Effects of biaxial pencil on writing biomechanics among children in kindergarten and early elementary school years

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ABSTRACT
Children’s writing posture has been a concern among parents and teachers [1, 2]. Poor writing posture often leads to arm, neck and back pain, scoliosis, kyphosis, fatigue, myopia, and other problems [2-4]. It also affects children’s learning [5]. A two-factor repeated measures ANOVA (pencil × trial interval) was performed in this study; comparing the effects of biaxial pencil and traditional pencil on writing posture and biomechanics. A total of 26 typically developed children participated in this study. The results revealed that, first, for the EMG data of upper extremity musculature, none of the muscles demonstrated statistical significance in pencils and intervals, except for extensor carpi radialis. Second, for the joint and postural angles measured via imaging, the significant differences were found on pencils in variables including shoulder horizontal inclination angle, head horizontal inclination angle, and trunk slant angle. Post-hoc analysis showed significant differences between the regular and biaxial pencils. No significant difference was found in trial intervals. Third, for participants’ subjective soreness and pain, the reported soreness scales for all three pencils were mild, and no specific location of pain was reported. Most subjects felt that biaxial pencil was the most comfortable pencil to write with, followed by regular pencil, then regular pen-restricted grip height. Results of this study showed that using biaxial pencil can improve writing posture.

Keywords
Biaxial pencil, writing posture, children, preschool

INTRODUCTION
Children’s writing posture has been a concern among parents and teachers. Poor writing posture often leads to arm, neck and back pain, scoliosis, kyphosis, fatigue, myopia, and other problems. It also affects children’s learning. There are many writing tools designed for improving writing biomechanics [6-9]. Among them, the cross-sectional shape and the diameter of the pencil have been studied extensively, however little influence on writing biomechanics was found. As to the design of pencil shaft, a z-shaped biaxial pencil was developed, yet no related research investigated its influences on pencil grip and writing posture. The aim of this study was to compare the effects of regular and biaxial pencils on writing posture and upper extremity biomechanics.

METHOD
A two-factor repeated measures ANOVA (pencil × trial interval) was performed in this study. The independent variables in this study were: (a) regular pencil, (b) regular pen-restricted grip height (limited to 2.8 cm in height to hold a pencil), and (c) biaxial pencil (limited to 2.8 cm in height to hold a pencil; biaxial angle of 23-degree). The dependent variables were forearm EMG, twin axis electrogoniometer, and photopraphy parameters while tracing Archimedes spiral mazes. Upon completion of trials, all participants were asked to fill out a subjective visual analogue scale to report any experience of pain. A two-factor repeated measure ANOVA (pencil x trial interval) was performed in this study, we evaluated the writing biomechanics including forearm muscle performance, wrist and trunk posture, and subjective soreness report while using regular and biaxial pencils in typically developed children.

RESULTS AND DISCUSSION
A total of 26 typically developed children (12 boys and 14 girls) participated in this study. The results revealed that, first, for the EMG data of upper extremity musculature, none of the muscles demonstrated statistical significance in pencils and intervals except for extensor carpi radialis (Fig. 2). Second, for the joint and postural angles measured via imaging technique, the significant differences were found on pencils in variables including (a) posterior view: shoulder-horizontal angle (SH), head-horizontal angle (HH) and trunk tilt inclination angle (TTI) (F=5.734, p=0.004; F=3.814, p=0.023; F=52.313, p=0.000)(Fig. 3, Fig. 4, Fig. 5). Post-hoc analysis showed differences between the regular and biaxial pencils. No significant difference was found in trial intervals. (b)lateral view: trunk forward inclination angle (TFI)(F=14.879, p=0.000)(Fig. 6). Post-hoc analysis showed differences between the regular and biaxial pencils, regular pen-restricted grip height and biaxial pencils. No significant difference was found in trial intervals. Third, for participants’ subjective soreness and pain, the reported soreness scales for all three pencils were mild, and no specific location of pain was reported. Most subjects felt that...
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Fig.1 (a) regular pencil = REG; (b) regular pencil-restricted grip height = REG-restricted; (c) biaxial pencil = BIA.

Fig.2 Extensor carpi radialis (ECR) EMG difference score on pencil. Effect on trial interval P<.05 (F=3.518, p=0.008), post-hoc Tukey HSD p=0.009 and p=0.040 between 1 and 2, 2 and 3.

Fig.3 Shoulder-horizontal angle (SH) difference score on pencil. Effect on pencil P<.05 (F=5.734, p=0.004), post-hoc Tukey HSD p=0.003 between REG and BIA.

Fig.4 Head-horizontal angle (HH) difference score on pencil. Effect on pencil P<.05 (F=3.814, p=0.023), post-hoc Tukey HSD p=0.022 between REG and BIA.

Fig.5 Trunk tilt inclination angle (TTI) difference score on pencil. Effect on pencil P<.05 (F=52.313, p=0.000), post-hoc Tukey HSD p=0.000; p=0.000 between REG and BIA, REG-restricted and BIA.

Fig.6 Trunk forward inclination angle (TFI) difference score on pencil. Effect on pencil P<.05 (F=14.879, p=0.000), post-hoc Tukey HSD p=0.000; p=0.000 between REG and BIA, REG-restricted and BIA.

Fig.7 Visual focus-vertical angle (VFV) difference score on pencil. Effect on pencil P<.05 (F=9.457, p=0.000), post-hoc Tukey HSD p=0.000; p=0.024 between REG and BIA, REG-restricted and BIA.
Fig.8 Pencil-desk angle (anterior view) (PD-a) difference score on pencil.
Effect on pencil $P<.05$ ($F=14.316$, $p=0.000$), post-hoc Tukey HSD $p=0.000$; $p=0.024$ between REG and REG-restricted, REG-restricted and BIA.

CONCLUSION

Failure to attain proper writing biomechanics during early school years often leads to problems such as shoulder and neck soreness, kyphosis, easy fatigue and myopia. These problems inevitably impact on children’s learning and academic success. The authors conclude that biaxial pencil could improve writing posture effectively, but not the upper extremity muscle exertion. The improvement in posture might relate to the z-shape design of the biaxial pencil, which limits the height of pen grip and avoids visual blockage between the eyes and the script. Along with further research, the effects of biaxial pencil design onto writing biomechanics in typical developed children and children with developmental disabilities such as cerebral palsy will be revealed. These results can also serve as guidelines for designing writing tools for children.

REFERENCES