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Use of a Standing Desk Increases Energy Expenditure in Obese but Not Normal Weight Subjects

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Abstract

Background: The use of standing desks has been associated with greater metabolic cost as compared to traditional seated desks. However, it is unclear as to the metabolic impact of standing desks in normal weight versus obese men and women. **Methods:** We compared the metabolic cost of using a standing and seated desk in 14 obese and 19 normal weight men and women. Subjects reported to the lab on a single occasion and participated in two, 30-minute sessions of standing and seated desk work (*i.e.*, typing), in random order. Expired gases were collected during the 2-hour period and calorie expenditure was estimated using indirect calorimetry. **Results:** We noted a significant ($p = 0.013$) increase in energy expenditure of 7.4 kcal·30 minutes^{-1} (+14.7%) during standing as compared to seated for the obese group. No significant difference in energy expenditure was noted for the normal weight group ($p = 0.674$). A condition effect was noted for heart rate and diastolic blood pressure, with standing being significantly higher than seated for both variables ($p < 0.05$). No group, condition, or group × condition effects were noted for typing performance or subjective feelings ($p > 0.05$). **Conclusion:** The use of a standing desk modestly increases energy expenditure in obese subjects but does not have the same effect in those of normal weight. It is unknown whether the increased energy expenditure would be maintained over time in the obese subjects/individuals, as they may adapt to the standing position. Moreover, if normal weight individuals choose a standing desk, they should do so for reasons unrelated to increased energy expenditure (e.g., improved spine health, greater feeling of productivity).

Keywords

Metabolic Rate, Standing Desk, Energy Expenditure, Workplace

1. Introduction

Overweight status (body mass index [BMI] ≥ 25 $kg \cdot m^{-2}$) and obesity (body mass index ≥ 30 $kg \cdot m^{-2}$) is on the rise, not only within the United States but also in most developed countries around the world. Obesity affects adults, adolescents, and children of all walks of life. Specifically and according to the CDC, approximately 35% of adults (age > 20 years) are obese [1] and 17% (12.5 million) of children and adolescents (age 2 - 19 years) are obese [2]. Obesity is a lifestyle disease, with individuals' lack of physical activity and poor dietary choices being the main culprits for the rampant rise. Moreover, obesity is strongly associated with other lifestyle diseases including type II diabetes and cardiovascular disease (e.g., high blood pressure, stroke, heart disease). The economic cost of obesity is substantial and estimated at $147 to $210 billion annually [3]. As a result, many individuals seek methods of reducing body weight, with physical activity being one such method.

The National Institutes of Health defines physical activity as any bodily movement that results in increased energy expenditure, relative to resting [4]. Many forms of physical activity exist, including swimming, walking, jogging, dancing, gardening, and yoga, with any form of planned, structured physical activity generically referred to as "exercise." In its most recent position statement, the American College of Sports Medicine (ACSM) states that physical activity regimens exceeding 250 minutes of physical activity per week result in clinically significant weight loss [5]. Indeed, multiple studies have indicated that extended (2000 - 4900 kcal/week), moderate-intensity aerobic exercise training results in significant (5.3% - 8% reduction in total body mass) weight loss in overweight and obese individuals [6] [7] [8]. However, obese individuals may find it difficult to initiate or sustain such exercise regimens. Thus, to augment traditional physical activity regimes, obese individuals seeking to lose weight may benefit from unique modalities that increase physical activity throughout the day. The use of a standing desk is one such modality.

Standing desks—desks designed to allow the user to stand while working at the desk—have increased in popularity in recent years. The rise can be at least partly attributed to the finding that the metabolic cost of using such a desk has been reported to be greater than that of a traditional seated desk [9] [10]. For those attempting to expend additional calories throughout the workday, this can be of interest. Proponents of these standing desks point to the negative outcomes associated with a sedentary lifestyle [11], while citing scientific support for use of the desks, including improved post-prandial glucose responses, increased HDL, decreased triglycerides, and improved total/HDL cholesterol ratio [12] [13] [14] [15]. Because many adults spend 8 - 10 hours of their day working at a desk, it appears logical that switching to a standing desk for even a few hours each day may help to expend additional energy, aiding in the achievement of the minimum 2000 kcal/week energy expenditure goal. Such increased energy expenditure may allow individuals to better control their body weight over time.

While the above many sound promising, data in support of the specific increase in energy expenditure is sparse, especially in obese individuals. Speck and Schmitz stated that the utilization of a standing desk for 7 minutes did not result in an increase in energy expenditure (relative to seated) in sedentary (mean BMI = 27.2 kg·m^{-2}) participants [16]. Conversely, other studies have indicated that typing at a standing desk can produce minor but potentially meaningful increases in energy expenditure [9] [10] [17] [18]. For example, Reiff *et al.* reported that energy expenditure increased by 0.34 kcal·min^{-1} when using a standing desk, relative to using a traditional desk, in young, normal weight individuals [17].

To our knowledge, no study to date has determined the energy cost of using a standing desk in those who are of normal weight (body mass index ≤ 25 kg·m^{-2}) as compared to those who are obese (body mass index ≥ 30 kg·m^{-2}). As many individuals enticed to use a standing desk for energy expenditure purposes are likely not of normal weight, it appears important to understand the degree to which energy expenditure increases (if at all) in obese individuals using a standing desk, as this could prove to be a potential aid to those seeking weight loss.

2. Methods

2.1. Subjects

A total of 33 men and women participated in this study, 14 of whom were obese and 19 of whom were of normal weight. Subjects were required to: 1) be aged 18 - 65; 2) have the ability to sit or stand at a desk for at least one hour continuously without pain or discomfort; 3) be of normal weight (body mass index 18 - 25 kg·m^{-2}) or obese (body mass index ≥30 kg·m^{-2}); 4) be a non-smoker; 5) be willing to eliminate the use of alcohol, caffeine, and other stimulants during the 24-hour period prior to the scheduled test day; 6) be willing to eliminate strenuous physical activity during the 24-hour period prior to the scheduled test day; (7) be capable of typing using a computer keyboard. Subject characteristics are presented in **Table 1**.

Prior to participation, each subject was informed of all procedures, potential risks, and benefits associated with the study through verbal and/or written form in accordance with the procedures approved by the University Institutional Review Board for Human Subjects Research (#PRO-FY2017-317). Subjects provided written informed consent prior to being admitted to participate.

2.2. Initial Laboratory Visit: Screening Visit

During the initial visit to the laboratory, subjects first were instructed to read and sign the informed consent document. They were then screened to determine if they met the study inclusion criteria as outlined above. Subjects' heart rate, blood pressure, height, weight, waist, and hip circumference were measured and used for descriptive purposes. Upon completion of the screening, eligible subjects were scheduled for their single testing visit.

Table 1. Characteristics of normal weight and obese men and women.

Variable	Normal Weight (n = 19)	Obese (n = 14)	p value
Age (years)	23.5 ± 5.5	29.1 ± 11.0	0.066
Height (cm)	173.9 ± 10.7	174.7 ± 9.0	0.965
Weight (kg)	69.7 ± 10.0	109.7 ± 26.2	< 0.0001
BMI ($kg \cdot m^{-2}$)	23.0 ± 1.7	35.7 ± 6.7	< 0.0001
Waist Circumference (cm)	81.1 ± 8.2	107.1 ± 18.8	< 0.0001
Hip Circumference (cm)	99.2 ± 5.5	121.8 ± 12.6	< 0.0001
Waist/Hip Ratio	0.82 ± 0.11	0.87 ± 0.06	0.119
Resting HR (bpm)	70.1 ± 14.9	76.6 ± 16.0	0.260
Resting SBP (mm Hg)	127.4 ± 10.2	126.1 ± 13.6	0.821
Resting DBP (mm Hg)	77.4 ± 9.7	82.9 ± 13.0	0.188

Values are Mean ± SD.

2.3. Laboratory Test Visit

Subjects reported to the Cardiorespiratory/Metabolic lab in the morning hours (between 7 - 9am). Upon arrival to the lab, researchers verbally confirmed that subjects had: undergone an overnight (8 hour) fast; not consumed alcohol, caffeine, or other stimulants in the preceding 24 hours; and not performed strenuous exercise in the preceding 24 hours. Subjects were provided with a standard meal (meal replacement shake: 320 kilocalories, 34 g protein, 15 g fat, 13 g carbohydrate). Following the consumption of the meal replacement shake, subjects rested for 30 minutes. After 30 minutes, subjects were asked to use the rest room and attempt to void, as they would soon begin their two-hour testing period. Upon returning, they were instructed to be seated in the chair at the desk station, log on to the computer, and open a blank Microsoft Word document. The desk station was situated in a private area of the lab, with limited traffic in order to minimize distractions. Subjects were outfitted with the mask of the Parvo Medics metabolic measurement system (Parvo Medics, Sandy, UT, USA), and baseline measurements of heart rate and blood pressure were obtained.

Subjects were then instructed to rest for five minutes while the metabolic system collected baseline measurements. At minute 5 (according to the metabolic system), subjects began to type a standardized script, which contained nutrition-specific information written in easy to understand language, using the keyboard. Subjects used either a desk with an adjustable-height chair or an adjustable-height standing desk (InMovement) with no chair. Subjects were allowed to adjust the seat height or desk height in order to maximize comfort. The seated or standing posture was alternated every 30 minutes, as it has been suggested that posture should be altered every 30 minutes for optimal health benefits. Therefore, subjects spent a total of 60 minutes standing and 60 minutes sitting; the order was randomized. Heart rate and blood pressure were measured two minutes before the end of each 30-minute period prior to alternating to the next posture. Word count during each typing session was calculated as a measure of performance.

During the entire two hour period, subjects wore a facemask used to collect all expired air. The expired air was analyzed for oxygen and CO_2 content via indirect calorimetry using a Parvo Medics metabolic measurement system. The oxygen content allowed for the determination of caloric cost during the seated and standing positions. At the end of each 30-minute collection period, the metabolic system was paused, the facemask was removed, and subjects were allowed to drink as much water as they desired. Following the conclusion of the 2-hour typing session, subjects were asked to comment on their liking, tolerance, and preference for seating and standing. This concluded their single lab session.

2.4. Data Analysis

Values for all variables were calculated, and the data are presented as mean ± SD. Data were analyzed using a condition × weight status analysis of variance, with subsequent post-hoc contrast testing as needed. All analyses were performed using JMP® Pro software (SAS, Cary, NC). Significance was determined as $p \le 0.05$.

3. Results

All participants completed the study. No participant reported a significant adverse event or problem associated with use of the standing desk or other testing protocols. A single trial from one posture was excluded for one participant due to abnormally low/negligible VO_2. All other data were included.

With regard to descriptive variables, several differences were noted between the normal weight and obese groups. As expected, the mean weight ($p < 0.0001$) and BMI ($p < 0.0001$) of the obese group were significantly greater than that of the normal weight group. Additionally, the waist circumference ($p < 0.0001$) and hip circumference ($p < 0.0001$) were also significantly greater for the obese group when compared to the normal weight group. No significant differences were noted between groups for age, height, resting heart rate (HR), resting systolic blood pressure (SBP), or resting diastolic blood pressure (DBP). Data for descriptive variables are reported in Table 1, with associated p values included for each variable.

3.1. Heart Rate and Blood Pressure

Data for HR, SBP, and DBP during testing are presented in Table 2. A condition effect was noted for HR, with standing greater than seated ($p < 0.0001$). No group or group × condition effects were noted for HR ($p > 0.05$).

With respect to blood pressure, a condition effect was noted for DBP, with standing greater than seated ($p = 0.0022$). No group or group × condition effects were noted for DBP ($p > 0.05$). Additionally, no group, condition, or group × condition effects were noted for SBP ($p > 0.05$).

3.2. VO_2 and Energy Expenditure

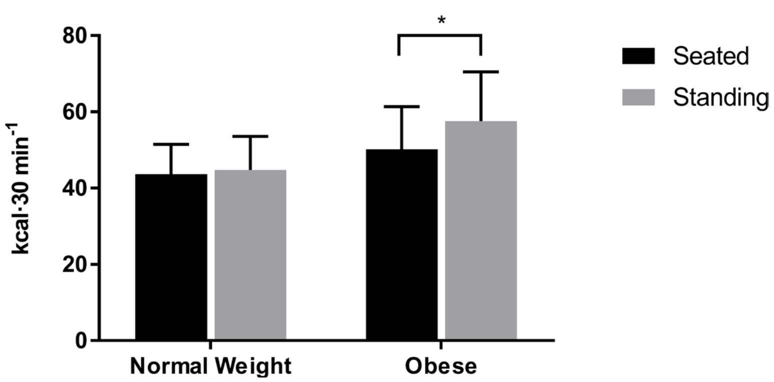
Data for VO_2 and energy expenditure are presented in Table 2. A group effect was noted for VO_2, with the VO_2 of the obese group being significantly greater than that of the normal weight group ($p < 0.0001$). A condition effect was also noted for VO_2, as VO_2 was significantly greater during standing than during seated ($p = 0.0310$). Further, the interaction effect for group × condition trended towards significance ($p = 0.096$), as the increase in VO_2 for the obese group (+0.05 L/min) was greater than that of the normal weight group (+0.1 L/min) when comparing standing versus seated positions.

With respect to energy expenditure, a group effect was noted, as the energy expenditure of the obese group was significantly greater than that of the normal weight group ($p < 0.0001$). A condition effect was also noted for energy expenditure. Participants expended significantly more kcal per 30 minutes when standing as compared to seated ($p = 0.0315$). A trend toward significance was noted for the group × condition interaction effect for energy expenditure ($p = 0.1073$), as the increase in energy expenditure between seated and standing was greater

Table 2. Heart rate, SBP, DBP, VO_2, and energy expenditure of normal weight and obese men and women performing 2 hours of typing while alternating between seated and standing postures every 30 minutes.

Variable	Normal Weight		Obese	
	Seated	Standing	Seated	Standing
HR (bpm)*	67.2 ± 11.6	80.3 ± 14.6	74.6 ± 12.5	83.6 ± 14.6
SBP (mm Hg)	120.9 ± 10.4	121.4 ± 11.4	123.1 ± 11.6	121.9 ± 11.2
DBP (mm Hg)*	73.3 ± 8.1	80.5 ± 8.8	80.4 ± 10.6	83.1 ± 11.8
VO_2 ($L·min^{-1}$)*†	0.30 ± 0.06	0.31 ± 0.06	0.35 ± 0.08	0.40 ± 0.09
Energy Expenditure ($kcal·30\ min^{-1}$)*†	43.7 ± 7.8	44.7 ± 8.8	50.2 ± 11.2	57.6 ± 12.9

Values are Mean ± SD. *A condition effect was noted for Heart Rate ($p < 0.0001$), DBP ($p = 0.0022$), VO_2 ($p = 0.0310$), and Energy Expenditure ($p = 0.0315$); †A group effect was noted for VO_2 ($p < 0.0001$) and Energy Expenditure ($p < 0.0001$).



Values are Mean ± SD. *Significant effect noted for the Obese group between standing and sitting ($p = 0.013$); No significant effect noted for the Normal Weight group ($p = 0.674$).

Figure 1. Energy expenditure of normal weight and obese men and women performing 2 hours of typing while alternating between seated and standing postures every 30 minutes.

for the obese group (+7.4 kcal·30min^{-1}) than for the normal weight group (+1.0 kcal·30min^{-1}). As displayed in **Figure 1**, energy expenditure was significantly greater during standing when compared to seated (+14.7%) for the obese group ($p = 0.013$). However, the normal weight group did not display a significant effect when comparing energy expenditure of seated and standing postures ($p = 0.674$).

3.3. Typing Performance and Subjective Feelings

Typing performance, as measured by word count, displayed a significant group effect ($p = 0.0002$), with the normal weight group typing significantly more words per 30 minutes (788.9 ± 30.9) than the obese group (605.8 ± 35.4). No significant condition ($p = 0.8577$) or group × condition ($p = 0.8513$) effects were noted for word count.

With regard to subjective feelings, no significant group, condition, or group × condition effects were noted ($p > 0.05$). Normal weight individuals reported feeling slightly more productive when typing while standing (7.4 ± 1.5) compared to seated (7.3 ± 1.4). Conversely, obese individuals reported feeling more productive when typing while seated (7.1 ± 1.6) than while standing (6.8 ± 1.8). The normal weight and obese groups both reported greater feelings of being at their physical best when typing while standing (7.0 ± 2.1 for normal weight; 6.5 ± 2.6 for obese) relative to seated (6.5 for normal weight; 6.3 ± 1.9 for obese). Additionally, the obese and normal weight groups both expressed a preference for typing while seated (7.3 ± 1.9 for normal weight; 7.2 ± 2.2 for obese) versus standing (6.5 ± 2.0 for normal weight; 6.2 ± 2.4 for obese).

4. Discussion

The findings of this study indicate that the use of a standing desk: 1) increases energy expenditure in obese but not normal weight individuals 2) results in a higher HR and DBP for obese and normal weight individuals 3) does not negatively impact productivity for obese or normal weight individuals, as measured by words typed per minute. These data are in reference to otherwise healthy men and women typing for a two-hour period in which they alternated between sitting and standing postures every 30 minutes. Extrapolating these findings to other populations and/or outside the realm of the current design should be done with caution.

The primary finding of this study is that the use of a standing desk can induce minor but significant increases in energy expenditure in obese but not normal weight individuals. Obese individuals exhibited a 7.4 kcal-per-30-minutes increase (+14.7%) in energy expenditure when typing at a standing desk, relative to typing at a seated desk. Based on these measurements, if obese individuals were to use a standing desk for 4 hours during a typical 8-hour work day, they could expend an additional 52.4 kcals per day. This would translate into a 260 kcal-per-week increase in energy expenditure over the course of a 5-day work week. It is important to note that an increase in energy expenditure of 260 kcals per week is not enough to serve as a weight loss intervention on its own. However, when combined with other interventions such as exercise and dietary manipulation, the use of a standing desk may serve as an adjunct therapy in achieving weight loss in obese individuals. Additionally, the use of a standing desk may help motivate individuals to lead more healthy lifestyles, and to participate in more non-exercise-related physical activity, as noted by several long-term studies [16] [19] [20].

To date, a handful of publications have addressed energy expenditure during working at a standing desk [9] [10] [12] [16] [17] [18] [21], but no studies to our knowledge have compared the energy expenditure of normal weight versus obese individuals in this setting. Perhaps the most comparable work has noted a 15% increase in energy expenditure for obese individuals (mean BMI = 32 $kg \cdot m^{-2}$) when they passively stand with their arms by their side for 20 minutes [22]. Studies in overweight individuals tend to report similar results. Thorp *et al.* noted that overweight individuals (mean BMI = 29.6 $kg \cdot m^{-2}$) displayed a 13% increase in energy expenditure while working in a standing position for 50% of their workday [21]. Further, Gibbs *et al.* reported a 7.8% increase in energy expenditure in predominantly overweight individuals alternating between standing and seated deskwork every 30 minutes [10]. However, findings from other studies suggest that, as BMI decreases, so does the additional energy expenditure garnered from using a standing desk. For example, Júdice *et al.* reported that overweight/obese men demonstrated significantly greater increases in energy expenditure when standing compared to sitting, as compared to their normal weight counterparts [23]. An additional study noted only a 4.1% increase in energy expenditure when normal weight and overweight individuals performed clerical work in a standing position versus a seated position [9]. When taken together, the findings of these studies, in combination with the present study, suggest that the use of a standing desk can generate modest increases in energy expenditure in obese individuals, and that effect appears to taper as BMI decreases, suggesting that normal weight individuals should use standing desks for reasons other than increased metabolic rate (e.g., improved posture).

With regard to typing performance and subjective feelings, the use of a standing desk did not impact the objective measure of performance (negatively or positively) for obese or normal weight individuals, as measured by words count. However, both normal weight and obese individuals tended to report (non-significant) greater feelings of productivity during the seated trials, relative to the standing trials. Interestingly, this finding is consistent with other studies, which have found that participants report feeling more productive when seated compared to standing but that standing does not affect objectively measured performance [24] [25]. Additionally, individuals in this study reported non-significant differences in feeling at their physical best, indicating that standing desks are just as preferable as traditional desks for most individuals. These findings indicate that individuals considering the use of a standing desk in their workplace can do so without worrying that it will impede job performance or make them uncomfortable during work.

This study also noted significant increases in HR and DBP when using a standing desk. The increase in heart rate during standing deskwork has been noted in other studies and is characteristic of increased physical activity [10]. Conversely, the noted elevation in DBP during standing is an unexpected finding. Studies that have reported comparisons of blood pressure during passive standing versus passive sitting indicate that blood pressure is similar or even greater when sitting, compared to standing [26]. It may be that the measurement technique used to assess participant's blood pressure during the standing trials (*i.e.* hand resting on the keyboard tray of the desk, proximal arm by the participants side) led to the observed difference in DBP [27]. Regardless, this finding is likely benign but should be explored further.

5. Conclusion

The use of a standing desk while typing is capable of modestly increasing energy expenditure in obese individuals (7.4 kcal per 30 minutes) without impacting productivity. This modest increase in energy expenditure is likely not significant enough to be used alone as a weight loss intervention. Instead, obese individuals should use standing desks as a proverbial tool in their weight-loss arsenal, similar to taking the stairs instead of the elevator or parking far away from the entrance to work. This increase in energy expenditure does not appear to translate to normal weight individuals, though the use of a standing desk does not appear to impede productivity in these individuals either. Thus, normal weight individuals should not use standing desks to increase caloric expenditure but for other potential benefits instead (e.g., improved posture). Additional studies of longer duration are needed to determine the impact of regular use of the standing desk on body weight and associated measures of health.

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Conflict of Interest

No author declares a conflict of interest related to this work.

References

[1] Centers for Disease Control (2018) Adult Obesity Facts. https://www.cdc.gov/obesity/data/adult.html

[2] Centers for Disease Control (2017) Childhood Obesity Facts. https://www.cdc.gov/obesity/data/childhood.html

[3] Tremmel, M., Gerdtham, U.G., Nilsson, P.M. and Saha, S. (2017) Economic Burden of Obesity: A Systematic Literature Review. *International Journal of Environmental Research and Public Health*, **14**, 435. https://doi.org/10.3390/ijerph14040435

[4] National Institutes of Health. Physical Activity and Your Heart. https://www.nhlbi.nih.gov/health/health-topics/topics/phys

[5] Donnelly, J.E., Blair, S.N., Jakicic, J.M., Manore, M.M., Rankin, J.W. and Smith, B.K. (2009) Appropriate Physical Activity Intervention Strategies for Weight Loss and Prevention of Weight Regain for Adults. *American College of Sports Medicine*, **41**, 459-471. https://doi.org/10.1249/MSS.0b013e3181949333

[6] Ross, R., Dagnone, D., Jones, P.J., Smith, H., Paddags, A., Hudson, R. and Janssen, I. (2000) Reduction in Obesity and Related Comorbid Conditions after Diet-Induced Weight Loss or Exercise-Induced Weight Loss in Men. *Annals of Internal Medicine*, **133**, 92-103. https://doi.org/10.7326/0003-4819-133-2-200007180-00008

[7] Ross, R., Janssen, I., Dawson, J., Kungl, A.M., Kuk, J.L., Wong, S.L., Nguyen-Duy, T.B., Lee, S., Kilpatrick, K. and Hudson, R. (2004) Exercise-Induced Reduction in Obesity and Insulin Resistance in Women: a Randomized Controlled Trial. *Obesity Research*, **12**, 789-798. https://doi.org/10.1038/oby.2004.95

[8] Donnelly, J.E., Honas, J.J., Smith, B.K., Mayo, M.S., Gibson, C.A., Sullivan, D.K., Lee, J., Herrmann, S.D., Lambourne, K. and Washburn, R.A. (2013) Aerobic Exercise Alone Results in Clinically Significant Weight Loss for Men and Women: Midwest Exercise Trial 2. *Obesity*, **21**, 219-228. https://doi.org/10.1002/oby.20145

[9] Beers, E.A., Roemmich, J.N., Epstein, L.H. and Horvath, P.J. (2008) Increasing Passive Energy Expenditure during Clerical Work. *European Journal of Applied Physiology*, **103**, 353-360. https://doi.org/10.1007/s00421-008-0713-y

[10] Gibbs, B.B., Kowalsky, R.J., Perdomo, S.J., Grier, M. and Jakicic, J.M. (2017) Energy Expenditure of Deskwork when Sitting, Standing or Alternating Positions. *Occupational Medicine*, **67**, 121-127. https://doi.org/10.1093/occmed/kqw115

[11] Tremblay, M.S., Colley, R.C., Saunders, T.J., Healy, G.N. and Owen, N. (2010) Physiological and Health Implications of a Sedentary Lifestyle. *Applied Physiology, Nutrition, and Metabolism*, **35**, 725-740. https://doi.org/10.1139/H10-079

[12] Buckley, J.P., Mellor, D.D., Morris, M. and Joseph, F. (2014) Standing-Based Office Work Shows Encouraging Signs of Attenuating Post-Prandial Glycaemic Excursion. *Occupational and Environmental Medicine*, **71**, 109-111. https://doi.org/10.1136/oemed-2013-101823

[13] Thorp, A.A., Kingwell, B.A., Sethi, P., Hammond, L., Owen, N. and Dunstan, D.W. (2014) Alternating Bouts of Sitting and Standing Attenuate Postprandial Glucose Responses. *Medicine & Science in Sports & Exercise*, **46**, 2053-2061. https://doi.org/10.1249/MSS.0000000000000337

[14] Alkhajah, T.A., Reeves, M.M., Eakin, E.G., Winkler, E.A., Owen, N. and Healy, G.N. (2012) Sit-Stand Workstations: A Pilot Intervention to Reduce Office Sitting Time. *American Journal of Preventative Medicine*, **43**, 298-303. https://doi.org/10.1016/j.amepre.2012.05.027

[15] Healy, G.N., Winkler, E.A., Owen, N., Anuradha, S. and Dunstan, D.W. (2015) Replacing Sitting Time with Standing or Stepping: Associations with Cardio-Metabolic Risk Biomarkers. *European Heart Journal*, **36**, 2643-2649. https://doi.org/10.1093/eurheartj/ehv308

[16] Speck, R.M. and Schmitz, K.H. (2011) Energy Expenditure Comparison: A Pilot Study of Standing Instead of Sitting at Work for Obesity Prevention. *Preventative Medicine*, **52**, 283-284. https://doi.org/10.1016/j.ypmed.2011.02.002

[17] Reiff, C., Marlatt, K. and Dengel, D.R. (2012) Difference in Caloric Expenditure in Sitting versus Standing Desks. *Journal of Physical Activity and Health*, **9**, 1009-1011. https://doi.org/10.1123/jpah.9.7.1009

[18] Roemmich, J.N. (2016) Height-Adjustable Desks: Energy Expenditure, Liking, and Preference of Sitting and Standing. *Journal of Physical Activity and Health*, **13**, 1094-1099. https://doi.org/10.1123/jpah.2015-0397

[19] Saunders, T.J., Larouche, R., Colley, R.C. and Tremblay, M.S. (2012) Acute Sedentary Behaviour and Markers of Cardiometabolic Risk: A Systematic Review of Intervention Studies. *Journal of Nutrition and Metabolism*, **2012**, Article ID: 712435. https://doi.org/10.1155/2012/712435

[20] Peddie, M.C., Bone, J.L., Rehrer, N.J., Skeaff, C.M., Gray, A.R. and Perry, T.L. (2013) Breaking Prolonged Sitting Reduces Postprandial Glycemia in Healthy, Normal-Weight Adults: A Randomized Crossover Trial. *American Journal of Clinical Nutrition*, **98**, 358-366. https://doi.org/10.3945/ajcn.112.051763

[21] Thorp, A.A., Kingwell, B.A., English, C., Hammond, L., Sethi, P., Owen, N. and Dunstan, D.W. (2016) Alternating Sitting and Standing Increases the Workplace Energy Expenditure of Overweight Adults. *Journal of Physical Activity and Health*, **13**, 24-29. https://doi.org/10.1123/jpah.2014-0420

[22] Levine, J.A. and Miller, J.M. (2007) The Energy Expenditure of Using a "Walk-and-Work" Desk for Office Workers with Obesity. *British Journal of Sports Medicine*, **41**, 558-561. https://doi.org/10.1136/bjsm.2006.032755

[23] Júdice, P.B., Hamilton, M.T., Sardinha, L.B., Zderic, T.W. and 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. https://doi.org/10.1007/s00421-015-3279-5

[24] Commissarism, D.A., Könemann, R., Hiemstra-van Mastrigt, S., Burford, E.M., Botter, J., Douwes, M. and Ellegast, R.P. (2014) Effects of a Standing and Three Dynamic Workstations on Computer Task Performance and Cognitive Function Tests. *Applied Ergonomics*, **45**, 1570-1578. https://doi.org/10.1016/j.apergo.2014.05.003

[25] Chau, J.Y., Sukala, W., Fedel, K., Do, A., Engelen, L., Kingham, M., Sainsbury, A. and Bauman, A.E. (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 Opt to Stand Pilot Study. *Preventative Medicine Reports*, **3**, 68-74. https://doi.org/10.1016/j.pmedr.2015.12.003

[26] Eşer, I., Khorshid, L., Güneş, U.Y. and Demir, Y. (2007) The Effect of Different Body Positions on Blood Pressure. *Journal of Clinical Nursing*, **16**, 137-140. https://doi.org/10.1111/j.1365-2702.2005.01494.x

[27] Netea, R.T., Lenders, J.W., Smits, P. and Thien, T. (2003) Both Body and Arm Position Significantly Influence Blood Pressure Measurement. *Journal of Human Hypertension*, **17**, 459-462. https://doi.org/10.1038/sj.jhh.1001573