International Journal of EXERCISE SCIENCE

Original Research

The Short-Term Effects of Lying, Sitting and Standing on Energy Expenditure in Women

COLLIN J. POPP[†‡1], WILLIAM C. BRIDGES[‡2], and ELLIOT D. JESCH[‡1]

[1]Food, Nutrition and Packaging Sciences Department, Clemson University, Clemson, SC, USA; [2]Mathematical Sciences Department, Clemson University, Clemson, SC, USA

[†]Denotes graduate student author, [‡]Denotes professional author

ABSTRACT

International Journal of Exercise Science 11(2): 129-136, 2018. The deleterious health effects of too much sitting have been associated with an increased risk for overweight and obesity. Replacing sitting with standing is the proposed intervention to increase daily energy expenditure (EE). The purpose of this study was to determine the short-term effects of lying, sitting, and standing postures on EE, and determine the magnitude of the effect each posture has on EE using indirect calorimetry (IC). Twenty-eight healthy females performed three separate positions (lying, sitting, standing) in random order. Inspired and expired gases were collected for 45-minutes (15 minutes for each position) using breath-by-breath indirect calorimetry. Oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured to estimate EE. Statistical analyses used repeat measures ANOVA to analyze all variables and post hoc t-tests. Based on the ANOVA the individual, time period and order term did not result in a statistically significant difference. Lying EE and sitting EE were not different from each other ($P = 0.56$). However, standing EE (kcal/min) was 9.0 % greater than lying EE (kcal/min) ($P = 0.003$), and 7.1% greater than sitting EE (kcal/min) ($P = 0.02$). The energetic cost of standing was higher compared to lying and sitting. While this is statistically significant, the magnitude of the effect of standing when compared to sitting was small (Cohen's d = 0.31). Short-term standing does not offer an energetic advantage when compared to sitting.

KEY WORDS: Posture, standing desk, stand up desk

INTRODUCTION

The deleterious health effects of too much sitting have been associated with an increased risk for overweight and obesity (1, 10, 12, 17, 20). Standing is the proposed intervention for replacing sitting activity and has shown to improve mood, local muscle pain, subjective energy levels, and postprandial glucose levels (3, 16, 19). Recommendations to stand to increase daily EE are based on evidence that standing results in greater energy expended (7, 8, 9, 13, 18). An increase in daily EE without a concomitant increase in daily caloric intake may be a solution for preventing weight gain.

The measurement of EE associated with difference postures dates back to the early 1950's. Edholm and Fletcher (14) found differences between the EE of lying, sitting, standing, marching and running in twelve cadet males, and Passmore et al. (15) found similar results in five young men who perform various activities. More recently, studies have assessed the EE of different postures (7, 8, 11, 13, 18). For example, Reiff et al. (18) found that standing kilocaloires expended per minute were significantly greater than those while sitting. However, most studies have compared two positions (i.e., sitting, standing) and none have assessed the magnitude of the difference between each posture. The aims of this study are to determine the short-term effects of lying, sitting, and standing postures on EE during an indirect calorimetry (IC) measurement, and determine the magnitude of the effect each posture has on EE. We hypothesize that the EE of lying and sitting will not be different from each other; however, the EE associated with standing will be greater than both lying and sitting.

METHODS

Participants

A sample of 29 female participants was recruited from faculty, staff and students of Clemson University and the surrounding community. Recruitment was conducted via e-mails, flyers posted around campus and word of mouth. To partake in the study participants had to be between the ages of 18 and 65 years old. Participants were apparently healthy and had no locomotion limitation that would prevent them from performed each posture. All participants read and signed a written informed consent document prior to testing. The Institutional Review Board at Clemson University approved all study procedures for human participants.

Protocol

The study was a randomized trial of indirect calorimetry on three different postures. The postures were measured during one continuous test lasting a total of 45 minutes, switching positions every 15 minutes. Height and weight were measured, and date of birth was then recorded. Height and weight were measured using a SECA 763 digital scale (SECA North America, Chino, CA, USA). Participants removed their shoes, and any personal belongs from their pockets and stood looking forward with arms to their side and weight evenly distributed. Both height and weight were measured to the nearest tenth of a centimeter and kilogram, respectively. Participants then randomly selected the order of their testing postures by picking a number 1 through 3, which was associated with a position (1= lying, 2 = sitting, 3 = standing). Participants were fitted with a face mask, then connected to a metabolic cart where energy expenditure was measured: 1) while lying supine on a padded table, 2) while seated in an office chair (without armrests), and 3) while standing "naturally." Participants were instructed to remain awake while lying supine on the table, remain sitting upright while seated and were allowed to shift weight between legs while standing. They were not allowed to listen to music or watch television on their computer or cellular phone. They were allowed to read or work on schoolwork while sitting or standing., this included reading on their cellular phone.

Breath-by-breath indirect calorimetry was measured between the hours of 8:00 am and 4:00 pm. Participants were not asked to abstain from food or drink prior to analysis. A ParvoMedics' TrueOne® 2400 (Parvo-Medics', Sandy, UT, USA) metabolic cart was used to take all measurements. Gas and flow calibration were performed according to the manufacturer's recommendations. Temperature, humidity and barometric pressure were measured (Vantage VUE Digital Barometer, Davis Instruments, Hayward, CA, USA) before each subject test. Expired air was collected by using a 7450 V2 respiratory mask (Hans Rudolph Inc., Shawnee, KS, USA) fitted with a two-way non-rebreathing valve covering the nose and mouth prior to beginning each test. The respiratory mask was connected to the calorimeter by a 6 foot, 35 mm breathing tube (ParvoMedics' Inc., Sandy, UT, USA). This system permits limited mobility of each subject as they move from position to position. The absolute and relative volume of oxygen consumption (VO_2) and volume of carbon dioxide production (VCO_2) were measured and used to estimate absolute EE (absEE) and relative EE (relEE) using the Weir equation (23). All measurement parameters were collected on a laboratory computer (Dell Inc., Round Rock, TX, USA). All testing was done under conditions that were as consistent as possible (Temperature 24.2 ± 0.83 °C; Barometric Pressure 741.9 ± 3.05 mmHg; Humidity 57.6 ± 4.1%).

Statistical Analysis

A statistical model was developed that related the variables to a position, time period, individual and order that positions were performed. The effects of position, time, individual and order were determined using ANOVA. The ANOVA was adjusted for the repeated time measures for individuals. Comparisons of specific positions were performed with Fisher's Protected Least Significant Difference test. Data are reported as mean ± standard deviation. Effect size was calculated using Cohen's d classification to compare postures, where effect size of small ($d = 0.2$), medium ($d = 0.5$), large ($d = 0.8$) and very large ($d > 1.3$) are assigned. All statistical comparisons were made at the alpha level of 0.05. All statistical calculations were performed using JMP® Pro 10 (SAS Institute Inc., Cary, NC, USA).

RESULTS

The final sample included 28 females. One participant's mask was leaking and was unable to reschedule a time to complete the energy expenditure measurement. Her demographics were not included in the final analysis. Demographics are presented in Table 1.

Table 1. Demographics[1]

	Mean ± SD	Range
Age (years)	33.2 ± 11.2	22 - 61
Height (cm)	163.8 ± 5.7	152.4 - 176.5
Weight (kg)	68.8 ± 13.5	51.6 - 104.8
BMI (kg/m^2)	25.6 ± 4.7	19.92 - 39.8

[1]n = 28; BMI = Body Mass Index

Based on the ANOVA the individual, time period and order term did not result in a statistically significant difference. However, the ANOVA suggests that there are postural differences for all variables, except relative VCO_2 (ml/kg/min) ($P = 0.065$) (See Supplemental Table 1). There was no significant difference between lying VO_2 and sitting VO_2 ($P = 0.49$), and lying VCO_2 and sitting VCO_2 ($P = 0.807$). Standing VO_2 was 9.5% greater than lying VO_2 ($P = 0.002$) and 7.7% greater than sitting VO_2 ($P = 0.013$). Similarly, standing VCO_2 was 7.2% and 4.8% greater than lying VCO_2 (P = 0.002) and sitting VCO_2 (P = 0.022) (d = 0.29), respectively. Similar results were observed when relative VO_2 was normalized to body weight (See Supplemental Table *1*).

The integrated means for absEE (panel A) and relEE (panel B) while lying, sitting and standing during the 15-minutes are shown in Figure 1. Standing absEE was 9.0 % greater lying absEE (P = 0.003) and 7.1% greater than sitting absEE (P = 0.016). RelEE resulted in similar differences. There was a medium effect of standing on EE (Cohen's d = 0.38) when compared to lying, and a small effect on EE when compared to sitting (Cohen's d = 0.31). Supplemental Table 2 presents the effect size for all positions.

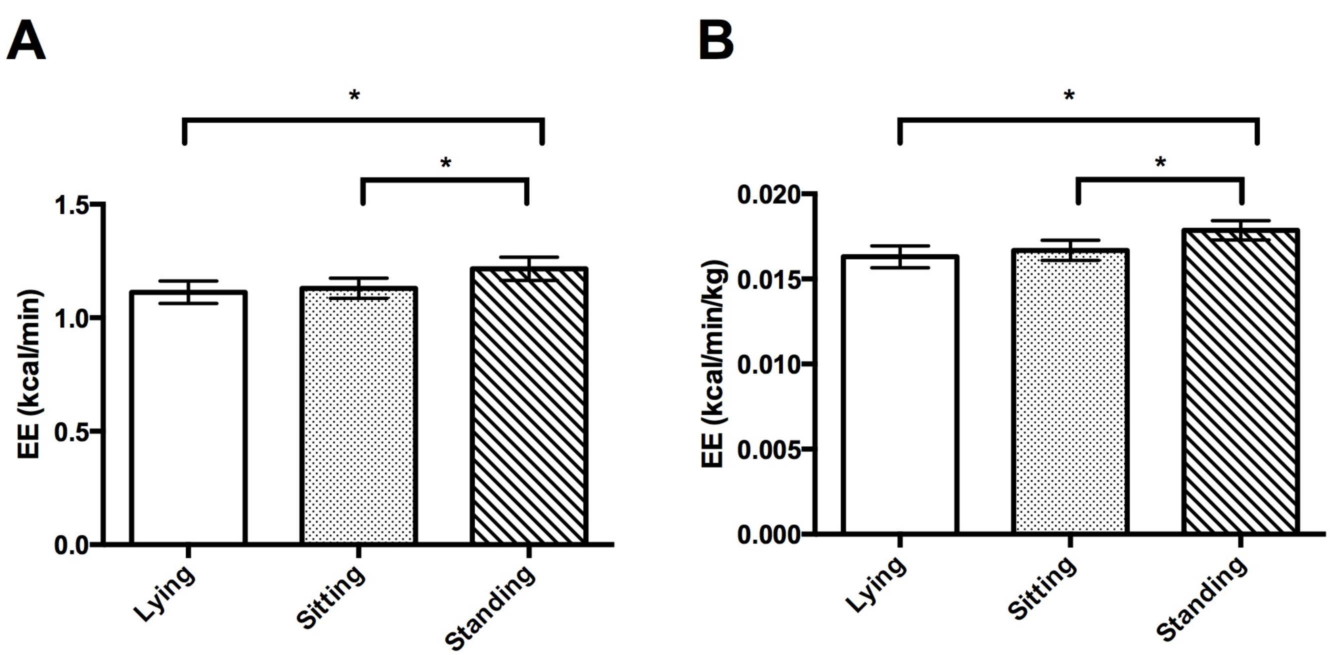

Figure 1. Comparison of mean ± SD absolute EE (Panel A) and relative EE (Panel B) while lying ( ), sitting ( ) and standing ( ). EE = energy expenditure. Significant differences between positions are indicated: * $p < 0.05$.

Figure 2 shows the minute-by-minute mean EE for lying, sitting and standing during the 15-minutes. Based on the repeated measures ANOVA, there was large variability in lying EE during the 15-minute. Lying EE was significantly greater than standing EE at minutes 1 (P = 0.049) and 2 (P = 0.048). However, these differences were lost by minute 3, 4 and 5. By the 6^{th}-minute standing, EE was significantly greater than lying EE (P = 0.0004), and this trend continued until the IC measurement was terminated. Sitting EE followed a similar trend to lying and decreased over the course of the 15-minutes. There was no significant difference in minute-by-minute EE between lying and sitting at any point during the 15-minutes (See Supplemental Table 3).

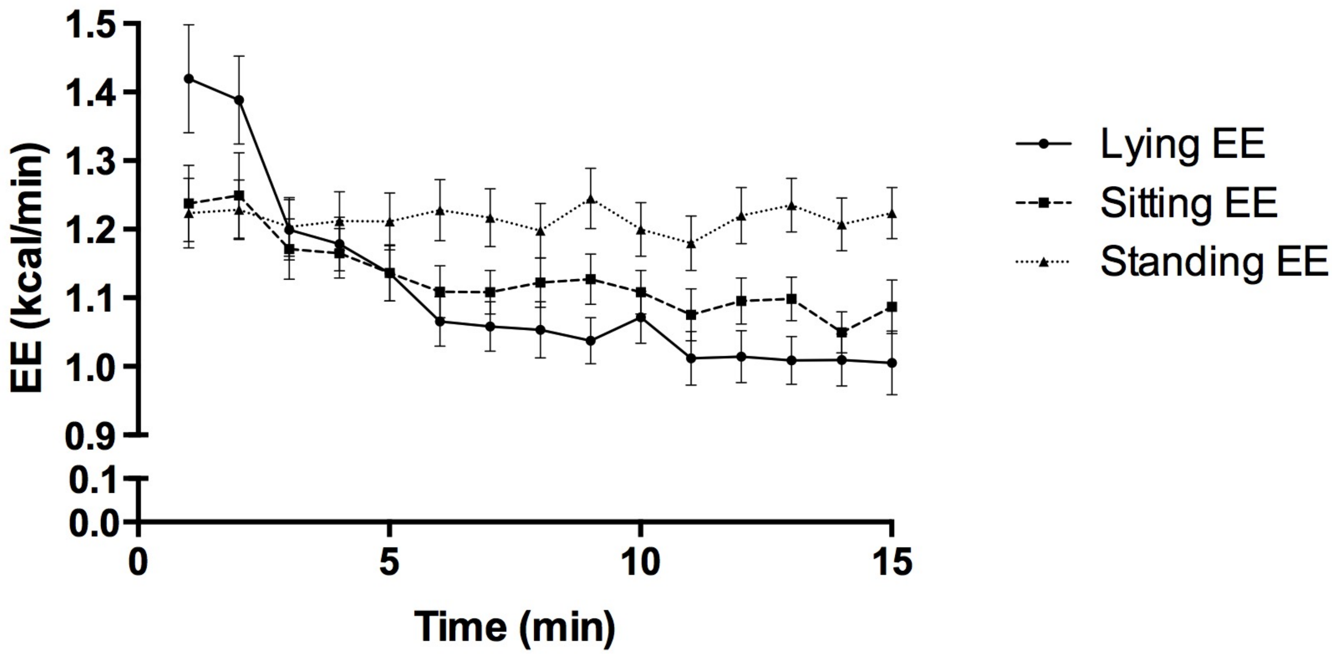

Figure 2. Minute-by-minute comparison of mean ± SD EE while lying, sitting and standing over the 15-minute time period.

DISCUSSION

The aims of this study were to determine the short-term effects of lying, sitting, and standing postures on EE during one continuous indirect calorimetry (IC) measurement, and determine the magnitude of the effect each posture has on EE. The results of this study support the original hypothesis that lying and sitting EE are lower than standing EE. There was no effect of order of postures, time period or individual on mean EE. We found that the integrated mean of standing VO_2, VCO_2, absEE, and relEE were significantly greater than the integrated mean of lying and sitting over 15-minutes. We speculate this is due to an increase in recruitment of postural (e.g. erector spinae) and lower extremity musculature (e.g., vastus lateralis, gastrocnemius,). Tikkanen et al. (21) found that muscle activity during standing is almost 2.5 higher than during sitting in middle-aged males and females. Participants were instructed to stand upright, but not asked to remain motionless. Shifting of weight and fidgeting could also explain greater EE while standing (11).

Our results support prior a finding of a non-significant difference between lying EE sitting EE. Miles-Chan et al. (14) reported the EE of a supine position was not significantly different compared to sitting (< 2% difference) in both genders with similar BMI (23 kg/m^2). This information is applicable for researchers and clinicians working with populations limited by their ability to lay or sit (e.g., congestive heart failure, pulmonary edema).

The results of our study support previous studies assessing the EE associated with different postures (7, 8, 9, 13, 18). Overall, all have found that standing EE is significantly greater and sitting EE. Miles-Chan et al. (13) reported a 7.7% change in EE from sitting to standing, a change that was only evident during the first 5 minutes of the 10-minute standing period. Kanade et al. (8) found the energetic cost of standing was 7.9% higher than sitting in Indian adult women. We found a similar result, as standing absEE was 7.1% greater than sitting absEE. When expressed in kcal/min, Reiff et al. (18) found that standing EE resulted in 1.36 kcal/min compared to 1.02 kcal/min while sitting during a 45-minute testing period. Our results were slightly lower for standing and higher for sitting, which can be explained by a shorter testing period. In addition, Júdice et al. (7) found that adult women (n = 25) expended 0.92 ± 0.13 kcal/min standing compared to 0.88 ± 0.11 kcal/min sitting for 10 minutes.

There is conclusive evidence that short-term continuous standing is statistically greater than sitting at varying time durations. However, the results of our study, as with others, indicate standing may ultimately have little impact on daily EE. The magnitude of the effect of standing, when compared to sitting on EE, was small (Cohen's d = 0.31), and over time may be negligible. We found that the difference of between the integrated mean of sitting and standing was 0.08 kcal/min. Hypothetically speaking, if these numbers are extrapolated to 60 minutes, and assuming no deviation kcal/min EE, standing EE results in 72.6 kilocalories expended compared to 67.8 kilocalories expended while sitting, a 4.8 kilocalories difference. Therefore, standing would offer little advantage over the short-term. In a review, Tudor-Locke et al. (22) came to a similar conclusion stating "that efforts to decrease sitting behavior only by replacing it with [continuous] standing behavior appear to promise only a negligible difference in EE." We do not believe that replacing sitting with continuous standing behavior will have a cumulative effect on daily EE and energy balance. Sit-to-stand desks, calisthenics (e.g., squats, lunges) and treadmill desks may offer a greater metabolic advantage on EE and energy balance than just standing alone (2, 6, 7, 10).

Our study supports previous studies that standing EE is greater than sitting EE over the short-term. However, there are a few limitations. Participants were not asked to refrain from dietary supplementation or required to fast for 12 hours prior to testing. There was the potential effect of diet-induced thermogenesis as evident in the higher respiratory quotient (RQ) values when compared to previous studies (13, 18). The use of a facemask allowed for more mobility when switching postures, but a facemask can significant increase oxygen consumption when compared to a more accurate canopy system (5). There could have been an overestimation of lying and sitting EE due to a carry-over effect when transitioning from posture-to-posture. Júdice et al. (7) eliminated the first 5 minutes of each posture to prevent any overestimating in EE Supplemental Figure 1 shows the order of randomization. Standing prior to lying could explain why lying EE was greater during the first 3 minutes of the IC measurement as seen in Figure 2. We did not establish a baseline measuring of resting energy expenditure, and therefore, do not have a standard measure to compare each posture. Future research should assess randomized individuals to sitting and standing interventions in a crossover design over a longer daily time period (4 hours per day) to determine if these small changes result in significant changes in EE. Moreover, no studies have assessed the impact standing has on body weight, fat mass or lean body mass when combined with a hypocaloric diet.

Based on our results standing EE was statically greater than lying and sitting EE. However, the magnitude of the effect of continuous standing was small when compared to sitting. Therefore, continuous standing for 15-minutes does not offer an energetic advantage. The health benefits of standing may be aside for increasing daily EE.

ACKNOWLEDGEMENTS

We want to thank Dr. Michelle Bohan Brown for her edits and revisions to the manuscript. Thank you to Dr. Andrew Brown at Indiana University for his suggestions and comments. Also, thank you to Nadia Najm at Clemson University for her contribution to the data collection and manuscript writing process.

REFERENCES

1. Biddle SJH, Bennie JA, Bauman AE, Chau JY, Dunstan D, Owen N, van Uffelen JGZ. Too much sitting and all-cause mortality: is there a causal link? BMC Public Health 16:635, 2016. https://doi.org/10.1186/s12889-016-3307-3

2. Carter SE, Jones M, Gladwell VF. Energy expenditure and heart rate response to breaking up sedentary time with three different physical activity interventions. Nutr Metab Cardiovasc Dis 25(5):503–509, 2015. https://doi.org/10.1016/j.numecd.2015.02.006

3. Dutta N, Koepp G, Stovitz S, Levine J, Pereira, M. Using Sit-Stand Workstations to Decrease Sedentary Time in Office Workers: A Randomized Crossover Trial. IntJ Environ Res Public Health 11(7):6653–666, 2014. https://doi.org/10.3390/ijerph110706653

4. Edholm OG, Fletcher JG, Widdowson EM, McCance RA. The energy expenditure and food intake of individual men. Br J Nutr 9(3):286–300, 1955.

5. Forse RA. Comparison of gas exchange measurements with a mouthpiece, face mask, and ventilated canopy. JPEN 17(4):388–391, 1993.

6. Fountaine CJ, Johann J, Skalko C, Liguori GA. Metabolic and Energy Cost of Sitting, Standing, and a Novel Sitting/Stepping Protocol in Recreationally Active College Students. Int J Exerc Sci 9(2):223–229, 2016.

7. Júdice PB, Hamilton MT, Sardinha LB, Zderic TW, Silva AM. What is the metabolic and energy cost of sitting, standing and sit/stand transitions? Eur J Appl Physiol 116(2):263–273, 2016. https://doi.org/10.1007/s00421-015-3279-5

8. Kande AN, Gokhale MK, Rao S. Energy costs of standard activities among Indian adults. Eur J Clin Nutr 55(8):708–713, 2001. https://doi.org/10.1038/sj.ejcn.1601211

9. Levine JA. Measurement of energy expenditure. Public Health Nutr 8(7A):1123–1132, 2005.

10. Levine JA, Miller JM. The energy expenditure of using a “walk-and-work” desk for office workers with obesity. Br J Sports Med 41(9):558–561, 2007. https://doi.org/10.1136/bjsm.2006.032755

11. Levine JA, Schleusner SJ, Jensen MD. Energy expenditure of nonexercise activity. Am J Clin Nutr 72(6):1451–1454, 2000.

12. Long YC, Tan TMC, Inoue T, Tang BL. The biochemistry and cell biology of aging: metabolic regulation through

mitochondrial signaling. Am J Physiol Endocrinol Metab 306(6):E581-E591, 2014. https://doi.org/10.1152/ajpendo.00665.2013

13. Miles-Chan JL, Sarafian D, Montani JP, Schutz Y, Dulloo AG. Heterogeneity in the energy cost of posture maintenance during standing relative to sitting: phenotyping according to magnitude and time-course. PloS One 8(5):e65827, 2013. https://doi.org/10.1371/journal.pone.0065827

14. Miles-Chan JL, Sarafian D, Montani JP, Schutz Y, Dulloo AG. Sitting comfortably versus lying down: Is there really a difference in energy expenditure? Clin Nutr 33(1):175-178, 2013.

15. Passmore R, Thomson JG, Warnock GM, Dixon CM, Kitchin AH, Smith AH, Vaughan MC, Watt JA. A balance sheet of the estimation of energy intake and energy expenditure as measured by indirect calorimetry, using the Kofranyi-Michaelis calorimeter. Br J Nutr 6(3):253–264, 1952.

16. Pronk NP, Katz AS, Lowry M, Payfer JR. Reducing occupational sitting time and improving worker health: the Take-a-Stand Project, 2011. Prev Chronic Dis 9:E154, 2012. https://doi.org/10.5888.pcd9.110323

17. Proper KI, Singh AS, van Mechelen W, Chinapaw MJM. Sedentary behaviors and health outcomes among adults: a systematic review of prospective studies. Am J Prev Med 40(2):174–182, 2011. https://doi.org/10.1016/j.amepre.2010.10.015

18. Reiff C, Marlatt K, Dengel DR. Difference in caloric expenditure in sitting versus standing desks. J Phys Act Health 9(7):1009–1011, 2012.

19. Thorp AA, Kingwell BA, Owen N, Dunstan DW. Breaking up workplace sitting time with intermittent standing bouts improves fatigue and musculoskeletal discomfort in overweight/obese office workers. Occup Environ Med 71(11):765-71, 2014. 765–771. https://doi.org/10.1136/oemed-2014-102348

20. Thorp AA, Owen N, Neuhaus M, Dunstan DW. Sedentary behaviors and subsequent health outcomes in adults a systematic review of longitudinal studies, 1996-2011. Am J Prev Med 41(2):207–215, 2011. https://doi.org/10.1016/j.amepre.2011.05.004

21. Tikkanen O, Haakana P, Pesola AJ, Häkkinen K, Rantalainen T, Havu M, Pullinen T, Finni T. Muscle activity and inactivity periods during normal daily life. PloS One 8(1):e52228, 2013. https://doi.org/10.1371/journal.pone.0052228

22. Tudor-Locke C, Schuna JM, Frensham LJ, Proenca M. Changing the way we work: elevating energy expenditure with workstation alternatives. Int J Obes 38(6):755–765, 2014. https://doi.org/10.1038/ijo.2013.223

23. Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. J Physiol 109(1–2):1–9, 1949.