukey HSD tests when necessary. For all these statistical treatments, the significance level was set at $p < 0.05$.

Results

Kinematic characteristics

Table 1 summarizes kinematic characteristics. Finger displacement showed a similar RT, MD, MV and ACC/MD among the three postures in FOA, revealing that temporal parameters of upper-limb movements were not affected by postural conditions, and their spatial features remained similar.

Table 1
Comparison between Kinematic parameters.

Posture	Reaction Time (ms)	Movement duration (ms)	Velocity (m/s)	Acceleration time/ Movement duration
SitSup	532.87 (44.51)	747.84(39.85)	3.47(0.5)	0.36(0.04)
SitUnsup	568.65 (44.34)	772.00(65.28)	3.62(0.4)	0.37(0.04)
Up	571.41 (3.13)	760.99(25.68)	3.08(0.3)	0.36(0.03)
Mean values kinematic parameters. Values are given as mean (SD). Postures: Sit Unsup (Sit without support); Sit Sup (Sit with feet support) and Up (Upright position).				

Muscle Activation Timing between postures

Simultaneously activation was observed between all the postural muscles recorded in FOA (Fig. 2). In addition, no organized order between proximal and distal lower limb muscles showed up and posture effect was observed on muscles Onset.

Muscle Activation Magnitude in the APAs period between postures

Table 2 summarizes normalized integrated electromyographic activity (EMGi). SOL, TA and RF showed similar behavior and presented no relevant posture effects among the three postures. ST showed a main posture effect [$F(2, 2.54) = 0.016$] and the post-hoc test showed the highest APA integral in the SitUnsup posture, compared to the others ($p < 0.05$).

Table 2
Comparison between normalized integrated electromyographic activity (EMGi).

Posture	TA(%)	SOL(%)	RF(%)	ST(%)
SitSup	14.59(10.19)	-8.14 (3.20)	11.99(5.71)	8.84 (5.95)
SitUnsup	18.51 (27.891)	-6.04(3.76)	10.45 (5.03)	31.53 (13.99)*
Up	13.01(7.96)	-7.75 (3.73)	7.98 (4.19)	9.83 (4.76)

Normalized integrated electromyographic activity (EMGi) of muscles Mean values integral parameters (%). Values are given as mean (SD). * p < 0.005 difference between Sit UnSup and the two other postures.

Temporal organization of finger and knee displacements

Figure 3 displays the ankle forward/backward trajectory, relating it to upward finger displacement. We observed that subjects sat with no foot support adopted a backward displacement of their ankles after finger displacement and had no anticipation related to the focal movement. It suggests a synergic pattern of lower-upper limbs that follows the movement of the arms with no APAs.

Discussion

In this paper, we aimed to investigate the APAs features in FOA subjects when the condition of stability is modified by the adopted posture to realize a pointing task. Our main finding showed that the manipulation of the equilibrium context did not reflect modifications for the subjects, neither in the kinematic features to execute the task, nor in the motor plans (i.e. APAs). Besides the subjects conserved the same pattern of muscle activation among the different positions, no differences showed up in APAs under different equilibrium context. Indeed, FOA presented no anticipation in the onset of the postural muscles and similar kinematic performance in the task execution, what represents inefficient APAs .

Kinematic features of the upper limb

Kinematic data revealed that FOA faced similar difficulty to perform the pointing task in the different postures, since no increasing in RT, MD, MV or modification in the velocity profile was observed. These parameters are classically described as indicators of higher index of task difficulty when RT and MD are increased and ACC/MD decreased[21]. These results mean that no adaptation related to the postural stability was adopted by FOA to facilitate the task. This behavior is interesting since it was previously demonstrated that, in healthy subjects, kinematic features are commonly modulated according to their stability constraint. In the literature, healthy adults presented, higher RT and MD and longer deceleration duration of the pointing movement when adopting the less stable posture [4]. It seems that for healthy adults, equilibrium constraints were considered to plan the movement and provoked greater difficulty to plan the task (i.e. smaller peak of velocity), acting as a subtask (balance). In our paper, FOA seemed to have greater difficulty, no matter the stability manipulation, and no differences regarding the stability were taken into account to plan the task.

Muscles activation features

Our results support the hypothesis that FOA conserved the same motor programming among the different positions, as the CNS was more focused on the accuracy and execution of the task than in the postural preparation. As a consequence, they presented a global activation, with almost no selectivity, and postural muscles started activating synchronized to DEL. Contrary to what was previously reported in healthy subjects, no APAs were observed independently of the posture adopted and no specific order of activation between the proximal and distal lower limb muscles could be described. In young adults, previous results demonstrated that an unstable posture (i.e. Upright position) was associated with APAs in a different pattern compared to sitting posture. Distal leg muscles (SOL and TA) followed the proximal thigh muscles (ST and RF) in Up posture was described in this population while a reverse order showed up under seated posture. This may be attributed to the pelvis stabilization in seated postural chain, where ST acts as knee flexor instead of hip extensor. Indeed, a simultaneous upward finger (during the pointing task) and forward ankle displacement was previously demonstrated in healthy young and it was proposed as a strategy to facilitate the movement [4]. Considering this, we may say that FOA have lost this programing ability, what could be demonstrated by the kinematic and EMG data. In fact, we observed that no muscle was affected by the posture stability and no strategy of simultaneous or anticipated upward finger (arm) and forward ankle displacement showed up. These remarks may explain the less efficient kinematic profile adopted by this population no matter the posture stability.

We observed that distal muscles presented activation of TA and deactivation of SOL during APA interval, as previous described by Fautrelle et al [22], while the proximal muscles, RF and ST activated. However, the magnitude of this activation/deactivation was only directly affected by the postural stability in ST. Higher APAs magnitude were previously demonstrated in healthy subjects under more unstable constraints[4]. In FOA, however, only ST suffered a postural effect whit higher EMGi in SitUnsup posture when compared to both Up and SitSup postures. This may be related to the backward ankle displacement, as a reactive event to the beginning of upper limb the movement.

In summary, contrarily to previously described in healthy subjects, who presented different APAs patterns under different stability levels, in FOA the adopted posture and body stabilization did not reflect differences in APAs or kinematic features.

Our study has a potential limitation. When we calculated the activation rate for each muscle in each posture (which corresponded to the percentage of trials showing significant muscle activation), FOA presented an average of only 45% of trials with burst (i.e. onset in APA period). This average means that APAs was not present in the majority of trials and one can speculate about the consistence of data. On the other hand, we believe that this strongly reinforce the lack and inefficiency in FOA to adopt anticipatory strategies when the body is destabilized.

Understanding the deficits of APAs and its consequences on postural control in FOA population is important for clinical implications in daily living activities management and in rehabilitation programs as aged patients usually fall when moving (dynamic equilibrium) rather than during orthostatic equilibrium.

Conclusion

The inefficient postural adjustments we found illustrate a decrease in the predictive abilities that occur with pathological aging. The frail older adults, as well as less efficient to perform hand movement, may be less precise to predict the disturbance associated with it and to initiate postural compensations before the arm begins to move. The results of this study are consistent with this interpretation. Considering this, further studies may investigate how specific training could improve postural stability in FOA patients.

Abbreviations

Acceleration time to total movement duration (ACC/MD)

Ankle displacement (AD)

Anticipatory Postural Adjustments (APAs)

Center of Pressure (COP)

Central nervous system (CNS)

Deltoids anterior (DEL)

Electromyographic (EMG)

Frail older adults (FOA)

Integrated EMG (EMGi)

Movement duration (MD)

Movement velocity (MV)

Reaction force (Fz)

Reaction time (RT)

Rectus femoris (RF)

Root Mean Square (RMS)

Semitendinosus (ST)

Sitting with Support (Sit Sup)

Sitting without Support (SitUnsup)

Soleus (SOL)

Standard deviation (SD)

Tibialis anterior (TA)

Upright (Up)

Declarations

Ethics approval and consent to participate

The Federal University of Pará granted Ethical approval to carry out the study within its facilities (Ethical Application report #1384907). The subjects gave written informed consent form agreeing with their participation. All experiments were performed in accordance with the tenets of Helsinki declaration

Consent for publication

Not Applicable

Availability of data and material

Data available as supplementary files

Competing interests

The author(s) declare no competing interests.

Funding:

This research was supported by the following grants: Pará Amazon Research Support Foundation (FAPESPA) grant number #180/2012; and Coordination for the Improvement of Higher Education Personnel (CAPES) / COFECUB research grant number #819-14. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Author Contributions

Conceived and designed the experiments: GS, BC, FM.

Performed the experiments: BC, MBD, DRG, GCSA.

Analyzed the data: AK, BC, CFA, GSS.

Contributed with materials and analysis tools: BC, BMOA, CFA.

Wrote the paper: AK, BC, GS, BMOA, FM.

All authors have read and approved the manuscript: AK, BC, GS, MBD, GCSA, CFA, BMOA, DRG, FM and GSS”

Acknowledgments

We thank Bruno Giovanni Afonso da Silva for the development of figure 1.

References

1. Massion J (1992) Movement, posture and equilibrium: Interaction and coordination. Prog Neurobiol 38:35–56. https://doi.org/10.1016/0301-0082(92)90034-C
2. Wolpert DM, Flanagan JR (2001) Motor prediction. Curr Biol 11:R729–R732. https://doi.org/10.1016/S0960-9822(01)00432-8
3. Bouisset S, Zattara M (1987) Biomechanical study of the programming of anticipatory postural adjustments associated with voluntary movement. J Biomech 20:735–742. https://doi.org/10.1016/0021-9290(87)90052-2
4. Callegari B, Saunier G, Duarte MB, et al (2018) Anticipatory postural adjustments and kinematic arm features when postural stability is manipulated. PeerJ 2018:. https://doi.org/10.7717/peerj.4309
5. Bertucco M, Cesari P (2010) Does movement planning follow Fitts' law? Scaling anticipatory postural adjustments with movement speed and accuracy. Neuroscience 171:205–213. https://doi.org/10.1016/j.neuroscience.2010.08.023
6. Woollacott MH (1993) Age-Related Changes in Posture and Movement. Journals Gerontol 48:56–60
7. Bleuse S, Cassim F, Blatt J-L, et al (2006) Effect of age on anticipatory postural adjustments in unilateral arm movement. Gait Posture 24:203–210. https://doi.org/10.1016/j.gaitpost.2005.09.001
8. Kanekar N, Aruin AS, Kanekar, N; Aruin A (2014) The effect of aging on anticipatory postural control. Exp brain Res 232:1127–1136. https://doi.org/10.1007/s00221-014-3822-3.The
9. Woollacott MH (1988) Age-related changes in anticipatory postural adjustments associated with arm movements. J Gerontol Med Sci 43:M205–M213
10. Inglin B, M. W (1988) Age-related changes in anticipatory postural adjustments associated with arm movements. J Gerontol 43:105–113
11. Yiou E, Kanekar, N; Aruin A, Yiou E, et al (2017) Adaptability of anticipatory postural adjustments associated with voluntary movement. Front Hum Neurosci 11:75. https://doi.org/10.3389/fnhum.2017.00087
12. Kubicki A, Bonnetblanc F, Petrement G, et al (2012) Delayed postural control during self-generated perturbations in the frail older adults. Clin Interv Aging 7:65–75. https://doi.org/10.2147/CIA.S28352

13. Davis DHJ, Rockwood MRH, Mitnitski AB, Rockwood K (2011) Impairments in mobility and balance in relation to frailty. Arch Gerontol Geriatr 53:79–83. https://doi.org/10.1016/j.archger.2010.06.013
14. Kubicki A, Bonnetblanc F, Petrement G, Mourey F (2014) Motor-prediction improvements after virtual rehabilitation in geriatrics: Frail patients reveal different learning curves for movement and postural control. Neurophysiol Clin Neurophysiol 44:109–118. https://doi.org/10.1016/j.neucli.2013.10.128
15. Aruin A, Shiratori T (2003) Anticipatory postural adjustments while sitting: The effects of different leg supports. Exp Brain Res 151:46–53. https://doi.org/10.1007/s00221-003-1456-y
16. Yoshida S, Nakazawa K, Shimizu E, Shimoyama I (2008) Anticipatory postural adjustments modify the movement-related potentials of upper extremity voluntary movement. Gait Posture 27:97–102. https://doi.org/10.1016/j.gaitpost.2007.02.006
17. Robinovitch SN, Feldman F, Yang Y (2013) Erratam: Video capture of the circumstances of falls in elderly people residing in long-term care: An observational study (Lancet (2013) 381 (47-54)). Lancet
18. Fried LP, Tangen CM, Walston J, et al (2001) Frailty in Older AdultsEvidence for a Phenotype. Journals Gerontol Ser A 56:M146–M157. https://doi.org/10.1093/gerona/56.3.M146
19. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G (2000) Development of recommendations for SEMG sensors and sensor placement procedures. J Electromyogr Kinesiol 10:361–374. https://doi.org/10.1016/S1050-6411(00)00027-4
20. Santos MJ, Kanekar N, Aruin AS (2010) The role of anticipatory postural adjustments in compensatory control of posture: 1. Electromyographic analysis. J Electromyogr Kinesiol 20:388–397. https://doi.org/10.1016/j.jelekin.2009.06.006
21. Berret B, Bonnetblanc F, Papaxanthis C, Pozzo T (2009) Modular control of pointing beyond arm's length. J Neurosci 29:191–205. https://doi.org/10.1523/JNEUROSCI.3426-08.2009
22. Fautrelle L, Prablanc C, Berret B, et al (2010) Pointing to double-step visual stimuli from a standing position: very short latency (express) corrections are observed in upper and lower limbs and may not require cortical involvement. Neuroscience 169:697–705. https://doi.org/10.1016/j.neuroscience.2010.05.014

Figures

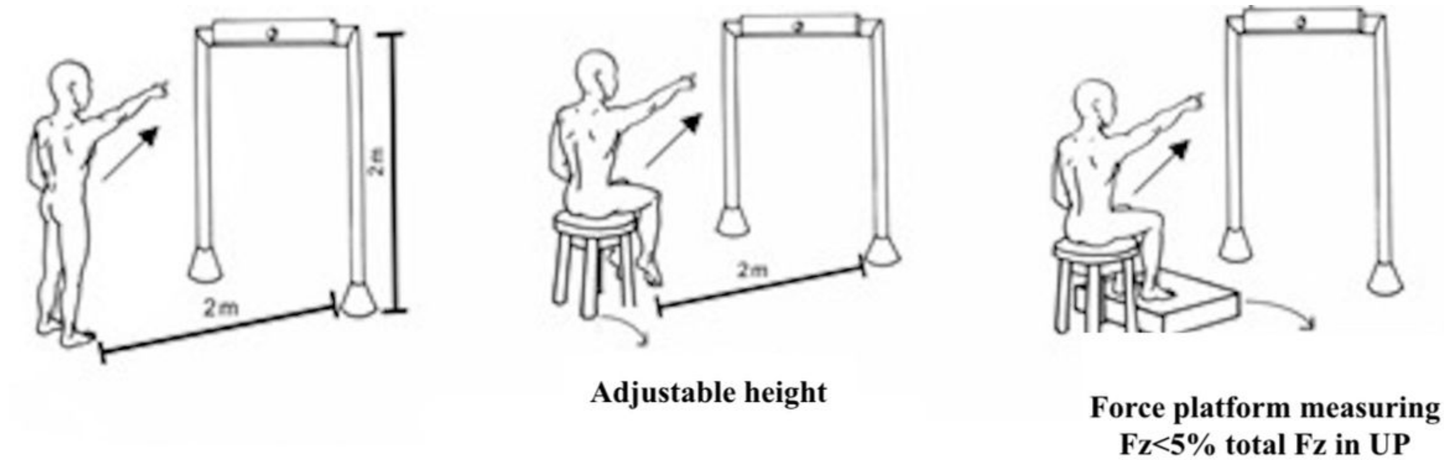

Figure 1

Experimental pointing task. View of experimental set-up for the task displaying a subject in final posture and the diode of the bar, placed precisely in front of each subject's right shoulder. Participants were asked to point their index finger to the diode, as soon as it turned on. We thank Bruno Giovanni Afonso da Silva for drawing the figure.

Figure 1

Experimental pointing task. View of experimental set-up for the task displaying a subject in final posture and the diode of the bar, placed precisely in front of each subject's right shoulder. Participants were asked to point their index finger to the diode, as soon as it turned on. We thank Bruno Giovanni Afonso da Silva for drawing the figure.

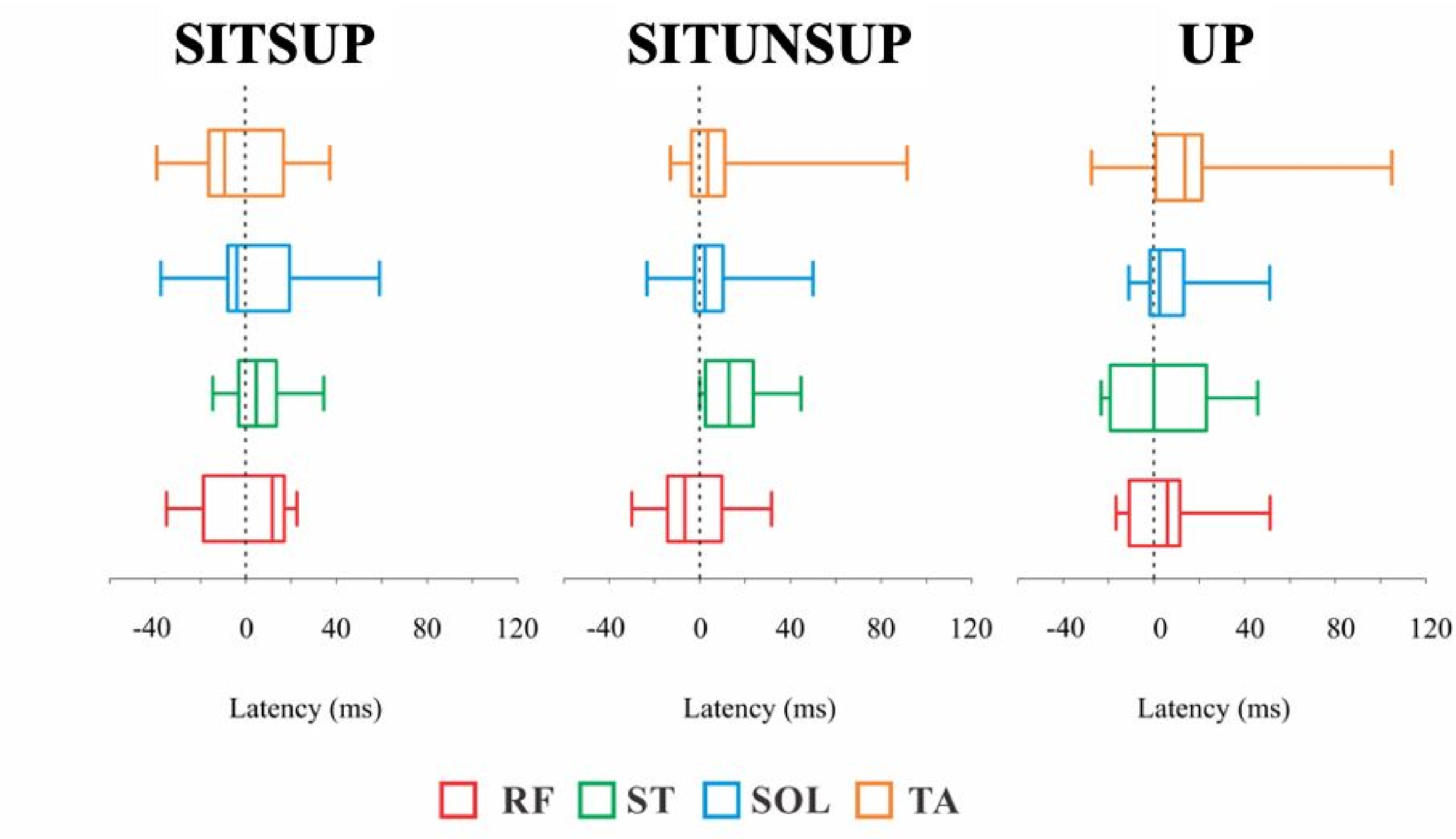

Figure 2

Lower limb muscles' latency related to deltoids onset. Up: Upright posture; SitSup: Sit posture + foot contact support; SitUnsup: Sit unsupported posture; Muscles: ST: Semitendinosus; RF: Rectus Femoris; SOLSoleous; TA: Tibialis Anterior. Data expressed by black line = median ; box = 25 and 75 percentiles ; whiskers = min and max values.

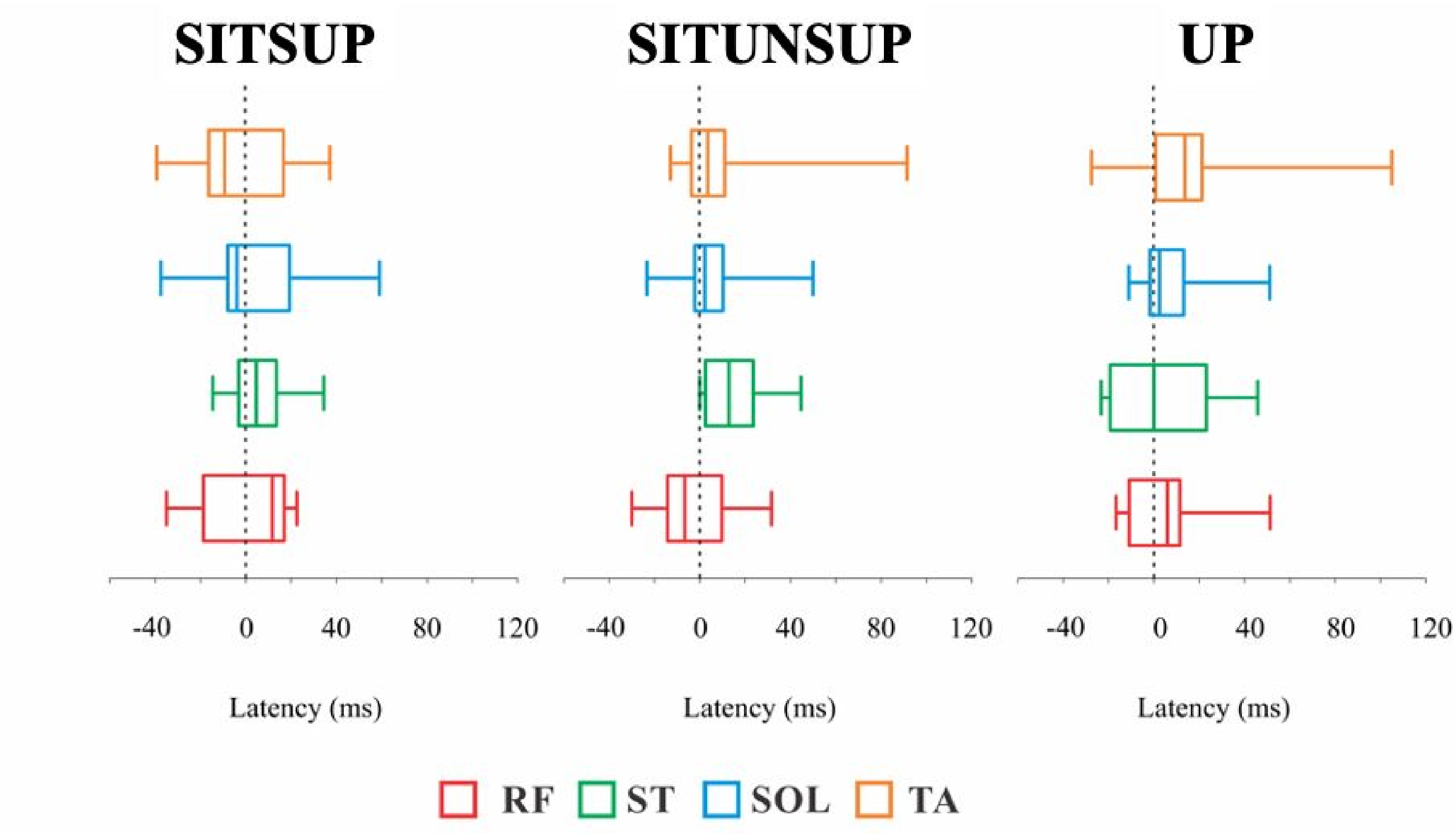

Figure 2

Lower limb muscles' latency related to deltoids onset. Up: Upright posture; SitSup: Sit posture + foot contact support; SitUnsup: Sit unsupported posture; Muscles: ST: Semitendinosus; RF: Rectus Femoris; SOLSoleous; TA: Tibialis Anterior. Data expressed by black line = median ; box = 25 and 75 percentiles ; whiskers = min and max values.

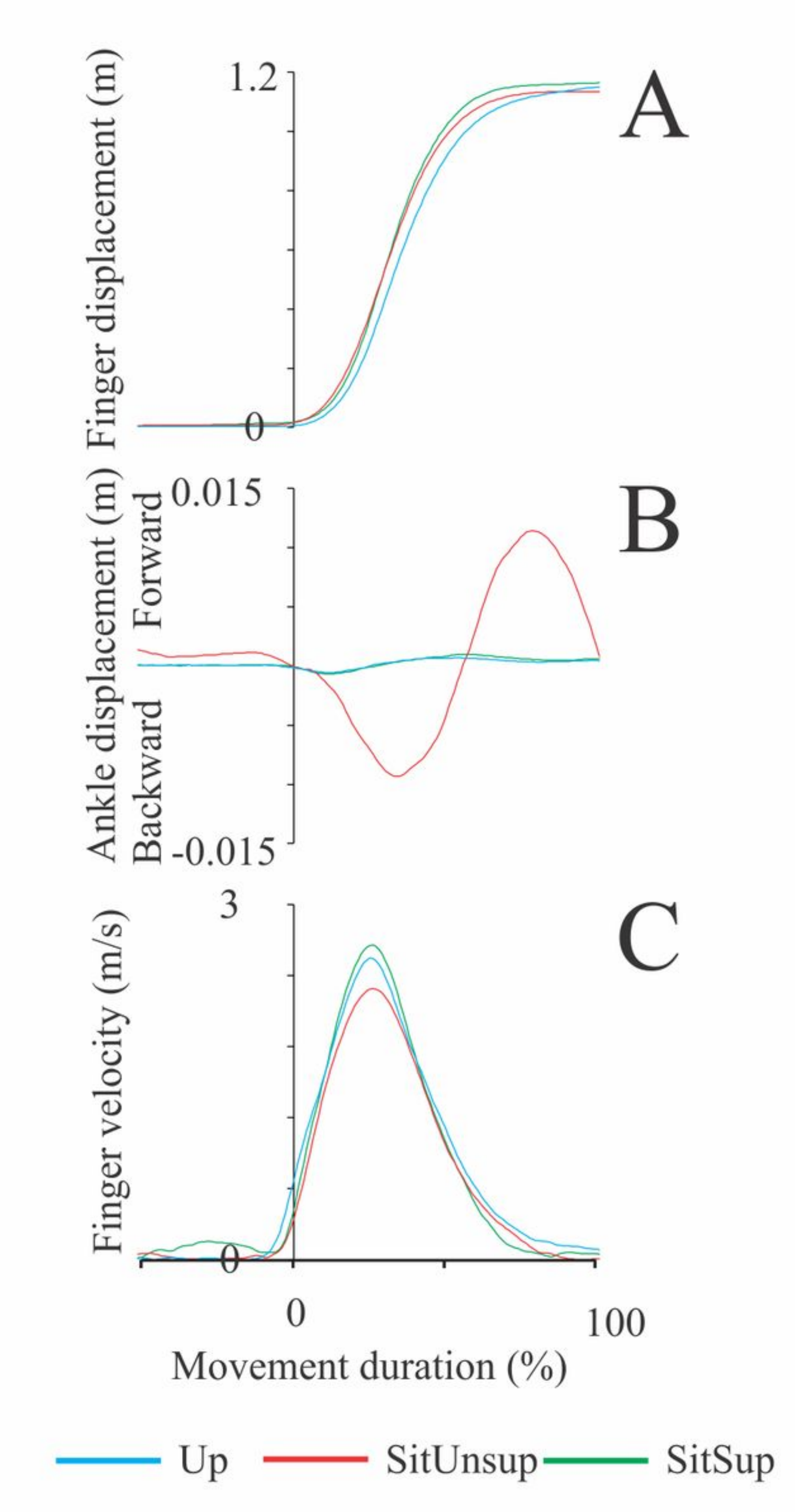

Figure 3

Kinematic synergy of a subject recorded while carrying out a single trial. Signals were plotted according to the raw time of their total movement. Up: Upright posture; SitSup: Sat posture with foot contact support; SitUnsup: Sat unsupported posture (no foot contact on the floor).

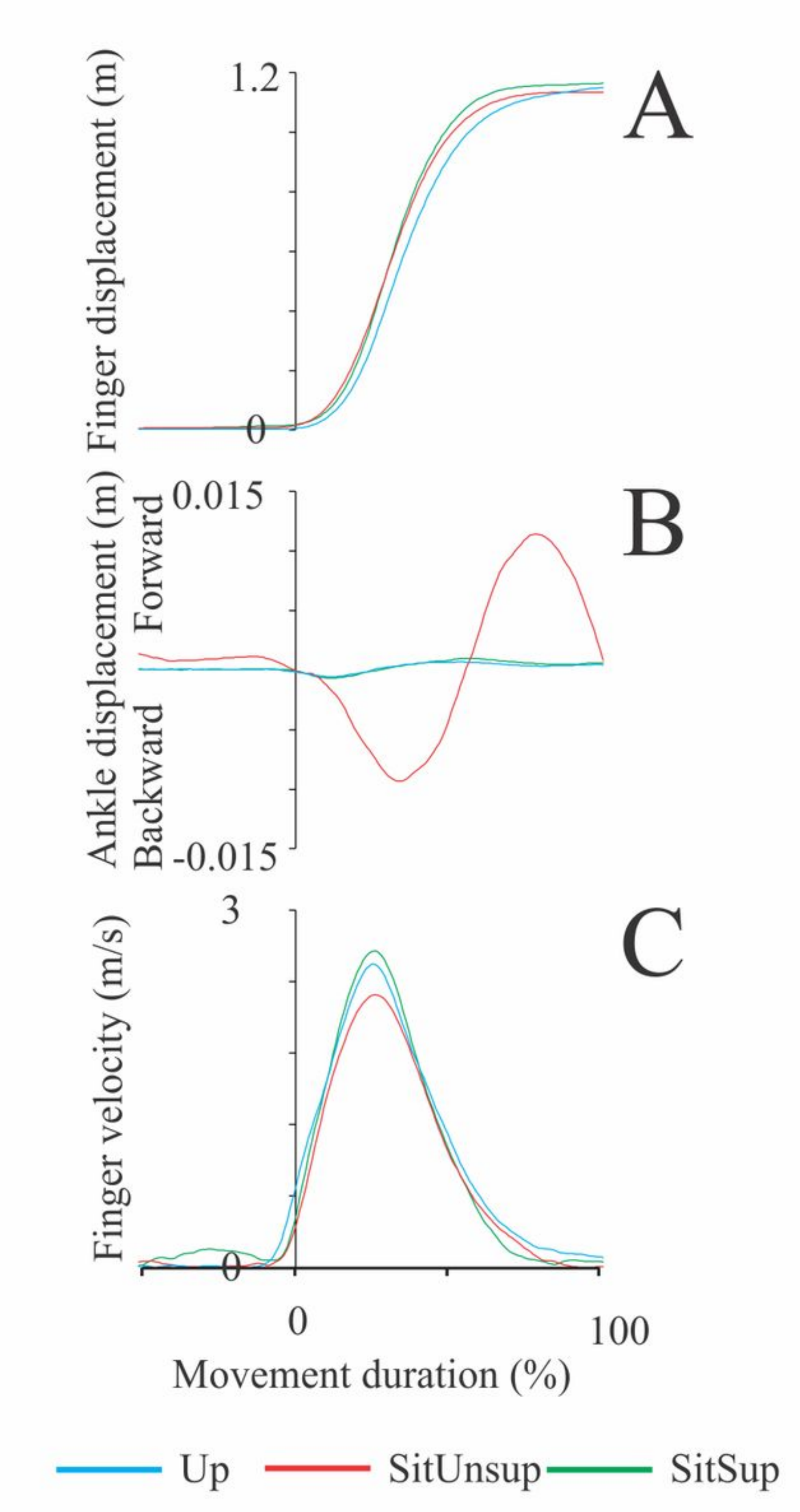

Figure 3

Kinematic synergy of a subject recorded while carrying out a single trial. Signals were plotted according to the raw time of their total movement. Up: Upright posture; SitSup: Sat posture with foot contact support; SitUnsup: Sat unsupported posture (no foot contact on the floor).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- ACERSupplementarydata.xlsx
- ACERSupplementarydata.xlsx