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Postural changes in a working environment: A possible mechanism to alleviate sedentary behavior

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Postural changes in a working environment: A possible mechanism to alleviate sedentary behavior

Objectives: The purpose of this study was to investigate the effects of standing and sitting-standing positional changes on energy cost as a method for interrupting sedentary sitting time while working.

Background: Sedentary lifestyles have recently been identified as a potential mechanism for obesity and associated metabolic diseases linked to ill health.

Method: 26 healthy male volunteers performed normal typing and editing work for 100 minutes under three conditions. The conditions included; sustained sitting, sustained standing and sitting-standing alternation every 20min using a sit-stand desk. Respiratory parameters measured included minute ventilation (VE), oxygen consumption (VO2) and energy expenditure (EE). Measurements were recorded using a calibrated $K4b^2$ portable gas analysis system. Analysis of variance was used to identify any differences between the three conditions.

Results: The mean value for VE in the standing position was the highest, followed by sitting-standing alternation. Both were significantly different from sitting. The maximum VE and EE for standing and sitting-standing alternation were significantly higher than that of sitting. No significant differences were observed in the mean VO_2 among the three conditions. However, the maximum VO_2 for both standing and sitting-standing alternation was significantly higher than sitting. There were no significant differences observed in the mean EE levels between sitting and sitting-standing alternation. However, the mean EE while standing increased significantly compared with sitting.

Conclusion: This study provides evidence how sitting-standing alternations affect energy cost compared with sustained sitting. The findings of this study indicate that sitting-standing alternations may be implemented as an effective intervention to interrupt prolonged sitting while working. The findings also suggest that the changes in respiratory parameters observed, may provide an effective method to help prevent the onset of obesity and sedentary behavior.

Application: The office workers using a sit-stand desk performing minimal intensity sitting-standing alternations (longer duration of standing than sitting in one cycle) to reduce adverse effects of sedentary behavior.

Keywords: Sedentary behavior, Sitting-standing alternation, Energy expenditure, Health benefits

INTRODUCTION

Sedentary behavior has long been associated with increased ill health (Dunstan et al., 2012; Healy et al., 2008). Evidence suggests that there is a positive relationship between sitting time and risk of type II diabetes, (Proper et al., 2011; Wilmot et al., 2012) as well as cardiovascular disease (Ekblom-Bak et al., 2010; Matthews et al., 2012; Owen et al., 2010). In addition, low energy consumption associated with a seated position (Hamilton et al., 2007) is considered an important contributory factor in the increased prevalence of overweight and obesity (John et al., 2011; Levine et al., 2007; Wanner et al., 2016).

Previous studies have suggested that strategies of interrupting sedentary behavior may improve health outcomes (Chae et al., 2015). Research by (Buckley et al., 2015) provided guidelines for employers to promote the avoidance of prolonged periods of sedentary work, suggesting that seated-based work should be regularly alternated with the goal of accumulating 2 hours of standing per day. This included light walking, eventually progressing to a total accumulation of 4 hours per day. Potential mechanisms for promoting health by reducing sedentary time may be associated with increased oxidative metabolism when using treadmill and sit-stand workstations during walking and standing. In a work-based environment, energy expenditure while sitting is reported to be 45-76 kcal/h, which increases to 88 kcal/h while standing and 148-191 kcal/h while walking (Levine & Miller, 2007; Beers et al., 2008; Cox et al., 2011). More recently, Carter et al (Carter et al., 2015) reported that treadmill walking led to a higher total energy consumption and heart rate compared with sitting and standing. However, the relatively high cost of treadmill desk related equipment is likely to limit practical applications (Carr et al., 2012). Moreover, high intensity activity (moderate-to-vigorous intensity) such as jogging on a treadmill may potentially impair work productivity and could be dangerous (Liao & Drury, 2000).

Alternatively, standing has been considered an effective intervention to avoid the negative effects of sedentary time without affecting work productivity (Chaua et al., 2016). Buckley et al. (Buckley et al., 2013) noted that along with attenuated postprandial blood glucose, energy expenditure during an afternoon standing while working was 0.83 Kcals/min higher than performing the same task while sitting. However, previous research has demonstrated that prolonged standing may lead to lower leg swelling, knee discomfort and venous pooling (Chester et al., 2002). Lower back fatigue and pain have also been frequently reported as a consequence of prolonged standing (Gallagher & Callaghan, 2015; Marshall et al., 2011). Júdice et al. (Júdice et al., 2016) compared the metabolic/energy cost between sitting, standing and sitting-standing transition. They observed that sitting-standing transition (1set/min) and sustained standing had a metabolic cost of 0.32 Kcal/min and was 0.07 Kcal/min higher than sitting, respectively. However, a limitation of the study was that it only measured metabolic cost for a short time period (10mins).

Because it is not feasible to repeat one set of sitting-standing transition per minute during an 8-hour work period, the effects of longer durations of standing or sitting-standing alternations on the energy cost involved in minimizing sedentary behavior remains unclear. Therefore, the purpose of this study was to explore any respiratory differences in minute ventilation (VE), relative oxygen consumption (VO_2) and energy expenditure (EE) between sitting, standing and sitting-standing alternation every 20mins during 100-minutes of working hours. It was hypothesized that standing and sitting-standing alternation would increase energy cost when compared with sustained sitting.

METHOD

Participants

26 healthy males volunteered to participate in this experiment. The average age of participants was 23.20±1.83 years, average stature was 177.65±4.47 cm, average mass was 69.5±3.68 kg, and the average Body Mass Index (BMI) was 21.99±0.89 kg/m^2. Participants with a smoking history, cardiovascular disease, endocrine and metabolic disorders were excluded following medical screening.

Equipment

A calibrated $K4b^2$ portable gas analysis system (COSMED, Rome, Italy) was used to measure energy expenditure. The $K4b^2$ system has been validated as a reliable device for measuring oxygen consumption (Duffield et al., 2004). It is a portable telemetric analysis system measuring VE (minute ventilation), F_EO_2 (fractional concentrations of expired oxygen) and F_ECO_2 (carbon dioxide) during breathing. VO_2 (oxygen consumption) and VCO_2 (the volume of carbon dioxide generated) were calculated using the unit's microprocessor in conjunction with the Haldane transformation algorithm. A sit-stand desk (Loctek, China), the height of which was adjusted to the specific height of the participants via an electric system, was used in the experiment (Fig 1).

Study Design and Data Collection

Environmental temperature in the laboratory was kept controlled and constant between 21-24 °C. Participants were required to avoid strenuous exercise 24 hours prior to testing. The participants were also told to avoid using caffeine or other stimulants 24 hours prior to the test, and to avoid food consumption 2 hours prior to testing. Each subject was advised to adjust the desk height while sitting as well as standing. This facilitated a comfortable and erect posture under both conditions. Additionally, all subjects were given familiarization periods to ensure that they could work wearing the $K4b^2$ portable gas analysis system face mask. For each subject, tests were implemented under three conditions within three days. During measurement, all subjects were required to perform normal text editing tasks or video watching activities lasting 100min at the same time period of each day. This avoided the effects of diurnal variation on data collection between the three conditions. Subjects were randomly assigned to each condition. Talking was not allowed during the data collection period. The different testing conditions are outlined below;

Condition 1 (Day 1): On the first day, tests were performed under sitting conditions from 9: 30 am to 11: 10 am. The average height of desk was 86±4.92 cm.

Condition 2 (Day 2): On the second day, tests were performed under standing conditions from 9: 30 am to 11: 10 am. The average height of desk was 115±5.01 cm.

Condition 3 (Day 3): On the third day, tests were performed under sitting-standing conditions from 9: 30 am to 11: 10 am. Posture alteration occurred every 20 min with a starting posture of standing (session 1: standing from 9: 30 am to 9: 50 am; session 2: sitting from 9: 50 am to 10: 10 am; session 3: standing from 10: 10 am to 10: 30 am; session 4: sitting from 10:30 am to 10: 50 am; session 5: standing from 10: 50 am to 11: 10 am). The average height of desk while standing and sitting was 115±5.01 cm and 86±4.92 cm, respectively.

Figure 1 near here.

Statistical Analysis

Parameters of minute ventilation (VE), relative oxygen consumption (VO_2) and energy expenditure (EE) during the 100-minute test were selected for analysis. Descriptive subject characteristics are presented as means ± SD. All analyses were conducted using SPSS for Windows, version 19.0 (SPSS Inc., Chicago, IL, USA). An analysis of variance (ANOVA) was used to verify differences in VE, VO_2, and EE between the different postures of standing, sitting and sitting-standing. Significance level was set at $p<0.05$. Where significant differences were observed a Bonferroni post hoc test was conducted.

RESULTS

Fig 2 shows the comparison of relative oxygen consumption (VO_2), minute ventilation (VE), and energy expenditure (EE) between sitting, standing and sitting-standing during 100-minute testing period. Although the mean VO_2 for standing and sitting-standing alternation was 16.83 % and 14.36 % respectively higher than sitting, there were no significant differences among three conditions (Table 1). However, the maximum VO_2 for both standing and sitting-standing alternation was significantly higher than sitting (Table 1). As shown in Fig 2(a), the curve for VO_2 exhibits a rapid increase in the first 10 minutes for sitting and 20 minutes for standing and sitting-standing posture change. The curve for VO_2 in the standing condition enters into a relatively steady phase with a slight increase. During sitting, it shows a second peak approximately at the 50 minute testing stage. Different from the curve recorded for sitting and standing, the curve for sitting-standing posture change seems to be more irregular and fluctuating.

As shown in Fig 2(b), the mean VE for standing is the highest during the entire 100-minute testing period, followed by the sitting-standing postural change with sitting recording the lowest value. The curves of VE for standing and sitting show a constant trend compared with sitting-standing postural change. Similar to the curve observed for VO2, the curve for VE recorded for sitting-standing postural change also seems to be irregular and fluctuating. Changes for mean EE are comparable with VE corresponding to each condition (Fig 2(c)). The maximum VE and EE for standing and sitting-standing alternation were significantly higher than that of sitting (Table 1). Significant differences were also observed in the mean EE between sitting and standing (Table 1).

Figure 2 near here.

Table 1 near here.

As listed in Table 2, the total EE for standing was higher than sitting, and statistical analysis showed significant differences during all segmented periods. Difference in the total EE between sitting-standing postural change and sitting was not noticeable compared with sitting except for the first period (from 0 to 20 min) (P=0.041). Results of the mean EE per minute remained consistent with the total EE. With regard to the increase rate of EE per minute, it showed negative values during sitting periods of sitting-standing postural change (the second and fourth periods) with downward trends observed. EE also showed a raising/upward trend during standing periods (the first, third and fifth periods) (Fig 3).

Figure 3 near here.

Table 2 near here.

Table 3 displays the extrapolation of the amount of energy expended for longer periods of time. An extra 95.67 Kcal would be expended while standing assuming working eight hours every day. In addition, an additional 59.02 Kcal would be expended when utilizing sitting-standing postural change working for the same time. Larger energy consumption would be expected if standing or sitting-standing postural change was performed in a seated-based work environment over longer periods, assuming that a similar level of energy output is maintained.

Table 3 near here.

DISCUSSION

Office workers spend hours sitting at desks without ambulation; as a result, intermittent standing during office work is a simple and feasible intervention to reduce the negative effects of sedentary time by increasing energy expenditure. This study provides insight into how sitting-standing postural changes can have a positive effect on sedentary behavior in terms of energy cost.

Different from moderate exercise of sitting-standing transition with a frequency of one repetition per minute reported by Júdice et al. (Júdice et al., 2016), this study tested energy cost under minimal intensity physical activity of sitting-standing alternation every 20min. Additionally, longer durations of 100-minute testing is more conducive for simulating sedentary behavior than short periods of 10 minutes (Júdice et al., 2016). The VE (minute ventilation) while standing and sitting-standing alternation increased significantly compared with sitting. In contrast to the expected outcome, statistical significance in EE only existed between sitting and standing, while there was no difference detected between sitting and the sitting-standing condition. Thorp et al. (Thorp et al., 2016) investigated energy expenditure while sitting and alternating between standing and seated work posture every 30min among obese individuals. They found that intermittent standing at work can modestly increase (13%) daily workplace energy expenditure compared to seated work. Moreover, it is important to highlight that if the standing portion of the sit-stand cycle is too long, it may lead to musculoskeletal discomfort, swelling and fatigue in the lower limbs, lower back and contribute to chronic venous insufficiency (Chester et al., 2002; Roelen et al., 2008). Research by Hasegawa et al. (Hasegawa et al., 2001) supported the notion that a change of posture while sitting contributes to alleviating the feeling of fatigue during a short-term light reduplicative task. There was a gradual decline in EE during the second and fourth periods under the sitting-standing alternation condition, in contrast, the curves of sitting and standing showed to be flat with an obvious increase observed under the standing condition during the fourth period. It is sensible to regard sitting periods while sitting-standing alternation as recovery phases, which contribute to relieving fatigue causing by prolonged standing. With respect to work productivity, Ebara et al. (Ebara et al., 2008) stated that there was a tendency for high work performance under the combined condition of 10-minute sitting and 5-minute standing compared with sustained sitting within a 150 minute time period. In spite of a decline in EE during the second and fourth periods in this study, the mean EE of sitting-standing alternation was 8.39 % higher than sitting during the entire 100-minute testing period. Accordingly, it seems likely to assume that sitting-standing alternation with minimal intensity may lower health risks causing by sedentary behavior without affecting productivity while minimizing fatigue.

It is possible that the responses observed breaking up sedentary time with routines of 100-minute standing and sitting-standing alternations every 20min have the potential to produce longer term health benefits if the routines were performed over an extended period. Over an eight-hour working day, additional energy expenditure of 95.67 Kcal and 59.02 Kcal would be expected when performing sustained standing and sitting-standing alternations respectively compared with only sitting for the same period. However, it has been suggested that prolonged standing for less than1 hour and a total duration of less than 4 hours per day is considered safe (Waters & Dick, 2015).

There are several limitations in this study that need consideration. Firstly, it is difficult to include all related factors, such as work stress, meetings and other administrative duties that occur in a real work environment. Secondly, this study only recruited male subjects who were under 25 years of age; therefore, potential gender and age differences need to be explored in future research. Thirdly, in addition to energy expenditure, further studies should include evaluation of physiological/biochemical measures such as blood pressure, cholesterol, and postprandial glucose responses in an attempt to demonstrate underlying causality between improving health outcomes and interrupting sedentary time with the intervention of sitting-standing alternation.

CONCLUSION

This study confirmed that light intensity physical activity of sustained standing and sitting-standing alternations could increase energy cost compared with sustained sitting. The maximum VE and EE for standing and sitting-standing alternation were significantly higher than that of sitting. No significant differences were observed in the mean VO_2 among the three conditions. However, the maximum VO_2 for both standing and sitting-standing alternation was significantly higher than sitting. The mean minute ventilation while standing was the highest, followed by sitting-standing alternation. EE while standing was significantly higher than sitting, and that of sitting-standing alternation was 8.39% higher than sitting without significance, indicating that moderately extending standing portion of sitting-standing cycle may contribute to increasing EE compared with sustained sitting. However, considering the hazards of prolonged standing on health outcomes in the long term, it is suggested that office workers use a sit-stand desk performing minimal intensity sitting-standing alternations (longer duration of standing than sitting in one cycle). This may have benefits in reducing the adverse effects of sedentary behavior particularly for weight gain due to excessive sitting time.

ABBREVIATIONS

VE: Minute ventilation; VO2: Oxygen consumption; EE: energy expenditure

DECLARATIONS

Ethics approval and consent to participate.

This study was approved by the Human Ethics Committee of Ningbo University (Reference Number: ARGH20160621). All subjects were informed about the consent for inclusion in the study, the goal and funding organization of the study.

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KEY POINTS

- The mean VE (minute ventilation) while standing and sitting-standing alternation increased significantly compared with sitting.
- The maximum VO_2 for both standing and sitting-standing alternation showed to be significantly higher than sitting.
- The mean EE of sitting-standing alternation was 8.39 % higher than sitting during the entire 100-minute testing period.
- The sitting-standing alternation with minimal intensity may lower health risks causing by sedentary behavior without affecting productivity while minimizing fatigue.

REFERENCES

Beers, E. A., Roemmich, J. N., Epstein, L. H., & Horvath, P. J. (2008). Increasing passive energy expenditure during clerical work. *European Journal of Applied Physiology, 103,* 353-360.

Buckley, J. P., Hedge, A., Yates, T., Copeland, R. J., Loosemore, M., & Hamer, M. (2015). The sedentary office: a growing case for change towards better health and productivity, expert statement commissioned by public health england and the active working community interest company. *British Journal of Sports Medicine, 49*, 1357-1362.

Buckley, J. P., Mellor, D. D., Morris, M., & Joseph, F. (2014). Standing-based office work shows encouraging signs of attenuating post-prandial glycaemic excursion. *Occupational & Environmental Medicine, 71*, 109-111.

Carr, L. J., Walaska, K. A., & Marcus, B. H. (2012). Feasibility of a portable pedal exercise machine for reducing sedentary time in the workplace. *British Journal of Sports Medicine, 46*, 430.

Carter, S. E., Jones, M., & Gladwell, V. F. (2015). Energy expenditure and heart rate response to breaking up sedentary time with three different physical activity interventions. *Nutr Metab Cardiovasc Dis, 25*, 503-509.

Chae, D., Kim, S., Park, Y., & Hwang, Y. (2015). The effects of an academic-workplace partnership intervention to promote physical activity in sedentary office workers. *Workplace Health & Safety, 63*, 259-266.

Chau, J. Y., Sukala, W., Fedel, K., Do, A., Engelen, L., & Kingham, M. (2015). More standing and just as productive: effects of a sit-stand desk intervention on call center workers' sitting, standing, and productivity at work in the top to stand pilot study. *Preventive Medicine Reports, 3*, 68-74.

Chester, M. R., Rys, M. J., & Konz, S. A. (2002). Leg swelling, comfort and fatigue when sitting, standing, and sit/standing. *International Journal of Industrial Ergonomics, 29*, 289-296.

Cox, R. H., Guth, J., Siekemeyer, L., Kellems, B., Brehm, S. B., & Ohlinger, C. M. (2011). Metabolic cost and speech quality while using an active workstation. *Journal of Physical Activity & Health, 8*, 332-339.

Dunstan, D. W., Howard, B., Healy, G. N., & Owen, N. (2012). Too much sitting--a health hazard. *Diabetes Research & Clinical Practice, 97*, 368-76.

Ebara, T., Kubo, T., Inoue, T., Murasaki, G. I., Takeyama, H., & Sato, T. (2008). Effects of adjustable sit-stand vdt workstations on workers' musculoskeletal discomfort, alertness and performance. *Industrial Health, 46*, 497-505.

Ekblom-Bak, E., Hellénius, M. L., & Ekblom, B. (2010). Are we facing a new paradigm of inactivity physiology?. *British Journal of Sports Medicine, 44*, 834-5.

Gallagher, K. M., & Callaghan, J. P. (2015). Early static standing is associated with prolonged standing induced low back pain. *Human Movement Science, 44*, 111-121.

Hamilton, M. T., Hamilton, D. G., & Zderic, T. W. (2007). Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes, 56*, 2655.

Hasegawa, T., Inoue, K., Tsutsue, O., & Kumashiro, M. (2001). Effects of a sit–stand schedule on a light repetitive task. *International Journal of Industrial Ergonomics, 28*, 219-224.

Healy, G. N., Dunstan, D. W., Salmon, J., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2008). Television time and continuous metabolic risk in physically active adults. *Medicine & Science in Sports & Exercise, 40*, 639.

John, D., Thompson, D. L., Raynor, H., Bielak, K., Rider, B., & Bassett, D. R. (2011). Treadmill workstations: a worksite physical activity intervention in overweight and obese office workers. *J Phys Act Health, 8*, 1034-1043.

Júdice, P. B., Hamilton, M. T., Sardinha, L. B., Zderic, T. W., & Silva, A. M. (2016). What is the metabolic and energy cost of sitting, standing and sit/stand transitions?. *European Journal of Applied Physiology, 116*, 263-273.

Levine, J. A., & Miller, J. M. (2007). The energy expenditure of using a “walk-and-work” desk for office workers with obesity. *Br J Sports Med, 41*, 558-561.

Liao, M. H., & Drury, C. G. (2000). Posture, discomfort and performance in a vdt task. *Ergonomics, 43*, 345-59.

Marshall, P. W., Patel, H., & Callaghan, J. P. (2011). Gluteus medius strength, endurance, and co-activation in the development of low back pain during prolonged standing. *Human Movement Science*, *30*, 63-73.

Matthews, C. E., George, S. M., Moore, S. C., Bowles, H. R., Blair, A., & Park, Y. (2012). Amount of time spent in sedentary behaviors and cause-specific mortality in us adults. *American Journal of Clinical Nutrition, 95*, 437-445.

Miriam, W., Martin, B. W., Autenrieth, C. S., Emmanuel, S., Flurina, M., & Christine, B. (2016). Associations between domains of physical activity, sitting time, and different measures of overweight and obesity. *Preventive Medicine Reports, 3*, 177-184.

Owen, N., Healy, G. N., Matthews, C. E., & Dunstan, D. W. (2010). Too much sitting: the population health science of sedentary behavior. *Exercise & Sport Sciences Reviews, 38*, 105-113.

Proper, K. I., Singh, A. S., Van, M. W., & Chinapaw, M. J. (2011). Sedentary behaviors and health outcomes among adults : a systematic review of prospective studies. *American Journal of Preventive Medicine, 40*, 174-182.

Roelen, C. A., Schreuder, K. J., Koopmans, P. C., & Groothoff, J. W. (2008). Perceived job demands relate to self-reported health complaints. *Occupational Medicine, 58*, 58-63.

Thorp, A. A., Kingwell, B. A., English, C., Hammond, L., Sethi, P., & Owen, N. (2015). Alternating sitting and standing increases the workplace energy expenditure of overweight adults. *J Phys Act Health, 13*, 24-29.

Waters, T. R., & Dick, R. B. (2015). Evidence of health risks associated with prolonged standing at work and intervention effectiveness. *Rehabilitation Nursing, 40*, 148–165.

Wilmot, E. G., Edwardson, C. L., Achana, F. A., Davies, M. J., Gorely, T., & Gray, L. J. (2012). Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. *Diabetologia, 55*, 2895.

Table 1. Characteristics of VO_2, VE and EE during 100-minute sitting (Sit); standing (Stand) and sitting-standing alternation (Sit-stand) (mean ± SD).

		Sit	Stand	Sit-stand
VO_2(ml/min/kg)	Mean	4.04±0.38	4.72±0.42	4.62±0.49
	Increase %	-	16.83±3.46	14.36±2.72

	Max	4.50±0.18	5.40±0.20 **	5.14±0.17 #
VE(min^{-1})	Mean	10.59±0.69	13.33±0.71 **	12.04±0.62 #
	Increase %	-	25.87±5.83	13.69±2.02
	Max	12.15±0.42	14.81±0.43 **	14.80±0.40 ##
EE(Kcal/min)	Mean	1.43±0.07	1.62±0.09 *	1.55±0.08
	Increase %	-	13.28±1.88	8.39±0.94
	Max	1.67±0.07	1.84±0.10 **	1.93±0.08 #

Note: Increase % refers to percentage increases of the mean VO_2, VE and EE while standing and sitting-standing alternation compared with sitting. - refers to none value. * $P<0.05$, Sit vs Stand; # $P<0.05$, Sit vs Stand-sit; ** $P<0.01$, Sit vs Stand; ## $P<0.01$, Sit vs Stand-sit.

Table 2. Comparison of energy expenditure during different phases.

Phases		Sit	Stand	Sit-stand
0-20	V(Kcal/min)	$(13.26\pm1.49)*10^{-3}$	$(20.67\pm3.01)*10^{-3}$	$(17.5\pm1.86)*10^{-3}$
min	Mean (Kcal/min)	1.260±0.089	1.464±0.133*	1.467±0.101#

	Total (Kcal)	25.191±2.37	29.292±2.61*	29.523±2.44#
20-40 min	V(Kcal/min)	(5.28±0.76)*10^{-3}	(-0.22±0.06)*10^{-3}	(-5.26±0.69)*10^{-3}
	Mean (Kcal/min)	1.350±0.037	1.570±0.011*	1.499±0.041
	Total (Kcal)	27.007±2.19	31.405±2.51*	29.971±2.22
40-60 min	V (Kcal/min)	(2.45±0.31)*10^{-3}	(1.59±0.27)*10^{-3}	(9.89±0.92)*10^{-3}
	Mean (Kcal/min)	1.479±0.015	1.609±0.007*	1.577±0.066
	Total (Kcal)	29.589±2.10	32.181±2.81*	31.537±2.38
60-80 min	V (Kcal/min)	(-0.88±0.01)*10^{-3}	(6.97±0.85)*10^{-3}	(-8.23±0.9)*10^{-3}
	Mean (Kcal/min)	1.481±0.006	1.699±0.048*	1.589±0.058
	Total (Kcal)	29.614±2.42	33.975±3.15*	31.771±2.75
80-100 min	V (Kcal/min)	(10.01±1.58)*10^{-3}	(3.73±0.30)*10^{-3}	(21.7±2.65)*10^{-3}
	Mean (Kcal/min)	1.558±0.070	1.782±0.023*	1.603±0.121
	Total (Kcal)	31.160±2.55	35.639±3.08*	32.056±2.75

Note: V (Kcal/min) indicates the increase of energy expenditure per minute. * $P<0.05$, Sit vs Stand; # $P<0.05$, Sit vs Stand-sit.

Table 3. Extrapolation of the amount of energy expenditure (Unit: Kcal).

Time period	Sit	Stand (Sit + Increase)	Sit-stand (Sit + Increase)
1 h	85.54	85.54+11.97	85.54+7.38
8 h working day	684.32	684.32+95.67	684.32+59.02

5 days of 8 h working days	3421.50	3421.50+478.33	3421.50+259.12
1 month of 8 h working days	13686.40	13686.40+1964.80	13686.40+1180.80
6 months of 8 h working days	88958.78	88958.78+12436.82	88958.78+7673.29
12 months of 8 h working days	177917.56	177917.56+24873.64	177917.56+15346.58

Note: Estimation were performed excluding possible events during working such as meeting and printing.

A B

Fig 1. Data collection while standing (A)/sitting (B) with K4b^2 portable gas analysis system before sit-stand desk.

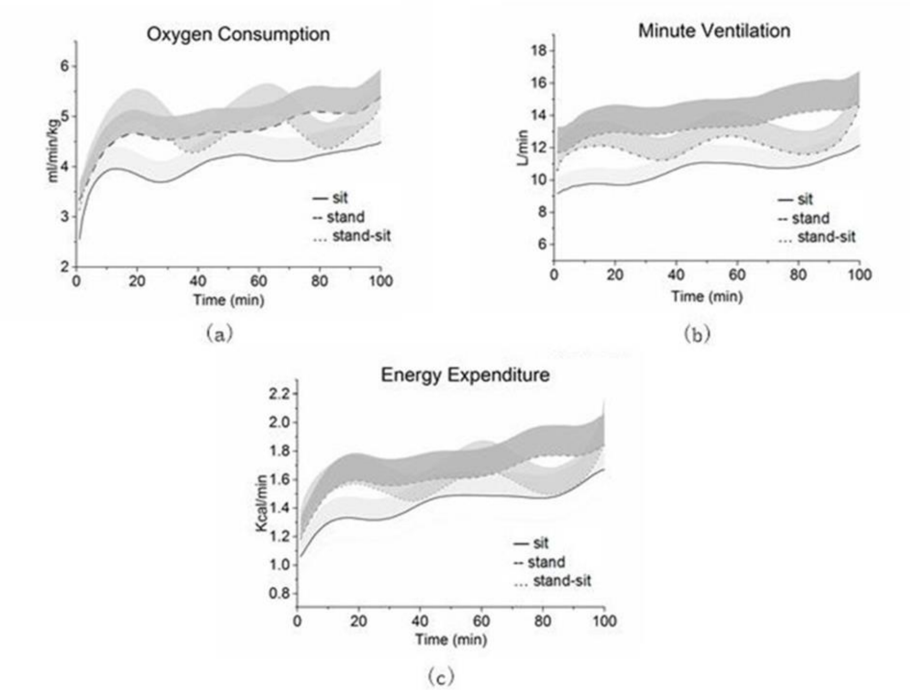

Fig 2. Comparison of VO_2 (a), VE (b) and EE (c) between sitting (solid line), standing (dashed line) and sitting-standing alternation (dot line) while 100-minute test.

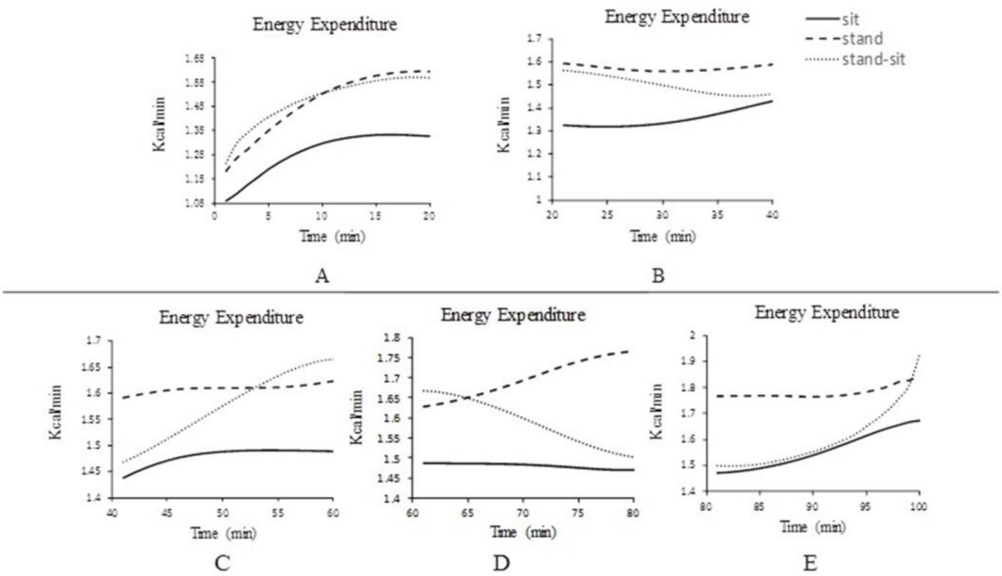

Fig 3. Shows the segmented energy expenditure every 20mins.