The Biomechanical and Physiological Effect of Two Dynamic Workstations

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Abstract. The aim of this research paper was to investigate the effect, both biomechanically and physiologically, of two dynamic workstations currently available on the commercial market. The dynamic workstations tested, namely the Treadmill Desk by LifeSpan and the LifeBalance Station by RightAngle, were compared to the more conventional seated and standing workstations, through a randomized repeated measures design. Hypothesized was that the use of these dynamic workstations would have an effect on posture, physical activity, energy expenditure and muscular activity. Preliminary results suggest that the dynamic workstation increase physical activity and heart rate compared to the seated workstation.

Keywords: physical activity, computer work, dynamic workstations, joint angle, electromyography, energy expenditure, heart rate.

1 Introduction

As a result of numerous factors, both lifestyle and work-related, physical inactivity is becoming an increasing problem which results in an elevated risk of developing numerous health problems [1]. As a consequence of industrialization, physical workload is being reduced which results in even more of the workforce being affected by physical inactivity. The implications of this change in the nature of how work is performed, results in the traditional ergonomics paradigm of “less is better” as no longer being suitable for today’s society [1].

As a result of physical inactivity, workers who maintain prolonged seated postures are at a greater risk of developing chronic diseases such as cardiovascular disorders and type II diabetes [2] as well as developing musculoskeletal disorders in the upper back and neck region [3]. The negative effects of inactivity as a result of a prolonged seated posture at work cannot be compensated by only increasing activity levels during leisure time [4]. In order to prevent the above mentioned health risks, it is necessary to find suitable means of introducing more activity into the workplace

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environment that goes beyond the extent of taking the stairs [5]. One of these potential solutions, which might increase long-term activity, is dynamic workstations which combine a computer workstation with physical activity [5].

There is only limited research-based information available on the effects that these machines can have on individuals. The effect of energy expenditure for obese office workers that a treadmill desk could have has been investigated [5]. Furthermore the effect that a walking station and a cycling workstation has on performance has been investigated by Straker et al. [6], but only limited physiological and physical measures were obtained in conjunction with the performance data.

2 Method

Through a randomized repeated measures design, the physiological and biomechanical effect of two different dynamic workstations was assessed in comparison to two more conventional workstations, namely a standing and a seated workstation. After an adaptation phase, each participant was required to complete a set of standardized tasks at each station. The order of the workstations and tasks was randomized for each participant.

The aim of this study was to determine the effect of the different workstations on physical activity, posture and muscle activation for the musculus trapezius p. descendens. The study was carried out in the laboratory under realistic VDU office conditions.

2.1 Participants

Twelve healthy participants, 6 males and 6 females, all who predominantly perform computer-based tasks as the main component of their work, volunteered. The participant group had a mean age of 38.7 years (SD 11.4 years), a mean height of 171.3 cm (SD 8.8 cm) and a mean weight of 75.0 kg (SD 15.4 kg). Participants with chronic diseases or any health problems were excluded. All procedures were explained and informed consent was obtained prior to testing.

For the EMG results, the participant group was reduced to 10 volunteers (5 males and 5 females). This sub-collective group had a mean age of 36.9 years (SD 11.0 years), a mean height of 170.4 cm (SD 9.3 cm) and a mean weight of 75.7 kg (SD 16.4 kg).

2.2 Workstations

Each dynamic workstation was assessed at two intensity levels. The Treadmill Desk TR1200-DT5 by LifeSpan was assessed at a speed of 0,6 km/h and 2,5 km/h and the

Fig. 1. The Treadmill Desk (left) and the LifeBalance Station (right) in the laboratory set-up with a participant wearing the data capturing equipment

LifeBalance Station by RightAngle was assessed at an intensity level of 4 (9 Watts) and 12 (17 Watts), both at 40 RPM. Figure 1 shows the dynamic workstations in the laboratory set-up with a participant wearing the CUELA [7] and EMG system.

2.3 Tasks

All participants performed a standardised set of five different office-based and computer tasks. The battery of tasks included a typing task, a reading task, a mouse dexterity task, a telephone task and a set of computer-based cognitive tasks. Participants were required to complete a habituation period for all tasks and workstations prior to the start of the testing phase.

2.4 Instrumentation and Measures Assessed

Physiological measures assessed included electromyography (EMG) of M. Trapezius, heart rate and indirectly-measured energy expenditure, calculated using heart rate and the formula by Strath et al. [9]. Bilaterally muscle activation for the musculus trapezius p. descendens was assessed by EMG measures using the Biomonitor ME6000 (Mega Electronics Ltd). Heart rate was recorded throughout testing using the Polar WearLink sensor and monitor model RS400.

Biomechanical measures assessed or determined included a comprehensive postural analysis and physical activity intensity index [8] for each station. The CUELA system [7] was used to determine body posture, joint angles and the acceleration of the individual body parts. The recorded values are presented as the difference to a predefined standing reference position. On the basis of the acceleration signals, the physical activity intensity index (PAI) was calculated [8] and can be considered as an indicator for body movement.

2.5 Analysis

The results were analysed using descriptive statistics and the mean, standard deviation and percentiles of the frequency distribution were calculated over all participants for each of the six stations. The results have been presented in the form of boxplots (5th, 25th, 50th, 75th and 95th percentile; the rhombus representing the mean).

The results of the posture analysis have been presented in degrees for the described joint or limb and the EMG data was normalised as the percentage of maximum voluntary contraction (%MVC). Due to the small values of the PAI, results have been presented as %g (100*absolute value). Significance testing and a more comprehensive statistical analysis are still outstanding and will be completed at a later stage.

3 Results

3.1 Muscle Activation

Figure 2 and 3 show the results of muscle activation of M. Trapezius left and right in the form of boxplots.

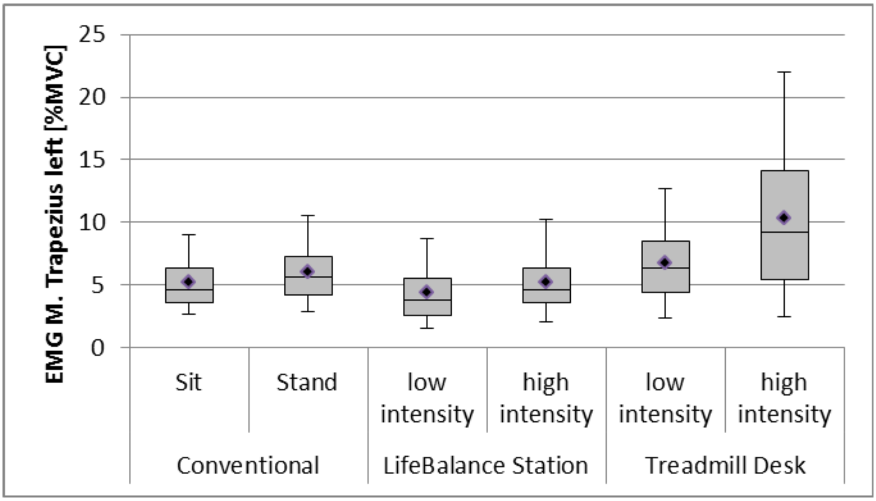

Fig. 2. Muscle activation of left Trapezius in %MVC (mean values represented by the rhombus)

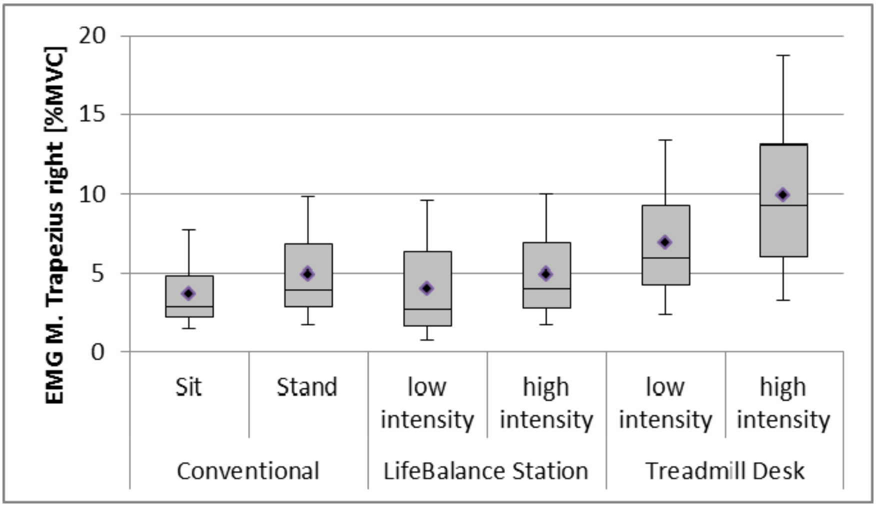

Fig. 3. Muscle activation of right Trapezius in %MVC (mean values represented by the rhombus)

The highest muscle activation was achieved on the Treadmill Desk for the high intensity condition. Figure 2 and 3 depict large differences between 5th and 95th as well as between 25th and 75th percentiles of the results. These differences are larger for both dynamic workstations and higher intensity levels when compared to conventional workstations.

3.2 Posture Analyse

Table 1 shows the 50th and 95th percentiles of the frequency distribution and the standard deviation for all workstations for the joint angles in degrees for cervical spine flexion, trunk inclination, trunk flexion and L5 inclination.

By differentiating the workstations into seated workstations (conventional sitting, LifeBalance Station low and high intensity) and standing workstations (conventional standing, Treadmill Desk low and high intensity), differences in posture can be analysed. Cervical spine flexion was predominantly lower for the standing workstations than for seated workstations. With regards to trunk inclination, a retroverted posture of the trunk in comparison to the reference position was measured for all stations except for the Treadmill Desk. A large difference in the above data can be seen for the seated and standing workstations with regards to trunk flexion.

Table 1. Joint angles (°) for cervical spine flexion, trunk inclination, trunk flexion and L5 inclination

	Conventional		LifeBalance Station		Treadmill Desk	
	Sitting	Standing	Low Intensity	High Intensity	Low Intensity	High Intensity
Cervical Spine Flexion (°)						
50%ile	8,7 (12,4)	5,6 (6,9)	9,6 (6,9)	10,5 (6,7)	8,3 (6,9)	8,0 (4,2)
95%ile	11,5 (12,6)	9,6 (9,6)	12,0 (6,7)	12,7 (6,5)	13,8 (8,0)	11,6 (5,3)
Trunk Inclination (°)						
50%ile	-10,1 (13,1)	-1,2 (6,4)	-11,5 (9,4)	-10,7 (10,8)	2,2 (5,5)	0,5 (5,5)
95%ile	-7,8 (13,3)	1,6 (7,8)	-10,1 (9,3)	-9,2 (10,7)	6,2 (6,3)	3,2 (5,9)
Trunk Flexion (°)						
50%ile	37,2 (15,6)	13,8 (10,4)	42,5 (16,4)	42,3 (15,5)	12,4 (10,5)	15,2 (11,3)
95%ile	39,5 (16,2)	17,5 (11,5)	45,6 (16,3)	45,0 (16,1)	16,8 (11,1)	18,7 (11,2)
L5 Inclination (°)						
50%ile	-28,4 (17,4)	-7,8 (8,9)	-32,7 (16,2)	-31,8 (17,5)	-3,9 (8,3)	-7,0 (10,3)
95%ile	-26,2 (17,5)	-5,3 (9,1)	-31,3 (16,1)	-29,8 (17,3)	-0,3 (8,3)	-4,3 (10,2)

3.3 Physical Activity Intensity

The results of the physical activity intensity indexes for the entire body are shown in boxplots in Figure 4.

The highest value for physical activity was, as expected, measured on the treadmill desk at the high intensity. The 50th percentile of the frequency distribution for the treadmill desk was over 12 times higher when compared to the conventional seated workstation. There was a slight increase for the LifeBalance Station compared to the conventional workstations.

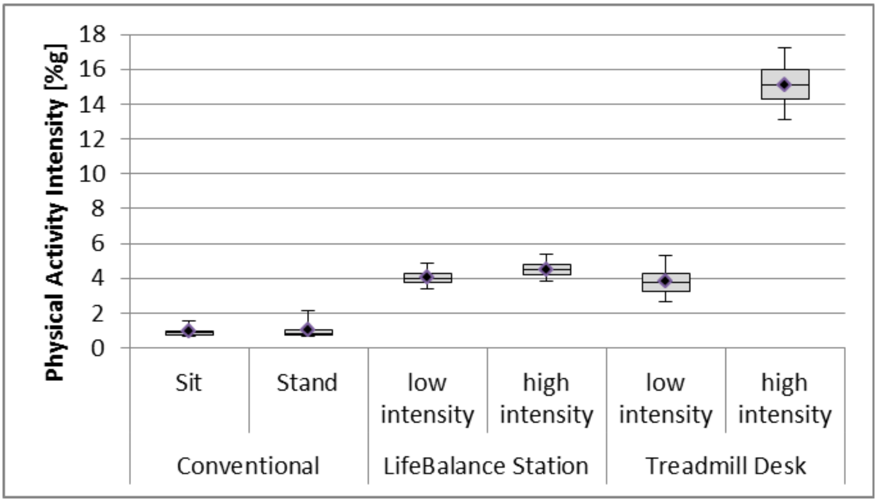

Fig. 4. Results of the physical activity intensity index for all stations in %g for the entire body (mean values represented by the rhombus)

3.4 Energy Expenditure

As shown in Figure 5, the lowest mean energy expenditure was recorded for the conventional seated workstation. For the dynamic workstations, the energy expenditure increased when compared to the seated workstations as well as for the higher intensities when compared to the lower intensities.

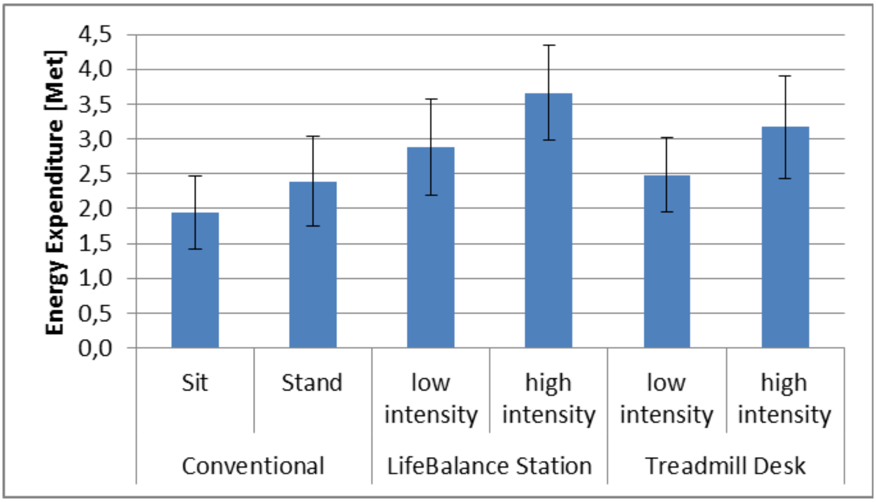

Fig. 5. Mean (and standard deviation) calculated energy expenditure for all stations in MET

4 Discussion

Significance testing and further statistical analysis has not yet been performed, therefore the following discussion will give a brief and superficial explanation for the above mentioned results.

The differences in posture with regards to trunk inclination, flexion and L5 inclination between the LifeBalance Station and the Treadmill Desk were expected. Similarly the posture resulting for both of the dynamic workstations, as expected, was comparable to the respective conventional workstations.

As reported in section 3.3 there was only a slight increase in physical activity from the lower to the higher intensity level of the LifeBalance Station. The results and differences for the PAI values for the two intensities on the LifeBalance Station were expected to be similar as to those recorded for the two intensities on the Treadmill Desk. As the physical activity was calculated on the basis of the acceleration signals and as there was no difference in RPM for the lower and higher intensity of the LifeBalance Station, the PAI only shows slight differences for this station. Despite this, there was still an increase in PAI on both dynamic workstations compared to conventional sitting. Both Thompson et al. [10] and Levine and Miller [5] have reported health benefits due to movement, even if it is only a small amount of physical activity. On the basis of the PAI results, these workstations may be able to bring more physical activity in daily office work.

As expected, the energy expenditure was greater for the dynamic workstations than for the conventional workstations. Even though the formula by Strath et al. [9] is known to overestimate energy expenditure for low strain tasks [11], it would appear, as expected, that the dynamic workstations have a higher energy expenditure than the conventional workstations. It may be possible that the presented results for the low intensities of the dynamic workstations were too high and therefore potentially the difference between the low intensity and high intensity conditions would be greater. Furthermore this would lead to a greater increase in energy expenditure for the higher intensities on the dynamic workstations in comparison to the conventional seated workstation. Due to these results, the dynamic workstations, especially the higher intensities, could be used to achieve a higher daily energy expenditure. The differences between the stations and intensity levels will be described at a later point in more detail after significance testing and more comprehensive statistical analyses have been performed.

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