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The effect of standing desks on manual control in children and young adults

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Abstract

The aim of the present study was to establish if and how the additional postural constraint of standing affects accuracy and precision of goal directed naturalistic actions. Forty participants, comprising 20 young adults aged 20 – 23 years and 20 children aged 9-10 years completed 3 manual dexterity tasks on a tablet laptop with a handheld stylus during two separate conditions (1) while standing (2) while seated. The order of conditions was counterbalanced across both groups of participants. The tasks were (1) a tracking task, where the stylus tracked a dot in a figure of 8 at 3 speeds (2) an aiming task where the stylus moved from dot to dot with individual movements creating the outline of a pentagram (3) a tracing task, where participants had to move the stylus along a static pathway or maze. Root Mean Squared Error (RMSE), movement time and path accuracy, respectively, were used to quantify the effect that postural condition had on manual control. Overall adults were quicker and more accurate than children when performing all 3 tasks, and where the task speed was manipulated accuracy was better at slower speeds for all participants. Surprisingly, children performed these tasks more quickly and more accurately when standing compared to when sitting. In conclusion, standing at a desk while performing goal directed tasks did not detrimentally affect children's manual control, and moreover offered a benefit.

Keywords: children, manual dexterity, postural control, standing desks.

Introduction

Sedentary behaviour (sitting) in children has adverse associations with a range of cardio-metabolic risk factors (e.g. obesity) as well as cognitive development and academic achievement (1). In adulthood, sedentary behaviour has been linked to an increased risk of many chronic conditions including some cancers, diabetes and obesity (2). Together, this suggests that successful reduction of sedentary behaviour is important for both the primary and secondary prevention of a range of diseases. Recent attempts to reduce sedentary behaviour, and increase physical activity levels has included modifying the classroom or work environment to encourage standing behaviour, via the installation of standing desks, with initial promising results (3).

Simple observation of classrooms and workplaces highlights the many dextrous tasks that have to be carried out, often at pace, that involve the coordination of intricate hand muscles (e.g. handwriting;(4)). In order to be able to perform a range of manual control tasks, adequate coordination of posture with these tasks is essential (5), which is particularly challenging for a developing system. At a young age, poor postural control can directly impact the ability to execute a manual control task (6), with tasks requiring accuracy and precision further exacerbating the difficulties children have with maintaining posture when producing accurate goal directed tasks simultaneously (7).

It is suggested that the disruptive effect that standing might have on manual control is in in part due to the increased number of degrees of freedom to be controlled and the destabilising effects moving the arms and hands has on the centre of gravity (COG) ((5, 6)). Anticipatory postural adjustments (APA's) are suggested to be important in minimising the imminent perturbation to the stable base (8). However, while some research suggests that adult-like APA's only emerge at about 10 years of age (9, 10), other research noted absence of adult-like levels of integration between the postural and manual control system even at age 10, particularly when they stand and concurrently complete manual tasks which require precision and accuracy (11).

Many of the age-related differences observed in postural control during supra-postural tasks can be attenuated by reducing the degrees of freedom to be controlled, via the adoption of a seated posture (e.g. (4, 12-14). Flatters et al., (4) showed that when children were seated, hypothesised differences in postural control between 5-10 year olds were not observable. Furthermore, this work showed head movements affect postural control, more so in younger children (15), and that overall postural stability varied as a function of the task demands. For example, when less APA's were required, as was the case during a tracing task, increased postural stability and a reduction in head movements were noted, but the opposite was reported when an aiming task was performed. However, we should note that this study did not directly compare sitting versus standing posture within the same experimental design.

Given that seating can attenuate some of the maturational-dependent differences in postural control, and that initial work attests to the efficacy of the use of standing desks to decrease sedentary behaviour in the classroom, it seems appropriate to establish if and how the additional postural constraint of bipedal stance affects accuracy and precision of goal directed naturalistic actions akin to those that as important to a child's academic performance (e.g. writing). This study aims to examine manual control during sitting and standing in 9-10 year old children and adults. We chose to study 9-10 year olds as there is a suggestion in the literature that at this age adult like APA's are only beginning to emerge and the use of a standing desk should pose too much of a challenge for the developing nervous system- which would be further exacerbated in children of a younger age. If this is the case we should see deficits in the accuracy and precision of goal directed tasks when standing compared to when sitting.

Method

Participants

Forty participants, comprising 20 young adults (7 male) aged 20 – 23 years (M=21.48 years ±0.83) and 20 children (10 male) aged 9-10 years (M = 9.82 ±0.39) formed an opportunistic sample. All participants were healthy and had no impairments relevant to the study, and all were right handed. Both the young adults and the parents of the school children gave written informed consent, and children gave written assent to participate. The local ethics committee approved the study.

Apparatus and Procedures

All participants completed a battery of motor tasks, which closely resembled writing with a pen and paper. The software used to present the battery was created using LabVIEW (version 8.2.1, National Instruments TM) deployed on a tablet PC (Toshiba Portege, M750) (see (16) for a detailed explanation of tasks and software development). The position of a hand held stylus was sampled at 120 Hz as each participant completed the battery in two conditions; seated (C_{sit}) and standing (C_{stand}). Conditions were counterbalanced within both groups and completed 1 week apart. In C_{sit}, participants were seated and the height of the table altered so that hips and knees were at 90 degrees, with their feet flat on the floor, and right elbow rested on the table at 90 degrees, with the left elbow placed on the participants lap. In C_{stand}, all participants stood at a height adjustable desk, with their feet placed 8cm apart from the medial malleolus of the ankle in a designated area. This standing position ensured that the elbow of the dominant hand rested on the table at 90 degrees, and the left elbow hung freely by the side of the participant. The tablet PC was placed 15cm away from the edge of the desk in landscape orientation, on- screen instructions were displayed prior to the start of each subtest and participants completed the tests with their dominant hand in the following fixed order.

Motor Tasks

Tracking

Participants started with the stylus on a dot (10mm), which after 2s started to move in a figure of 8 around the screen. In each trial, the speed at which the dot moved increased after 3 paths had been completed, until a total of 9 paths were completed, at a slow, medium and fast pace (42, 84 and 168mm/s respectively).

Participants were asked to keep the stylus as close to a dot as they could during each trial, and accuracy for each speed was computed as distance from the stylus to the centre of the target dot (Root Mean Squared Error; RMSE).

Aiming

Participants held the stylus on the ‘start button’ for 2s, and this triggered a dot to appear. Participants were instructed to move from one dot to another, while keeping the stylus on the screen at all times, with the individual movements creating the outline of a pentagram. This subtest comprised 75 movements, and an intra-individual mean value was calculated for each participant’s movement time (MT) across the 75 individual aiming movements. MT was defined as the time taken from leaving one target dot to arriving at the next target dot.

Tracing

This task required participants to move the stylus along a static pathway. Participants held the stylus on the ‘start’ box for 1s and then a maze appeared, the trial finished when the stylus reached ‘finish’ box. The participants were instructed to remain within a hollow box which moved along the pathway every 5s, for the duration of the trial (35s). The task comprised three repetitions of two different pathways, and for each of these pathways, the minimum 2D distance to the idealised reference path was calculated and is presented as path accuracy (PA). To control for instances where participants did not stay in the box, a ‘penalised path accuracy’ (PPA) was calculated (4). As the expected MT for a participant staying within the box outline throughout the trial was 36 seconds, each participants’ mean PA score was inflated by the percentage that their MT deviated from the expected

36 seconds. A composite score was calculated as the mean of the scores (PA and PPA) for each shape (presented as PA), with a higher score indicating a less accurate pathway.

Statistical Analyses

In order to examine the effects of age and posture on manual control during the aiming and tracing tasks a 2 group (adults, children) × 2 condition (C_{sit}, C_{stand}) mixed ANOVA with repeated measures was used. The data from the tracking subtest was analysed using a mixed ANOVA with an extra within subject factor of speed (slow, medium and fast). Where Mauchly's test indicated a violation of sphericity, p values and degrees of freedom were corrected using the Greenhouse-Geisser correction factor. Bonferonni corrections were applied to all pairwise corrections, and interactions are explored using appropriate inferential statistics.

Results

Tracking

There was a main effect of speed ($F(2, 76) = 319.06$, $p \leq 0.001$). Fast moving targets elicited a larger RMSE than the medium and slow targets, and the medium a larger error than the slow (all $ps<.001$; see Fig 1). Adults were more accurate than children ($F(1, 38) = 19.98$, $p \leq 0.001$), and a larger error was noted in C_{stand} compared to C_{sit} ($F(1, 38) = 5.51$, $p \leq 0.05$). A group x speed x condition ($F(1.08, 41.20) = 6.35$, $p \leq 0.05$) can be clearly seen in Figure 1, and to explore this we examined group and condition at each level of speed separately.

For the slow speed task a main effect of group emerged ($F(1,38) = 17.74$, $p < 0.001$) with adults being more accurate than children. There was no main effect of condition but there was a significant group x condition interaction ($F(1,38) = 8.02$, $p < 0.01$). Independent t-tests revealed a significant group difference in the sitting condition ($p<0.001$) but not standing one ($p = 0.15$). Paired t-tests showed a significant increase in accuracy in standing compared to sitting for the children ($p<0.01$) but condition had no effect on the accuracy of the adults ($p = 0.47$).

For the medium speed task a main effect of group emerged ($F(1,38) = 8.77$, $p < 0.01$) again with adults being more accurate than children. There was no main effect of condition or group x condition interaction. Finally, for the fast speed task a main effect of group emerged ($F(1,38) = 15.16$, $p < 0.001$), again with adults being more accurate than children. There was also a main effect of condition ($F(1,38) = 5.62$, $p < 0.05$) and group by condition interaction ($F(1,38) = 8.81$, $p < 0.01$). Independent t-tests revealed significant group differences in both C_{sit} ($p<0.01$) and C_{stand} ($p<0.01$). Paired t-tests showed a significant increase in accuracy in standing compared to sitting for the children ($p<0.05$) but condition had no effect on the accuracy of the adults ($p = 0.36$).

Aiming

MT was slower during C_{stand} than C_{sit} ($F(1,38) = 6.36$, $p < 0.05$) and adults were faster than children at completing this task ($F(1, 38) = 30.92$, $p < 0.001$). Figure 2 shows a condition x group interaction ($F(1, 38) = 24.90$, $p < 0.001$), and follow up independent t-tests confirmed that the MT was significantly faster for adults compared to children in both C_{sit} ($p \leq 0.001$) than C_{stand} ($p \leq 0.01$). Furthermore, paired sample t-tests, which compared MT when sitting (C_{sit}) with MT when standing (C_{stand}) within each group, indicated that overall adults showed a trend towards a lower MT whilst sitting ($p \leq 0.056$), in contrast to children who had a significantly lower MT whilst standing ($p \leq 0.001$).

Tracing

Adults had a significantly better path accuracy score then children ($F(1, 38) = 30.36$, $p \leq 0.001$). There was no main effect of condition ($F(1,38)=2.328$, $p >0.05$), but condition and group interacted ($F(1,38) = 7.80$ $p \leq 0.01$). Independent samples t-tests, comparing both groups' mean scores for condition 1 and 2 showed that adults performed significantly better than children when sitting ($p \leq 0.001$), and standing ($p \leq 0.001$). Further analysis using paired samples t-tests compared path accuracy scores during sitting and standing within each group. These indicated that children had significantly better path accuracy during C_{stand} ($p \leq 0.05$), whilst for adults condition had no effect on path accuracy ($p = 0.35$) (see Fig 3).

Discussion

The main objective of this study was to determine how the increased postural demands associated with standing at a desk affected manual control in adults and children. Participants completed a battery of motor tasks that represent many of the dextrous tasks undertaken in either a school or work environment, while sitting and standing at a desk. As expected, our data showed that across all three motor tasks, adults demonstrated higher levels of manual dexterity than children, regardless of postural constraints (see Figs 1-3). At 8-10 years, both the postural and manual control systems are in a transition period as they near adult like levels of control (11, 17, 18). Furthermore, others suggest that immature postural responses, and increased postural sway are present even at 15 years of age (19, 20). Overall, without COP data it is difficult to attribute the lower level of manual dexterity to deficits in manual or postural control, or in the integration of the two control systems.

The adults showed no significant differences in performance between standing and sitting, except during the aiming task where performance was better when sitting, but the difference failed to reach conventional level of significance (p=0.056). The aiming task used requires constant rapid acceleration and deceleration of the stylus in a feed-forward manner with fast implementation of online corrections, which has been shown to pose a threat to upright postural control (8). We suggest that the provision of a chair reduces degrees of freedom and provides a stable base, in order to satisfy those complex task demands without detrimental effects on posture (4). The fact that performance on both tracking (predicting target movement) and tracing (force control) tasks did not derive benefit from sitting or standing, also supports the idea that postural control is modulated according to task difficulty (4).

We anticipated that standing would add a postural constraint that for children would increase the difficulty of the manual control. Interestingly, our data show that children demonstrated superior manual control when standing, compared to sitting in all tasks (see Fig 1-3). We suggest several explanations of this finding. When performing a standing task, the body’s degrees of freedom are adjusted to maintain posture and allow performance of a concurrent task. It could be that the redundancies in the degrees of freedom associated with standing at a desk ultimately provide movement flexibility, and permit greater end point accuracy (21, 22). In contrast, a seated posture reduces the functional degrees of freedom, leading to a reduced level of functional adaptability to ensure optimisation of task performance (23), while limiting the ability to attenuate perturbations to postural control. It is possible that due to the task constraints imposed whilst sitting, the potential for the children to use lower body movements, such as a rotation in the trunk, to enhance manual performance was limited.

The novelty of the experimental paradigm, e.g. interacting with the tablet PC, the motor tasks, and the use of the standing desk, could have focused the child's attention and this could have resulted in more accurate movements when standing This does seem plausible considering that although previous research has reported that while objective measurements showed no difference in 'focus' or attention of participants, all class teachers reported behavioural benefits associated with using standing desks in the classroom (3, 24).

Finally, research attests to the fact that lightly touching a surface with the fingertip whiles standing can prove a powerful sensory input that can be used for mechanical support to stabilise posture across the lifespan (25, 26). Thus, it is possible that the touch information provided by the stylus on the tablet while standing combined with proprioceptive information about the arm could have provided information of body position relative to the contact point (i.e., body orientation) (27) and aided postural control. Furthermore, given that the adults did not derive as much benefit from the haptic supplementation as the children it is possible that it is only when visual information is deficient in some way that haptic information supplementation can take effect. This seems possible given that at 10 years of age children are just emerging from a transition in the way visual feedback is used to control movement, and the immaturity of the visual system in some at this point in time enhances the positive effect that haptic information can have on postural control, and in the case of the present study, manual control.

These results indicate standing desks do not appear to have an adverse effect on manual control in children, and indeed they may even offer some benefit. However, the age of our participants limits the generalisability of our results to a limited age group (9-10 years), and given that postural control in younger children e.g. 5-9 years is even less well developed, we suggest that this study be replicated with a population that spans the primary school age years. In addition, given that data also suggests that at age 14-15, adolescents enter a period of ‘proprioceptive neglect’ it would also be important to investigate how standing desks affect manual control in children older than which we have already studied (28).

Overall, this research shows that if standing desks are used even for as little as 30 minutes a day they pose no immediate threat to manual control. However, given that children can spend up to 5 hours a day at a desk, further research which examines the effect of standing desks on manual control over a longer duration is now required. We suggest that with continued use standing desks could help start to form the behavioural habit of ‘standing’ some of the time at school which could lead to the ‘sit stand’ modification being more acceptable in secondary school and beyond.

Conflict of Interest

There are no conflicts of interest for any of the authors.

References

1. de Rezende LFM, Lopes MR, Rey-López JP, Matsudo VKR, do Carmo Luiz O. Sedentary behavior and health outcomes: an overview of systematic reviews. 2014.

2. Katzmarzyk PT, Church TS, Craig CL, Bouchard C. Sitting time and mortality from all causes, cardiovascular disease, and cancer. Med Sci Sports Exerc. 2009;41(5):998-1005.

3. Benden ME, Zhao H, Jeffrey CE, Wendel ML, Blake JJ. The evaluation of the impact of a stand-biased desk on energy expenditure and physical activity for elementary school students. International journal of environmental research and public health. 2014;11(9):9361-75.

4. Flatters I, Culmer P, Holt R, Wilkie R, Mon-Williams M. A new tool for assessing head movements and postural sway in children. Behavior research methods. 2014;46(4):950-9.

5. Bertenthal B, Von Hofsten C. Eye, head and trunk control: the foundation for manual development. Neuroscience & Biobehavioral Reviews. 1998;22(4):515-20.

6. Smith-Zuzovsky N, Exner CE. The effect of seated positioning quality on typical 6-and 7-year-old children's object manipulation skills. American Journal of Occupational Therapy. 2004;58(4):380-8.

7. Bucci MP, Gerard CL, Bui-Quoc E. The effect of a cognitive task on the postural control of dyslexic children. Research in developmental disabilities. 2013;34(11):3727-35.

8. De Wolf S, Slijper H, Latash M. Anticipatory postural adjustments during self-paced and reaction-time movements. Experimental Brain Research. 1998;121(1):7-19.

9. Haddad JM, Van Emmerik RE, Wheat JS, Hamill J. Developmental changes in the dynamical structure of postural sway during a precision fitting task. Experimental Brain Research. 2008;190(4):431-41.

10. Sparto PJ, Redfern MS, Jasko JG, Casselbrant ML, Mandel EM, Furman JM. The influence of dynamic visual cues for postural control in children aged 7–12 years. Experimental Brain Research. 2006;168(4):505-16.

11. Haddad JM, Claxton LJ, Keen R, Berthier NE, Riccio GE, Hamill J, et al. Development of the coordination between posture and manual control. Journal of experimental child psychology. 2012;111(2):286-98.

12. Angelakopoulos GT, Davids K, Bennett SJ, Tsorbatzoudis H, Grouios G. Postural stability and hand preference as constraints on one-handed catching performance in children. Journal of motor behavior. 2005;37(5):377-85.

13. Saavedra S, Woollacott M, van Donkelaar P. Effects of postural support on eye hand interactions across development. Experimental Brain Research. 2007;180(3):557-67.

14. Schneiberg S, Sveistrup H, McFadyen B, McKinley P, Levin MF. The development of coordination for reach-to-grasp movements in children. Experimental Brain Research. 2002;146(2):142-54.

15. Schärli A, van de Langenberg R, Murer K, Müller R. The influence of gaze behaviour on postural control from early childhood into adulthood. Gait & posture. 2012;36(1):78-84.

16. Culmer PR, Levesley MC, Mon-Williams M, Williams JH. A new tool for assessing human movement: the kinematic assessment tool. Journal of neuroscience methods. 2009;184(1):184-92.

17. Taguchi K, Tada C. Change of body sway with growth of children. Posture and gait: Development, adaptation and modulation. 1988:59-65.

18. Girolami GL, Shiratori T, Aruin AS. Anticipatory postural adjustments in children with hemiplegia and diplegia. Journal of Electromyography and Kinesiology. 2011;21(6):988-97.

19. Peterka RJ, Black FO. Age-related changes in human posture control: sensory organization tests. Journal of vestibular research: equilibrium & orientation. 1989.

20. Hirabayashi S-i, Iwasaki Y. Developmental perspective of sensory organization on postural control. Brain and development. 1995;17(2):111-3.

21. van Emmerik RE, van Wegen EE. On the functional aspects of variability in postural control. Exercise and sport sciences reviews. 2002;30(4):177-83.

22. Haddad JM, Rietdyk S, Claxton LJ, Huber J. Task-dependent postural control throughout the lifespan. Exercise and sport sciences reviews. 2013;41(2):123.

23. Davids K, Bennett S, Kingsbury D, Jolley L, Brain T. Effects of postural constraints on children's catching behavior. Research quarterly for exercise and sport. 2000;71(1):69-73.

24. Koepp GA, Snedden BJ, Flynn L, Puccinelli D, Huntsman B, Levine JA. Feasibility analysis of standing desks for sixth graders. ICAN: Infant, Child, & Adolescent Nutrition. 2012;4(2):89-92.

25. Jeka JJ, Lackner JR. The role of haptic cues from rough and slippery surfaces in human postural control. Experimental Brain Research. 1995;103(2):267-76.

26. Bair W-N, Barela JA, Whitall J, Jeka JJ, Clark JE. Children with developmental coordination disorder benefit from using vision in combination with touch information for quiet standing. Gait & posture. 2011;34(2):183-90.

27. Lackner JR, DiZio P. Vestibular, proprioceptive, and haptic contributions to spatial orientation. Annu Rev Psychol. 2005;56:115-47.

28. Viel S, Vaugoyeau M, Assaiante C. Adolescence: a transient period of proprioceptive neglect in sensory integration of postural control. Motor Control. 2009;13(1):25-42.