Author Manuscript
Author Manuscript
Author Manuscript
Author Manuscript

HHS Public Access
Author manuscript
Proc Hum Factors Ergon Soc Annu Meet. Author manuscript; available in PMC 2020 April 22.

Published in final edited form as:
Proc Hum Factors Ergon Soc Annu Meet. 2019 November 01; 63(1): 1062–1066. doi:10.1177/1071181319631308.

Effects of Visual Stress on Postural Control during Simulated Laparoscopy: A Preliminary Study

Yifan Li[1], **Kristin Chrouser**[2], **Clive D'Souza**[1]

[1]Department of Industrial and Operations Engineering, University of Michigan, Ann Arbor, MI, USA

[2]Department of Urology, University of Michigan, Ann Arbor, MI, USA

Abstract

Intraoperative stress can influence both surgeon health and patient outcomes, however stress management is not properly assessed during surgical training. Seven healthy, novice individuals participated in an experiment involving precision pin transfers using laparoscopic surgical instruments. A visual stressor introduced by altering the digital blur in a real-time video display (none, low, and high) was hypothesized to influence postural control and task performance. Preliminary descriptive analyses indicated a negative influence of the visual stressor on performance (i.e., pins transferred per minute), however the effects on postural control (i.e., linear accelerations at the forehead and center of pressure displacements) varied between participants, suggesting individuals differ in the magnitude of response to environmental stressors. Implications for surgical training and real-time measurement of intraoperative stress are discussed.

INTRODUCTION

Successful surgery requires competency in both technical and non-technical skills. Many surgical simulators focus on the development of individual technical skills. Assessment and feedback regarding other non-technical skills such as environmental and physical stress management are rarely included in surgical simulation curricula. However, these are critical skills for surgical trainees to acquire, since efficient, high-quality performance under stress can influence patient outcomes during an intraoperative crisis (Chrouser et al. 2018).

Prior research on the effects of intraoperative stress from external or environmental factors (e.g., noise, poor placement of the visual display, improper table height) has largely focused on aggregate performance metrics (e.g., movement time, accuracy, errors) measured post-task. However, aggregate performance metrics do not advance our understanding of how residents and surgeons respond to stressful conditions and adverse events during surgery across time. Continuous and objective measures are needed for investigating stress responses in surgical training and practice.

As part of an on-going effort to assess intraoperative stress and its performance effects using wearable physiological sensors, a preliminary study was conducted to measure effects of environmental stressors on postural control and task performance. A laparoscopic trainer was chosen for this study since laparoscopy is a commonly used modality in surgical practice. A laparoscopic trainer system is a lightweight portable device for learning and

Author Manuscript

developing basic manual skills required in laparoscopic surgery. Laparoscopic trainers are an integral part of standardized tests such as the Fundamentals of Laparoscopic Surgery (FLS) – Manual Skills module (Sroka et al. 2010) for assessing competency in manual dexterity tasks such as peg transfers, precision cutting, and suturing among medical students and residents.

Postural control and balance during standing tasks are correlated with psychomotor performance and degrade with increasing cognitive load. For instance, Pellecchia et al. (2003) reported an increase in postural sway measured using center of pressure (COP) displacement when standing on a 10 cm foam-padded force plate and performing a cognitive task (counting backwards) for 30s. Other studies investigating the effect of mental workload on postural control report contrasting results. Andersson (2002) found that COP displacement and postural sway while standing decreased during a cognitive task of counting backwards. However, balance was measured in pre-set position and only for 20s. Similar findings were reported by Prado (2007) wherein postural sway measured as average COP displacement decreased during a visual search task of 70s duration compared to viewing a blank screen.

Postural sway during simulated laparoscopy has been measured previously but for short duration tasks. Lee et al. (2007) utilized force plates to monitor postural sway while performing standard laparoscopic trainer tasks. However, this study focused mainly on aggregate performance metrics during peg transfer, circle-cutting, and endo-loop tasks which lasted less than 90s. Savoie et al. (2007) compared postural stability between novices and experts while performing different tasks; this study only examined the effects of task difficulty based on expertise. Butler et al. (2013) examined posture changes after longer task periods of laparoscopic surgeries or robot assisted surgery, but did not quantify changes across time.

The aim of the present study was to quantify effects of external stressors on task performance and postural control over time as participants performed a precision pin transfer task on a laparoscopic training simulator. The external stressor was introduced by means of visual blur in the real-time feedback display, akin to blur from fluids splashing on the surgical camera. Changes in postural control were explored using force plates and wearable accelerometers. Noise in the visual display was expected to increase cognitive demand in the visual-manual precision task and degrade performance and posture control.

METHODS

Participants

Seven healthy young adults participated in this preliminary study. Participants had an average (± standard deviation; SD) age of 24.7 ± 5.2 years, body mass of 71.7 ± 17.2 kg, and stature of 170.3 ± 6.6 cm. All of the participants were right-handed, free of any musculoskeletal disorders, and had normal or corrected vision. Participants had no prior experience performing the type of activity conducted in the experiment. The study was approved by the university's institutional review board.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Experiment Apparatus

The experiment apparatus consisted of a laparoscopic trainer placed atop a height-adjustable table (Figure 1). The work-surface height was set such that the top of the trainer system was at 80% of each participants' elbow height. The display of the training system was a Storz WideView™ monitor (display resolution 1920 x 1200 pixels). The top of the screen was set to each participants' eye level. The horizontal distance from the screen was approximately 36 inches from the participant's eye location. This set up was designed to facilitate optimal participant positioning from an ergonomic standpoint (Ronstrom et al. 2018).

The pin transfer task used in this study was a modified version of the O'Connor Tweezer Dexterity Test (Lafayette Instruments Inc.). Participants had to transfer 1 in. long, 1/16in diameter metal pins in a set sequence using Maryland graspers, a type of laparoscopic instrument. No support surface for the hand, wrist, or arm was provided. Pins were presented in a 5x5 horizontal array (2.5in x 2.5in) with pins spaced 1/2in apart on the non-dominant side of visual field. Participants were instructed to pick up each pin using the grasper in their non-dominant hand, transfer the pin to the grasper in their dominant hand, and place the pin vertically into the target hole one column over to the right. The pins had to be moved sequentially from the top of each column to the bottom. When a single column was completed, the participant moved onto the next column. Participants had to complete as many pin-transfers as possible over 12 minutes while minimizing pins dropped with an emphasis on accuracy over speed.

Experimental Procedure

Prior to the start of any experiment trials, participants were provided 10-15 minutes of practice time to familiarize with the pin-transfer task using the Maryland graspers. Participants stood with feet shoulder-width apart in a self-selected upright posture with a grasper in each hand as shown in Figure 1. Participants were instructed to not move their feet during the entirety of a trial.

For the timed trials, each participant completed three 12min trials of the pin-transfer task. First, each participant completed a baseline 12min trial with the unaltered video feed (i.e., *none*). The next two 12min trials had either a *low* and *high* level of the visual stressor during the middle 4mins of the trial (i.e., sandwiched between 4mins of unaltered video feed). The order of these two trials was presented in counterbalanced order. .Participants were instructed to continue the pin transfer task to the best of their ability regardless of changes to the video feed. A seated rest break of 10 minutes was provided between the trials to minimize cumulative effects of fatigue.

Visual Stressor

During the intervals where *low* and *high* levels of the stressor were applied, the visual feed was digitally altered in real-time prior to display on the screen (Figure 2). First, a 2.5% salt-and-pepper noise was applied (i.e., 2.5% of the pixels in each frame were randomly turned either white or black), in addition to a square-blur digital filter corresponding to either to a *high* (10 pixel blur) or *low* (3 pixel blur) level of visual stressor was layered on top. Thus, the visual stressor could be introduced at a predefined time and for a consistent, intermediate

Author Manuscript
Author Manuscript
Author Manuscript
Author Manuscript

duration of a timed-trial without stopping the primary pin-transfer task. The amount of blur applied in the *low* and *high* stressor settings was determined from pilot tests of visual hyperacuity across different blur settings.

Instrumentation

Participants performed the experiment while standing on platform comprising 4 force-plates (AMTI, Watertown, MA). Each force-plate data were sampled at 1680Hz, filtered using a 6Hz second-order zero-lag low-pass Butterworth filter, and combined to compute the overall COP displacement. Participants were also instrumented with an inertial measurement unit (IMUs; Delsys Trigno Avanti) on the forehead. Acceleration data from the IMUs in the Anterior-Posterior (A-P) and Medial-Lateral (M-L) directions were filtered using a 6Hz second-order zero-lag low-pass Butterworth filter for analysis. To facilitate the preliminary analysis, COP and accelerometer data were down-sampled to 1Hz.

Data Analysis

For analysis purposes, each trial was divided into three 4-minute intervals (*Before*: 0-4 minutes, *During*: 4-8 minutes, *After*: 8-12 minutes), the initial and final four-minute periods being un-altered visual display for all trials. The middle 4-minutes included one of 3 levels of visual stressor – *none, low, and high* – depending on the trial. COP and acceleration data were collected and integrated in the A-P and M-L directions, to represent the cumulative COP displacement and acceleration across each time interval.

Summary statistics for task performance (# of pins transferred), integrated COP and integrated acceleration were computed for each 4min interval (*Before*, *During*, *After*) by Stressor Level (*none, low, high*).

RESULTS

Table 1 summarizes the mean ± SD for task performance by Interval and Stressor Level. Task performance decreased when the stressor was present in the low and high condition, and matched baseline after the stressor was removed.

Figure 3 shows the mean trajectories and the SD about the means for cumulative COP displacement and cumulative head accelerations in the A-P direction by Stressor Level. Overall the mean trajectories increased with time, indicating a decrease in postural control, as expected. However, the rate of increase for mean COP displacement differed by Stressor Level. The rate of increase for mean cumulative head accelerations were similar in the *low* and *high* stressor, but greater compared to the *none* condition.

The graphs on the right panel indicate that the SD about the mean increases with time, suggesting increased variability and lowered postural control. These differences were more noticeable in the During and After Intervals. The latter might suggest a carryover effect of the stressor even after the stressor was removed.

Table 2 provides the mean and standard deviations for cumulative COP displacement for each interval in the A-P and M-L directions respectively. Table 3 provides similar data for cumulative head acceleration. These data suggest that relative to the *none* condition, the *low* and *high* levels of stressor tended to increase the amount of COP displacement and head accelerations in the During interval (i.e., when the stressor was in effect) both in the A-P and M-L directions. The magnitude of change was greater in the *high* vs. *low* stressor level.

DISCUSSION

Overall the findings from this preliminary study revealed that a visual stressor seemed to degrade both task performance (i.e., number of pins transferred) and postural control (i.e., COP displacement and head accelerations). Performance decreases were greater at higher levels of the visual stressor. The findings also suggest a short duration of carryover effect on postural control and potentially performance even after the stressor was removed, indicating some value in measuring these parameters across time as opposed to aggregate measures post-task.

Under the *high* Stressor condition, the participants in this study displayed higher amounts of COP displacement and shifts in head accelerations suggesting that tasks that are cognitively demanding might decrease postural control more that moderate levels of stressors. These results suggest a dose-response relationship between stressor levels and postural control and psychomotor performance. Our findings align with the results by Pellecchia (2003), wherein postural sway increased with increased cognitive workload.

This pilot study was limited by the small number of participants. The analysis was limited to exploratory and descriptive statistics; a more detailed analysis using inferential statistics is on-going. Participants in this study did not have previous experience with using a laparoscopy simulator and instruments so their performance and response to environmental stressors may not be directly comparable to that of more experienced surgeons and surgical trainees. Despite the ~10-15 minutes of practice, a learning effect may have occurred. Effects of cumulative fatigue, both mental and physical, may have negatively impaired performance, and are expected to occur in tasks requiring sustained attention including surgery which typically last more than 30 minutes. However, the dependent measures showed consistent trends across participants indicating similar underlying mechanisms, and promise for a larger and more elaborate subsequent study. Further investigation with additional physiological (e.g. heart rate variability) and subjective (state-trait anxiety inventory) measurements of stress are needed to develop a more generalizable model of human responses to environmental stressors with potential applications to surgical training and real-time surgical team monitoring.

ACKNOWLEDGEMENT

The authors are grateful to Dr. Deborah Rooney at the UM Clinical Simulation Center for providing the laparoscopic trainer system needed for the study.

This publication was supported by traineeship support received (to YL) through the training grant T42-OH008455 from the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the Centers for Disease Control and Prevention or the Department of Health and Human Services.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Author Manuscript
Author Manuscript
Author Manuscript
Author Manuscript

REFERENCES

Andersson G, Hagman J, Talianzadeh R, Svedberg A, & Larsen HC (2002). Effect of cognitive load on postural control. Brain Research Bulletin,58(1), 135–139. doi: 10.1016/s0361-9230(02)00770-0 [PubMed: 12121823]

Butler KA, Kapetanakis VE, Smith BE, Sanjak M, Verheijde JL, Chang YH, … Magrina JF (2013). Surgeon Fatigue and Postural Stability: Is Robotic Better Than Laparoscopic Surgery? Journal of Laparoendoscopic & Advanced Surgical Techniques, 23(4), 343–346. doi: 10.1089/lap.2012.0531 [PubMed: 23410117]

Chrouser KL, Xu J, Hallbeck S, Weinger MB, & Partin MR (2018). The influence of stress responses on surgical performance and outcomes: Literature review and the development of the surgical stress effects (SSE) framework. The American Journal of Surgery, 216(3), 573–584. doi:10.1016/j.amjsurg.2018.02.017 [PubMed: 29525056]

Lee G, & Park AE (2007). Development of a more robust tool for postural stability analysis of laparoscopic surgeons. Surgical Endoscopy,22(4), 1087–1092. doi: 10.1007/s00464-007-9664-3 [PubMed: 18030522]

Pellecchia GL (2003). Postural sway increases with attentional demands of concurrent cognitive task. Gait & Posture, 18(1), 29–34. doi: 10.1016/s0966-6362(02)00138-8 [PubMed: 12855298]

Prado JM, Stoffregen TA, & Duarte M (2007). Postural Sway during Dual Tasks in Young and Elderly Adults. Gerontology,53(5), 274–281. doi: 10.1159/000102938 [PubMed: 17510558]

Ronstrom C, Hallbeck S, Lowndes B, Chrouser KL (2018) Surgical Ergonomics In: Köhler T, Schwartz B (eds) Surgeons as Educators. Springer, Cham 10.1007/978-3-319-64728-9_22

Savoie S, Tanguay S, Centomo H, Beauchamp G, Anidjar M, & Prince F (2007). Postural control during laparoscopic surgical tasks. The American journal of surgery, 193(4), 498–501. [PubMed: 17368298]

Sroka G, Feldman LS, Vassiliou MC, Kaneva PA, Fayez R, & Fried GM (2010). Fundamentals of Laparoscopic Surgery simulator training to proficiency improves laparoscopic performance in the operating room—a randomized controlled trial. The American Journal of Surgery, 199(1), 115–120. doi:10.1016/j.amjsurg.2009.07.035 [PubMed: 20103076]

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

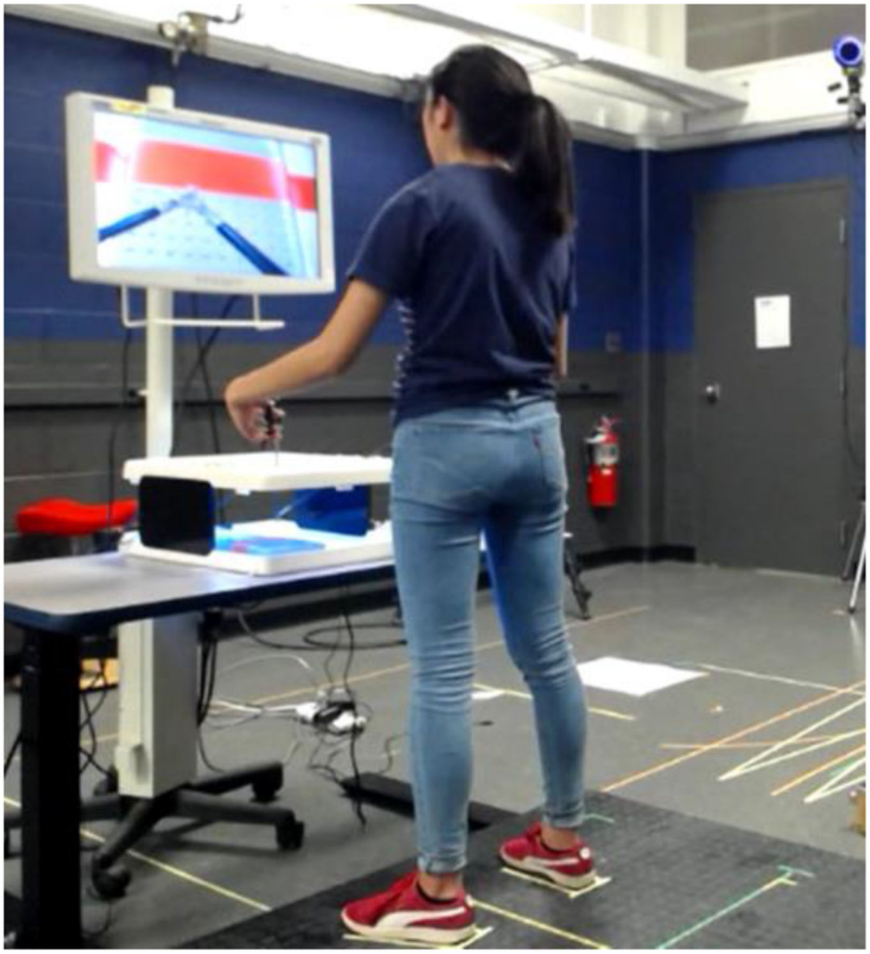

Figure 1:
Example of participant self-selected upright posture.

Author Manuscript
Author Manuscript
Author Manuscript
Author Manuscript

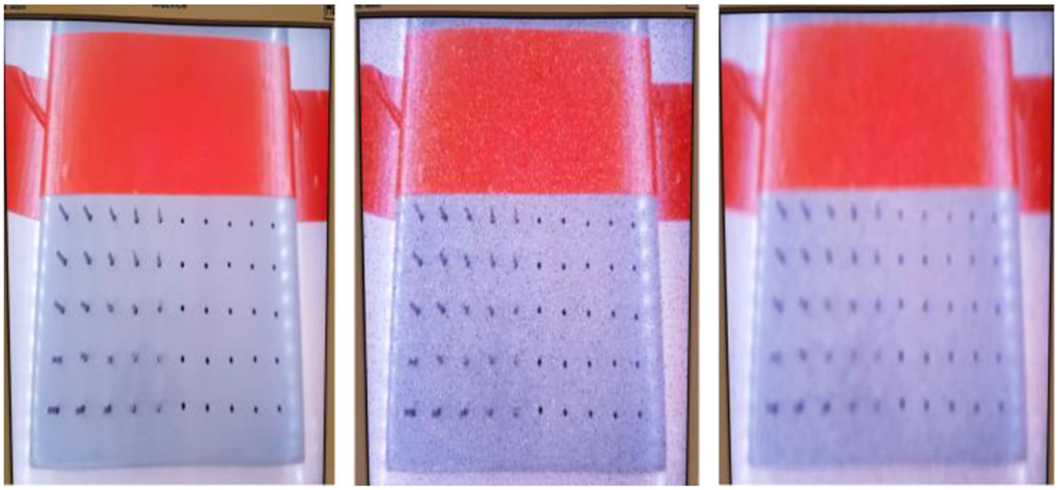

Figure 2:
Three levels of visual stressor, namely None representing the unaltered visual display (left), Low (middle) and high (right).

Author Manuscript
Author Manuscript
Author Manuscript
Author Manuscript

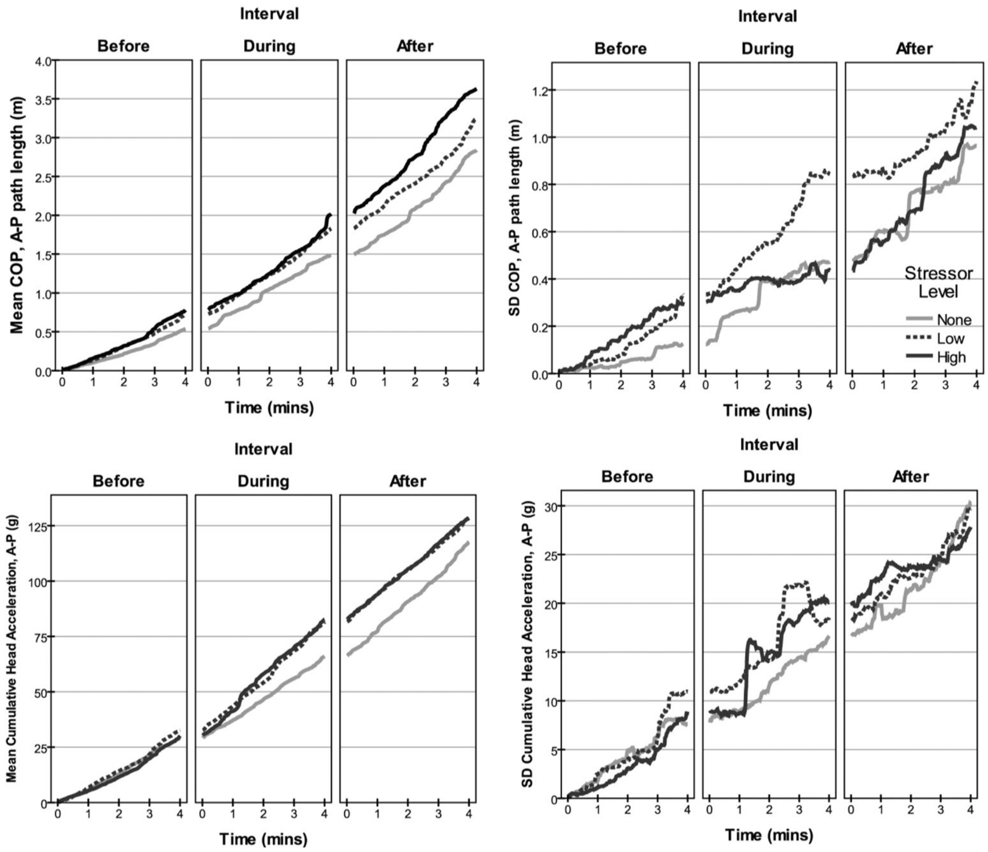

Figure 3:
Postural control: Mean (left) and SD (right) trajectories (n = 7) for COP path length (top) and cumulative head accelerations (bottom) in the A-P direction for the 12min timed trials by stressor level.

Author Manuscript
Author Manuscript
Author Manuscript
Author Manuscript

Table 1:

Task Performance:

Mean ± SD values (n = 7) for total pins transferred during each time period and stress condition.

Stressor	Before	During	After
None	9.57 ± 4.12	8.43 ± 2.94	10.00 ± 4.62
Low	12.14 ± 3.39	3.43 ± 1.62	10.00 ± 3.67
High	13.71 ± 3.30	2.71 ± 1.70	10.43 ± 4.47

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 2:

Postural control:

Mean ± SD (n = 7) values for cumulative COP displacement (cm) at the end of each 4-min interval (before, during and after) in the Anterior-Posterior and Medial-Lateral direction by stressor level.

Stressor Level	Anterior – Posterior			Medial – Lateral		
	Before	During	After	Before	During	After
None	53.8 ± 12.5	148.7 ± 47.2	283.7 ± 96.4	75.5 ± 24.4	215.8 ± 66.2	426.0 ± 135.4
Low	72.7 ± 33.5	182.9 ± 84.3	325.6 ± 123.6	111.4 ± 67.3	289.9 ± 174.3	509.7 ± 264.3
High	77.8 ± 30.2	201.76 ± 43.6	362.7 ± 104.0	128.9 ± 65.8	327.5 ± 120.8	588.1 ± 259.5

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Table 3:

Postural control:

Mean ± SD (n = 7) values for cumulative linear acceleration (g) at the head at the end of each 4-min interval (before, during and after) in the Anterior-Posterior and Medial-Lateral direction by stressor level.

Stressor Level	Anterior – Posterior			Medial – Lateral		
	Before	During	After	Before	During	After
None	29.0 ± 7.6	66.0 ± 16.7	117.6 ± 30.2	4.7 ± 2.3	11.2 ± 4.4	20.6 ± 9.2
Low	32.6 ± 10.9	81.5± 18.5	128.8 ± 29.7	6.0 ± 2.6	15.0 ± 4.8	23.8 ± 6.8
High	30.1 ± 8.9	82.6 ± 20.1	128.4 ± 27.8	4.3 ± 0.4	14.4 ± 3.7	23.3 ± 4.9