Usage and Physiological Effects of Dynamic Office Workstations - A Field Pilot Study

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Abstract. Prolonged sedentary work is increasingly discussed as a health risk factor for developing musculoskeletal disorders and cardiovascular diseases. Dynamic workstations are a modern concept to combine light physical activity and desk-based office work. Their effects are evaluated under laboratory conditions but research in occupational settings is limited. This pilot study examined the effects of two dynamic workstations, the Deskbike and the activeLife Trainer regarding aspects of lending and usage and physiological effects. Preliminary results for 8 male subjects show general interest in using these stations and an increased heart rate and energy expenditure compared to working while seated.

Keywords: Dynamic workstations · Usage · Physiological effects · Heart rate · Energy expenditure · Deskbike · activeLife Trainer

1 Introduction

Prolonged bouts of sitting are increasingly discussed as an independent health risk factor for the development of chronic complaints and diseases. Observational studies pointed on a negative correlation between physical inactivity and musculo-skeletal disease, adipositas, cardio-vascular diseases, Type-II-Diabetes and premature mortality [1–3]. Additionally to these long-term effects short-term effects like the loss of endurance and performance ability can occur.

According to the EuroBarometer study the average self-reported sitting time in northern European countries was 5–6 h daily [4], mostly spend at the office desk. In Germany today there are about 18 million employees working on office and monitor-based desks which partly require prolonged seated postures and therefore negatively support a lack of physical activity. Regarding the digitalization of future work environment it can be expected that the number of seated workplaces will increase steadily. As engaging in moderate to vigorous activity during leisure time seems not to be sufficient enough to adequately address the negative consequences [5], the development of workplace health interventions is required.

Besides behaviour-oriented prevention approaches like taking walks or exercising at the lunch break [6], new concepts for work tasks and work stations evolve rapidly in the last years. The promotion of possible ways to facilitate an increase of physical activity for desk-bound office workers includes sit-to-stand desks and so called

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"dynamic workstations" like adapted computer desks with integrated treadmills or seated elliptical machines. These stations offer a way to engage in light physical activity like walking or pedaling without leaving the desk. To examine the ability to consider these stations as feasible alternatives to conventional work stations scientific research on the effects on physiological parameters as well as the acceptance of the users and feasibility in the work environment had been conducted.

Beneath the effect on sitting time throughout working hours several studies assessed parameters like heart rate (HR) and energy expenditure (EE) while using dynamic workstations to analyze the impact on energy metabolism. The results of Carr et al. [7] and Straker and Levine [8] showed significant effects on these parameters by using an under-desk pedaling machine and an upright exercise cycle. A lab study by the Institute of Occupational Safety and Health (IFA) in cooperation with TNO was conducted in 2013 to investigate the contribution of a treadmill desk and a seated dynamic workstation to physical activity, the effect on posture and muscular activity and the subjective perception of the users. Main results showed that these stations may lead to an increase of physical activity but user acceptance and ergonomic design still had to be improved [9].

Current refinements in the development of dynamic workstations are portable devices which are commercially available, lightweight and can be fitted under standard or height-adjustable desks. According to their novelty on the market scientific research on health benefits and limitations in comparison to other dynamic workstations is limited. As knowledge about these parameters and users acceptance as well as examinations of feasibility is essential to implement these stations in real life working environments the conduction of field studies is required. Thus, the present paper aims to describe the acceptance of portable dynamic workstations by the employees and physiological loads associated with the use in real life office settings. Moreover, different types of dynamic workstations are compared in this regards.

Therefore the present study aims to answer three research questions:

1. Are dynamic workstations used as alternative workplaces in an occupational field setting?
2. Which physiological activation appears while using a dynamic workstation in an occupational field setting?
3. Does physiological activation while using a dynamic workstation differ between different types of work stations?

2 Methods

This study was conducted as a pilot study to generate preliminary findings about multiple effects of dynamic workstations being implemented in real-life occupation settings. It was conducted in a large telecommunication company in Germany with a modern approach to future office environments.

2.1 Participants

The departments of the Company were informed about the intention to conduct the study and could declare their interest to participate. Randomly one of these departments was chosen and an information event was held for all employees. After the participation to this event a total sample of 38 employees decided voluntarily to take part in the study, 29 of them agreed to complete all measurements required. As the pilot study is ongoing, here the results for 8 male participants are presented.

The participants were offered two different dynamic workstations for their voluntarily use. The sample for the statistical comparison of the physiological effects of the stations was limited to 8 participants who used both types of workstations. The anthropometric data of the whole sample and the sample of participants using both types of workstations is shown in Table 1.

Table 1. Data of 8 male participants using both types of workstations; BMI: Body Mass Index

	User of both workstations
Number	8
Age in years	42,88 (±10,43)
Height in m	1,82 (±0,72)
Weight in kg	84,88 (±13,29)
BMI in kg/m2	25,81 (±4,87)

2.2 Dynamic Workstations

The conventional workplaces of the participants and two commercial available dynamic workstations were chosen to be evaluated in the field. The first dynamic workstation was a portable ergometer called Deskbike, which can be placed under height-adjustable desks (following: DB), manufactured by the company “Worktrainer”. The second one was a portable pedaling machine manufactured by CCLab, which can be fitted under standard desks as well (following aLT). Both types of workstations can be moved from one desk to another by using integrated rolls. The workstations can be seen in Fig. 1. When using the Deskbike the upper body of the participant is in an upright position and the legs are moving in a cycling motion. The saddle is adjustable to fit the height of the user. The resistance can be infinitely adjusted by using a rotary knob. The activeLife Trainer can be used with a standard office chair and the use will lead to an elliptical foot motion. The user can choose between 8 levels of resistance by using a rotary knob as well.

Fig. 1. Dynamic workstations; left: Worktrainer Deskbike (source: Deutsche Telekom AG, Thomas Ollendorf), right: activeLife Trainer (source: IFA)

2.3 Treatment

Participants were provided free access to 8 dynamic workstations in total. The 4 Deskbikes and 4 activeLife Trainer were located in the office for a period of 30 working days in total. They were stored at two separated niches called lending stations. The dynamic workstations could be picked up there and had to be brought back after use. All participants were given an introduction on how to use the dynamic workstations and recommendations for the frequency and duration of use. The actual duration of lending and use as well as the intensity of use could be chosen voluntarily.

2.4 Measures

All data was assessed pseudonymized using participant codes, serial numbers and by coding the technical measurement systems. Anthropometric data was self-reported.

Lending and Usage of Dynamic Workstations. In cooperation with employees of the Hochschule Koblenz a system to register the duration of lending of each dynamic workstation was developed. Each participant received a Chipcard with a RFID (radio-frequency identification) system. Each workstation was numbered and assigned to a stationary device being located at the tables at the lending stations. These devices included a card reader and a computer system. By placing the RFID-card data on the device the record of the lending duration started and stopped when the card was being removed. The actual use of the station was measured as cadence of the movement of pedals and being registered and recorded with Sigma Rox 5.0 bike sensors (Sigma). All data was synchronized and saved once a week by a member of the study.

Recording and Valuation of Physiological Activation. The parameters heart rate (HR) and energy expenditure (EE) served as an indicator for individual cardiovascular load. Each participant was given an activity tracker "Fitbit Charge HR" (Fitbit) to assess these parameters. With the use of optical heart rate sensors (called PurePulse technology by Fitbit [10]) Heart Rate can be assessed every 3 s and is summarized as beats per minute (bpm). Resting heart rate was calculated as the average of the five lowest heart rate values recorded with the Fitbit tracker. Heart rate measurements for sitting and while using dynamic workstations were calculated as the average of all values recorded during these periods.

The calculation of the metabolic rate by the Fitbit Charge HR is based on typed-in information on the user's profile about age, height and weight and expressed as kilocalories per minute (kcal). According to the number of steps taken and the current heart rate the caloric expense when being active is calculated using standardized logarithms [10]. Energy consumption while working seated and using a workstation was calculated as the average of all values recorded during these periods.

2.5 Procedure

All participants were informed about aims of the study and the study design before the intervention period started an introduction to the concept of dynamic workstations including recommendations for use. Afterwards they filled in the baseline questionnaires containing anthropometric data. Then they were shown the location of the lending station and were instructed on how to use the lending system correctly. Afterwards all participants received their individual RFID-Cards and Fitbit activity trackers. They were instructed to wear them every day spent at the office from entering their desks up to leaving them. The displays of the trackers were blinded and the trackers were set to just show the number of steps taken if the blinding tape was removed. All data assessed by technical measurement systems (lending, use and physiological measurements) was recorded constantly throughout the intervention period. As the employees have flexible working hours the period from 6 am to 8 pm on every workday was included in the analysis. It was synchronized and saved once a week by a member of the study.

2.6 Processing of Data and Statistical Analysis

The combination of data being recorded by the lending system, the bike sensors and the Fitbit activity tracker illustrates the individual behaviour of each participant regarding physical activity at the workplace. The comparison of duration of lending, cadence of the pedals and steps recorded by the Fitbit tracker lead to the identification of intervals for working while seated, lending a dynamic workstation but not using it, working while using a dynamic workstation or moving in any other way (walking) for every participant individually. For each of these intervals individual average heart rate and energy expenditure values were calculated and summarized as an overall average value per person. For statistical comparison the average values of this data were calculated for the sample of 8 male participants using Microsoft Excel (version 2010).

For statistical analysis ANOVA repeated measures (general linear model) were used to examine differences between the main effect of the inner subject factor dynamic workstation on physiological activation (HR, EE) with a level of significance of $p \leq 0.05$. With the help of post hoc analysis possible differences between the mean values of working while seated and working while using dynamic workstations were examined. Because of the cumulative probability of errors occurring for multiple comparisons the significance level was adjusted according to Bonferroni. Working while seated was used as a reference and compared to the two different types of dynamic workstations regarding significant effects.

3 Results

3.1 Lending and Actual Use of Dynamic Workstations

Descriptive results for the lending and the usage of the dynamic workstations can be seen in Table 2. The results show very intra-individual variances between the subjects and strong differences between the two types of workstations. The total values of lending time in minutes and time of usage in minutes show a minimum of 34 min and a maximum of 4067 min, for the activeLife Trainer values vary between 63 min and 766 min. Therefore average values show very high standard deviations equally for the lending of the dynamic workstation and the time of usage.

Table 2. Descriptive results for the time of lending periods and usage periods for both dynamic workstations and 8 male subjects; SD: standard deviation

	Deskbike	activeLife Trainer
Lending periods in minutes		
Sum	8129	2668
Mean (SD)	1016,1 (±1341,1)	333,5 (±250,2)
Minimum	34	63
Maximum	4067	766
Sum	8129	2668
Usage periods in min		
Sum	3965	1161
Mean (SD)	495,6 (±479,5)	145,1 (±150,2)
Minimum	29	4
Maximum	1411	466

The analysis of minutes in sum shows that both workstations were actually used nearly one fourth of the lending period. The comparison of the total lending period between the Deskbike and the activeLife Trainer illustrates a nearly three times as long lending period for the Deskbike as for the activeLife Trainer. For the total time of usage the comparison shows that the Deskbike was even 3,5 times longer used than the activeLife Trainer. These results are illustrated in Fig. 2.

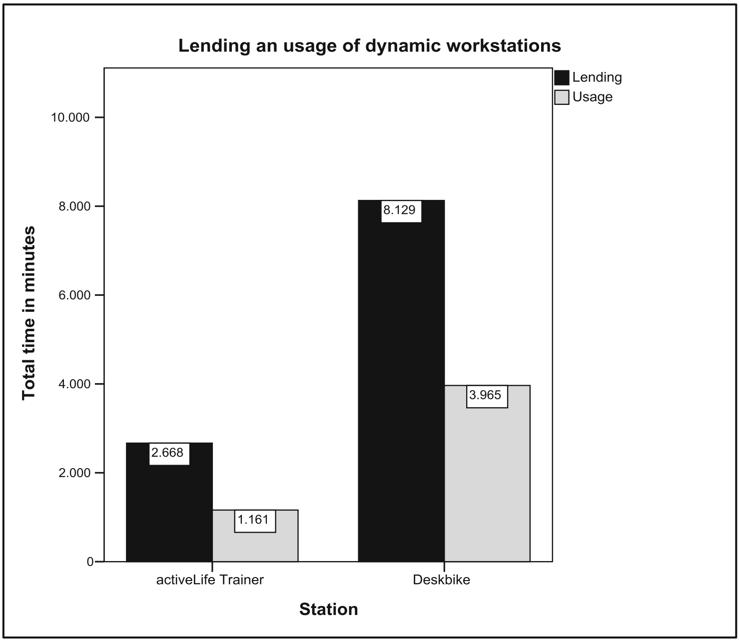

Fig. 2. Summarized time periods of lending and usage in minutes of both workstations for a sample of 8 male subjects

3.2 Results of Heart Rate Measurements

The average individual heart rate for each subject while using the Deskbike and the activeLife Trainer is displayed in Fig. 3. For the Deskbike average heart rate values vary between 62,4 bpm and 79,1 bpm, for the activeLife Trainer average heart rate values vary between 59 bpm and 80,7 bpm. The group mean value of heart rate while using the Deskbike is 69,5 (±6,2) bpm and 70,3 (±6,6) bpm while using the activeLife Trainer.

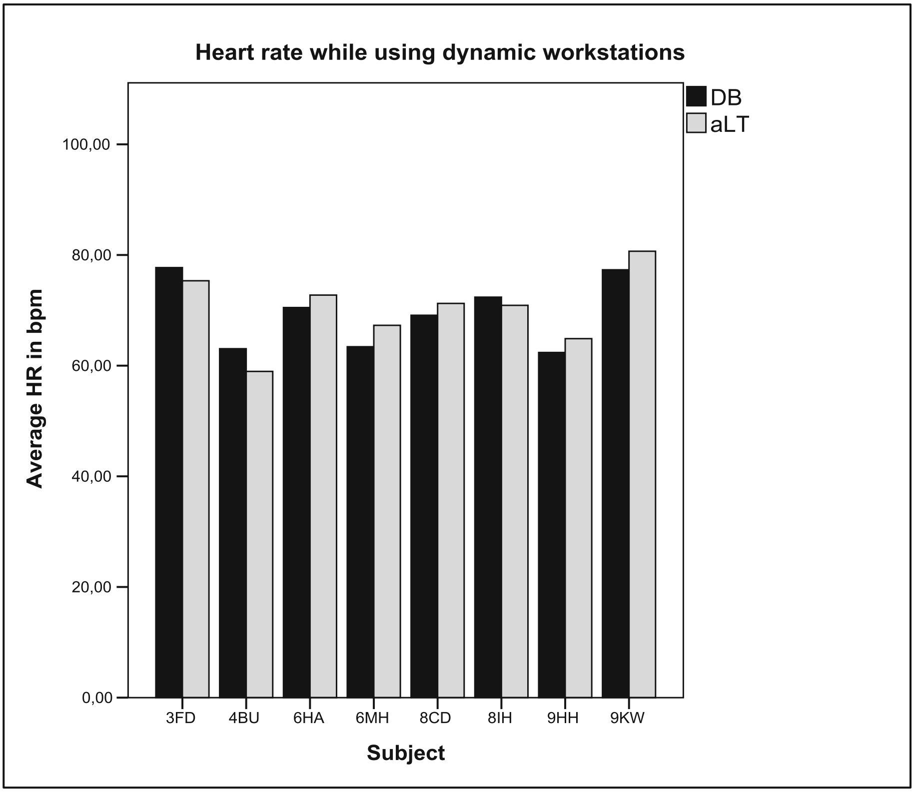

Fig. 3. Average heart rate (HR) measurements of each subject of the sample while using the Deskbike and activeLife Trainer

The results of the statistical analysis for the average heart rate calculated in beats per minute (bpm) are displayed in Table 3.

Table 3. Mean values and statistical results of 8 male subjects for heart rate (HR) for working while seated and the dynamic workstations, significant effect $p \leq 0.05$

	Conventional	Dynamic workstation		Factor workstation	Seated versus	
	Seated	Deskbike	activeLife Trainer		Deskbike	activeLife Trainer
Average HR in bpm (SD)	62,6 (5,6)	69,5 (6,2)	70,3 (6,6)	*	*	*

The average heart rate shows significant effects for the factor dynamic workstation. The use of both of the dynamic workstations results in a significant increase in average heart rate in comparison to working while seated.

3.3 Results of Energy Expenditure Measurements

For the Deskbike average individual energy expenditure values range from 1,3 kcal/min to 2,2 kcal/min. For the activeLife Trainer average individual energy expenditure values range from 1,2 kcal/min to 1,9 kcal/min. The results for each subject can be seen in Fig. 4. The group mean value of energy expenditure is 1,8 (±0,4) kcal/min while using the Deskbike and 1,6 (±0,2) kcal while using the activeLife Trainer.

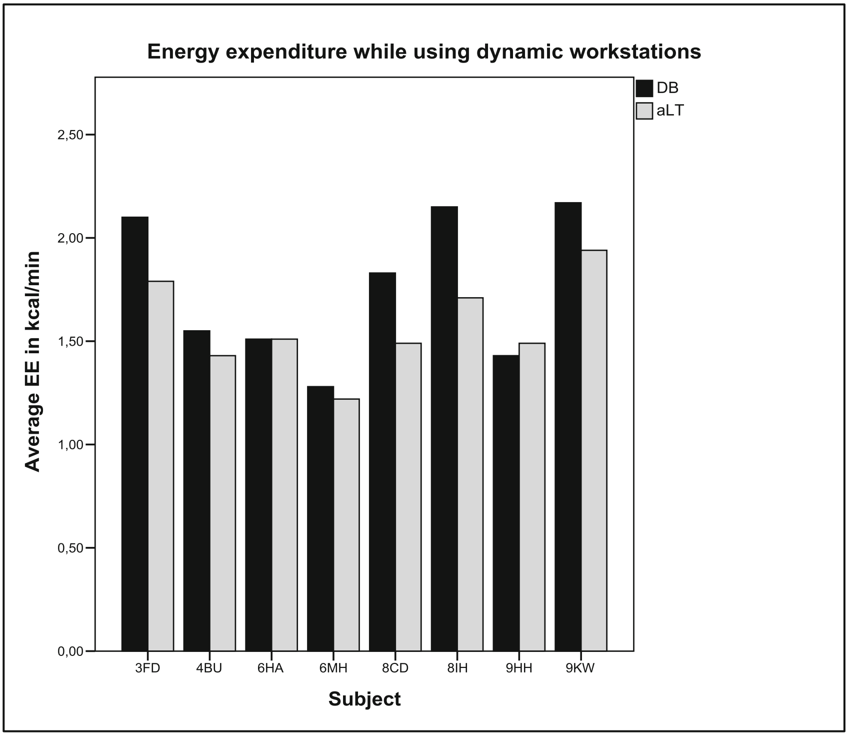

Fig. 4. Average energy expenditure (EE) measurements of each subject of the sample while using the Deskbike and activeLife Trainer

Table 4 includes all group values for the average energy expenditure calculated in kcal/min and the results of statistical analysis. The average energy expenditure in kcal/min shows significant effects for the factor dynamic workstation. And using the dynamic workstations while working in comparison to working seated causes a significant increase of average energy consumption for both types of stations.

Table 4. Mean values and statistical results of 8 male subjects for energy expenditure (EE) for working while seated and the dynamic workstations, significant effect $p \leq 0.05$

	Conventional	Dynamic workstation		Factor workstation	Seated versus	
	Seated	Deskbike	activeLife Trainer		Deskbike	activeLife Trainer
Average EE in kcal/min (SD)	1,4(0,2)	1,8 (0,4)	1,6(0,2)	*	*	*

4 Discussion

The present study examined two different dynamic workstations and their suitability as alternative workplaces based on the assessment of lending periods and the actual use of the stations and parameters of cardio-vascular load and metabolic effects. Moreover, two types for workstations which can be applied in different working environments were compared to each other regarding the assessed parameters.

The initial results show that the concept of both workstations caught the attention of the participants and were frequently used within the working hours. Regarding the physiological effects the usage of both types of workstations leads to a significant increase of heart rate and energy expenditure.

The results of the values recorded by the lending station and the comparison to the behaviour of the individual subjects of the study shows that both types of workstations have been lent and used at least once by all subjects, the other subjects used one of the different types. Therefore it can be concluded that the upright cycle Deskbikes and the under-desk pedaling machine activeLife Trainers demanding character is strong enough to result in testing and frequently using. However, the Deskbike seemed to be more attractive to the subjects than the activeLife Trainer being lent three times as much as the activeLife Trainer. One factor could be the change of the body position when using the Deskbike compared to using the activeLife Trainer which doesn't require getting up from the standard office chair. Another difference is the direction of movement of the legs. The Deskbike can be characterized as an upright ergometer where the legs move in a more vertical way. The body position when sitting in a standard office chair and using the activeLife Trainer can be compared to a semi recumbent ergometer which is characterized by a more horizontal movement of the legs [11]. According to personal preferences and the body physique one or the other type of movement alignment and therefore type of workstation will be chosen.

Another reason could be that the construction of the Deskbike enhances the impression and sense of the user to "do sports" a little more than the activeLife Trainer because of its' similarity to a real bicycle. Although the workstations were lent frequently the actual time periods of usage differ quite clearly. One possible explanation that the lending periods were three times longer than the actual usage could be the novelty of the concept combining physical activity with working at the desk for the subjects of the study. Although the level of physical activity might be not quite demanding it is likely that the subjects needed an initial phase of adaptation to moving while working. Another aspect to consider might be the different types of performed tasks while using the dynamic workstations. Although results of the IFA lab study showed no negative effects on work performance it was subjectively percieved as worse by the participants of the study while using y dynamic workstation compared to working while seated [9].

The results of assessing the cardiovascular load and metabolic effects are comparable to other studies examining these parameters. While using the dynamic workstations the heart rate increases compared to the conventional workplace. Results show that the average heart rate value is slightly higher for the time periods of using the activeLife Trainer than for the Deskbike. This seems to be a surprising effect regarding the comparatively smaller movement amplitude of the legs. On the one hand the individual values for average heart rate in between the subjects of the study sample show a greater range for the activeLife Trainer than for the Deskbike. On the other hand heart rate can be influenced by other factors than physical activity causing increased activity of the sympathetic nervous system like the emotional state, stress or excitement and caffeine [12]. Alternative methods to assess and compare individual heart rate values are calculating the individual heart rate reserve (HRR) [13] as an indicator for cardio-vascular load. The analysis of metabolic effects with the interpretation of energy expenditure showed that energy consumption in kcal per min increased while using both workstations compared to working while seated. As this is an important factor to consider the implementation of dynamic workstations as a preventive health measure at office environments they should be interpreted with particular care. The assessment of energy expenditure was made with the help of the activity tracker Fitbit Charge HR. Like the multitude of wearable activity tracker on the commercial market caloric consumption is estimated by combining self-reported anthropometric data, accelerometer data and heart rate measurements using standardized algorithms [10]. This method is prone to errors because of possible movement artefacts registered by the activity tracker. Furthermore the estimation of metabolic rates while being physically active is based on the assumption of standardized values of calorie consumption for specific movements. In comparison to more specific methods to assess energy expenditure like a breathing gas analysis [14] these devices are just able to display these parameters roughly.

5 Conclusion

The results for this sample of male participants show that the modern concepts of dynamic workstations like the Deskbike and the activeLife Trainer can be considered as alternatives to conventional seated workplaces. Both types of workstations generated interest and their practicability allowed them to be implemented in an occupational setting. Because of the relatively small sample size the interpretation of the effects on physiological parameters should be made with the high influence of individual measurements in mind. Future studies should investigate these effects with larger samples and both gender to generate more complex and reliable findings about the effect of dynamic workstations in occupational settings.

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