DISSERTATION / DOCTORAL THESIS

Titel der Dissertation / Title of the Doctoral Thesis

„Implementing two-desk sit-to-stand workstations in office environments: The short and medium-term effects of working in alternating postures (sit/stand) on cognitive performance and sedentary behaviour"

verfasst von / submitted by

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angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Doktor der Naturwissenschaften (Dr.rer.nat.)

Wien, 2018 / Vienna 2018

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	A 796 605 481
Dissertationsgebiet lt. Studienblatt / field of study as it appears on the student record sheet:	Sportwissenschaft (Naturwissenschaft) Sport science (Natural science)
Betreut von / Supervisor:	Univ.-Prof. Dipl.-Ing. Dr. Arnold Baca

Abstract

Far-reaching social development over the last few decades has caused extensive changes in physical activity patterns, especially in industrialized societies. Ongoing computerization and digitalization has led to a decrease in occupational physical activity and an increase in sitting time. As prolonged sitting, particularly in long lasting and uninterrupted bouts, constitutes a risk factor for several diseases independent of other physical activity, a growing number of workplace-based interventions have been implemented to improve this situation. Furthermore, height-adjustable desks (sit-to-stand workstations) allowing users to work either in a standing or sitting posture have received increased scientific interest over the last few years.

As many of the currently used sit-to-stand workstations have little or no effect on sedentary behavior because of practical factors (e.g. adjustment problems, workstation's complexity, available working-space) and their effect on cognitive performance and mental stress has not been sufficiently investigated, two randomized controlled trials were conducted within this PhD thesis.

The aim of the first study was to investigate the short-term (1 day) effect of alternating postures on cognitive performance (reaction time, concentration performance, working speed) and workload. Within this study 45 people executed a predefined study protocol either in a sitting or an alternating (sit and stand) body posture. Stringent inclusion criteria and identical environmental conditions, as well as the study's cross-over design, ensured enhanced comparability. In the course of this study, no differences in cognitive performance and workload were found between operations carried out in alternating postures and those in sitting only.

Based on short-term study results, the aim of the second one-year study was to analyze the medium-term effect (6 months) of alternating postures on cognitive performance (reaction time, concentration, working speed), workload, and sedentary behavior. Eighteen office workers, equipped with either traditional or novel sit-to-stand workstations for a period of 23 weeks, were investigated. Together with the study's cross-over design, pre/post comparisons enabled appropriate data analysis. Overall, a clear and regressive decrease in sitting time was found for sit-to-stand workstation users. Despite the simplicity of the concept, sitting was mainly executed in long-lasting periods. Although no difference in cognitive performance could be found for both types of workstation, increased text editing accuracies as well as changes in physiological stress responses were shown for sit-to-stand workstation users.

The results of this PhD thesis indicate that concerns regarding performance loss caused by alternating postures are baseless. Although the effect could not be completely clarified, decreased error rates as well as changes in stress responses during and after mental stress demonstrated the potential of working in alternating postures, especially for monotonous tasks. Significant reductions in sitting time, considerably above the average of previous interventions, illustrated the effectiveness and importance of simple and barrier-free sit-to-stand workstation concepts.

Keywords: postural changes, sit-to-stand desks, cognitive performance, height-adjustable desks, occupational sitting, randomized controlled trial, mental stress, office

Zusammenfassung

In den letzten Dekaden kam es aufgrund weitreichender sozialer Veränderungen zu einem deutlichen Wandel im physischen Aktivitätsverhalten industrialisierter Gesellschaften. Eine stetig anhaltende Industrialisierung und Computerisierung führte dabei zu einer deutlichen Reduktion körperlicher Aktivität am Arbeitsplatz, sowie zu einem stetigen Anstieg der im Sitzen verbrachten Zeit. Da lange Sitzzeiten, vor allem in langanhaltenden und ununterbrochenen Perioden, unabhängig vom Grad der körperlichen Ertüchtigung Risikofaktoren für verschiedenste Krankheiten darstellen, wurden in den letzten Jahren vermehrt arbeitsplatzbezogene Interventionen durchgeführt. Eine zunehmend in den wissenschaftlichen Fokus rückende Form der Intervention ist dabei die Implementierung höhenverstellbarer Tische am Arbeitsplatz (Sitz-Steh-Arbeitsplätze), welche es den Anwenderinnen und Anwendern erlauben, Tätigkeiten sowohl im Sitzen als auch im Stehen durchzuführen.

Da derzeitige Sitz-Steh-Arbeitsplätze aufgrund verschiedenster Randfaktoren (z.B. Adjustierungsdauer, Komplexität des Arbeitsplatzes, verfügbarer Arbeitsraum) oft nur geringe bis keine Änderungen im Sitzverhalten der AnwenderInnen hervorrufen und ihr Effekt auf das Stressverhalten und die kognitive Leistungsfähigkeit bis heute unzureichend erforscht ist, wurden im Rahmen dieser Dissertation zwei randomisierte kontrollierte klinische Studien durchgeführt.

Ziel der ersten Studie war es, den kurzzeitigen Effekt (1 Tag) wechselnder Körperhaltungen auf kognitive Leistungsparameter (Reaktionszeit, Konzentrationsleistung, Arbeitsgeschwindigkeit) und Arbeitsbelastung zu untersuchen. Im Zuge dieser Studie wurde ein vordefiniertes Studienprotokoll von 45 Personen entweder im Sitzen oder in alternierenden Körperhaltungen (Sitzen und Stehen) ausgeführt. Stringente Einschlusskriterien, idente Umgebungsbedingungen sowie das Cross-Over-Design der Studie führten dabei zu einer höchstmöglichen Vergleichbarkeit. Innerhalb dieser Studie konnten weder in der kognitiven Leistung noch in der Arbeitsbelastung Unterschiede zwischen in wechselnden Haltungen und ausschließlich im Sitzen ausgeführter Tätigkeit gefunden werden.

Ausgehend von den Ergebnissen der Kurzzeitstudie verfolgte die zweite, einjährige Studie das Ziel, den mittelfristigen Effekt (6 Monate) wechselnder Körperhaltungen auf kognitive Leistungsparameter (Reaktionszeit, Konzentrationsleistung, Arbeitsgeschwindigkeit), Arbeitsbelastung und die im Sitzen verbrachte Zeit zu analysieren. Dabei wurden 18 BüromitarbeiterInnen untersucht, welche in alternierender Reihenfolge und für die Dauer von 23 Wochen entweder mit einem neuartigen Sitz-Steh-Arbeitsplatzkonzept oder einem herkömmlichen Büroarbeitsplatz ausgestattet wurden. Vorher-Nachher-Vergleiche, gepaart mit dem Cross-Over-Design der Studie, ermöglichten adäquate Aussagen über die gemessenen

Parameter. Zusammenfassend konnte eine deutliche, zeitlich regressive Sitzzeitreduktion für die Verwendung des neuartigen Sitz-Steh-Konzepts aufgezeigt werden, welche trotz der Einfachheit des Konzepts in langanhaltenden Episoden absolviert wurde. Obwohl es in der kognitiven Leistungsfähigkeit zu keinen Unterschieden zwischen AnwenderInnen der zwei Bürotypen kam, konnte eine erhöhte Textbearbeitungsgenauigkeit, wie auch eine veränderte Stressantwort nach mentaler Belastung für Sitz-Steh-AnwenderInnen festgestellt werden.

Die Ergebnisse der Dissertation zeigen, dass Bedenken bezüglich eines haltungswechsel-induzierten Leistungsabfalls unbegründet sind. Wenngleich der Effekt noch nicht restlos geklärt werden konnte, deuten veränderte Fehlerraten und Stressantworten unter und nach mentaler Belastung, vor allem bei monotonen Tätigkeiten, auf das Potential wechselnder Körperhaltungen hin. Der deutliche Rückgang der Sitzzeit, weit über dem durchschnittlichen Effekt früherer Interventionen, verdeutlicht die Wirksamkeit und Bedeutung simpler und barrierefreier Arbeitsplatzkonzepte.

Schlüsselwörter: Haltungswechsel, Sitz-Steh-Tisch, kognitive Leistung, höhenverstellbare Tische, berufsbedingtes Sitzen, randomisierte kontrollierte Studie, mentaler Stress, Büroarbeitsplatz

Related publications

The following list of peer-reviewed, co-authored papers gives an overview of the publication activities in the course of this thesis. The author's contributions are stated explicitly.

Primary publications

The publications listed below are the core elements of the dissertation. Corresponding and first author Bernhard Schwartz contributed to the research design, collected and analyzed all study-related data on his own and led the development of these articles. The publications, sorted by date, are as follows:

Accepted and published primary publications

PP1: Schwartz B., Kapellusch J., Schrempf A., Probst K., Haller M., Baca A. (2017) *Effect of alternating postures on cognitive performance for healthy people performing sedentary work*, Ergonomics, 1–18. doi:10.1080/00140139.2017.1417642 (Schwartz et al., 2017)

In this article a randomized controlled trial was described, evaluating the short-term effect of alternating postures (sit/stand) on cognitive performance related parameters. Furthermore, the study protocol's suitability was proven for use in medium-term cases. No differences in cognitive performance and workload were found for people working in alternating working postures.

PP2: Schwartz B., Kapellusch J., Schrempf A., Probst K., Haller M., Baca A. (2016) *Effect of a novel two-desk sit-to-stand workplace (ACTIVE OFFICE) on sitting time, performance and physiological parameters: protocol for a randomized control tria*l, BMC Public Health, 16:578, doi: 10.1186/s12889-016-3271-y (Schwartz et al., 2016).

This article describes a study protocol for a one-year, randomized, controlled cross-over trial evaluating medium-term changes in physiological and cognitive parameters caused by the regular use of two-desk sit-to-stand workstations.

Manuscripts currently under review

PP3 (manuscript): Schwartz B., Kapellusch J., Baca A. (2018) "*Influence of a two-desk sit-to-stand workstation on sitting time: A randomized controlled pilot trial under real world conditions*", Plos One (under review) (Schwartz et al., 2018a) - submitted June 25th 2018

This article states the findings of a one-year, randomized, controlled trial, illustrating the effect of a two-desk sit-to-stand workstation on sitting time and physical activity. Study results indicated a great reduction in sitting time without any compensational loss in physical activity.

PP4 (manuscript): Schwartz B., Kapellusch J., Baca A., Wessner B. (2018) "*Mid-term effects of a two-desk sit/stand workstation on cognitive performance and workload for healthy people performing sedentary work: A secondary analysis of a pilot randomized controlled trial*", Ergonomics (under review) (Schwartz et al., 2018c) - submitted June 23rd 2018

This article shows the findings of a one-year, randomized, controlled trial, evaluating the medium-term effects of a two-desk sit-to-stand workstation on cognitive performance. Contrary to non-significant differences in cognitive performance, improvements in text editing accuracy were found. Furthermore, changed in cortisol levels occurred in regular sit-to-stand workstation users.

Secondary publications

The following list contains publications related to this thesis, but not forming part of it.

SP1: Schwartz B., Kapellusch J., Baca. A., *Performing sedentary work in alternating (sit/stand) body postures - Is there an effect on perceived workload? Study findings from two RCTs (short-term & mid-term),* Proceeding of the 20th Triennial Congress of the International Ergonomic Association (IEA 2018), Florence, Italy, 2018 (Schwartz et al., 2018b)
This conference abstract written by Bernhard Schwartz summarizes the short and medium-term effects of a two-desk sit-to-stand workstation on perceived workload.

SP2: Schwartz B. and Baca A., "*Wearables and Apps - Modern diagnostic frameworks for health promotion through sport*", German Journal of Sports Medicine, 2016, 67(6)131-136, DOI: 10.5960/dzsm.2016.237 (Schwartz & Baca, 2016)
This article was written by Bernhard Schwartz within his research internship at the University of Vienna. It contains general information concerning health-related wearables and apps.

SP3: Schwartz B. and Baca A., *Influence of a novel two-desk sit-to-stand workplace on sitting time and overall physical activity*", Proceeding of the 21st Annual Congress of the European College of Sport Science (ECSS 2016), Vienna, Austria, 2016 (Schwartz & Baca, 2016b)
This conference abstract written by Bernhard Schwartz illustrates the effect of a two-desk sit-to-stand workstation on sitting time and physical activity, examined solely via questionnaires.

SP4: Schwartz B., Schrempf A., Probst K., Haller M. *Postural Changes in Office Environments – Do they really affect user performance?* Proceeding of the 19th Triennial Congress of the International Ergonomic Association (IEA 2015), Melbourne, Australia, 2015 (Schwartz et al., 2015)

This conference abstract written by Bernhard Schwartz exhibits preliminary short and medium-term results regarding the effect of working in alternating postures (sit/stand) on cognitive performance.

SP5: Schwartz B., "*Cognitive and biomechanical effects of postural changes in office environments*", in „VerANTWORTung für Arbeit der Zukunft", Proceeding of the 61th Spring-Congress on the Society for Ergonomics and Work Science (GfA-Frühjahrskongress), Karlsruhe, Germany, 2015, ISBN 978-3-936804-18-8 (Schwartz, 2015)
This conference article contains general information as well as preliminary results regarding the author´s PhD thesis. It was written by Bernhard Schwartz and discussed within a doctoral program at the University of Karlsruhe in the course of the "Spring-Congress on the Society for Ergonomics and Work Science".

SP6: Probst K., Lindlbauer D., Haller M., Schwartz B., Schrempf A., "*Exploring the Potential of Peripheral Interaction through Smart Furniture", in Peripheral Interaction: Shaping the Research and Design Space"*, Workshop at CHI2014, Toronto, Canada, 2014, ISSN: 1862-5207 (Probst et al., 2014a)
The potential of peripheral interaction through smart furniture is described in this conference article. Bernhard Schwartz was part of the project team and supported the realization of a smart furniture solution.

SP7: Probst K., Lindlbauer D., Haller M., Schwartz B., Schrempf A., "*A Chair as Ubiquitous Input Device: Exploring Semaphoric Chair Gestures for Focused and Peripheral Interaction*", in CHI'14: Proceedings of the 32nd Int. Conference on Human Factors in Computing Systems, Toronto, Canada, 2014, pp. 4097-4106. (Probst et al., 2014b)

This conference article investigates the integration of gestural chair interactions into the desktop computing experience. An iterative design process from the definition of a basic set of semaphoric chair gestures to their application for focused and peripheral interaction scenarios was described. Bernhard Schwartz developed parts of the algorithm for this system.

SP8: Probst K., Lindlbauer D., Perteneder F., Haller M., Schwartz B., Schrempf A., "*Exploring the Use of Distributed Multiple Monitors Within an Activity-Promoting Sit-and-Stand Office Workspace*", in INTERACT'13: Proceedings of the 14th IFIP TC13 Conference on Human-Computer Interaction, Kapstadt, South Africa, 2013, pp. 476-493. (Probst et al., 2013b)

This conference article treats a pilot study investigating the effect of a two-desk sit-to-stand workstation on sedentary behavior. Bernhard Schwartz was part of the research team and helped to realize and analyze this study.

SP9: Probst K., Lindlbauer D., Greindl P., Trapp M., Haller M., Schwartz B., Schrempf A., "*Rotating, Tilting, Bouncing: Using an Interactive Chair to Promote Activity in Office Environments*", in Ext. Abstracts CHI'13: Proceedings of the 31st International Conference Extended Abstracts on Human Factors in Computing Systems, Paris, France, 2013, pp. 79-84. (Probst et al., 2013a)

Based on findings by Schwartz et al. (2013), this article describes the challenges and opportunities for performing human-computer interaction by means of an instrumented, interactive office chair. Bernhard Schwartz developed the algorithm for this system.

SP10: Schwartz B., Schrempf A., Probst K., Haller M., Glöckl J., "*Recognizing Static and Dynamic Sitting Behavior by Means of Instrumented Office Chairs*", in Biomed'13: Proceedings of the 10th IASTED International Conference on Biomedical Engineering, Innsbruck, Austria, 2013 (Schwartz et al., 2013)

This conference article written by Bernhard Schwartz describes the development of a measuring device detecting sitting postures in office environments. Additionally, it contains pilot study results evaluating the usability of this device.

Statutory Declaration

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

Place	Date	Signature

Eidesstattliche Erklärung

Ich erkläre an Eides statt, dass ich die vorliegende Arbeit selbstständig verfasst, andere als die angegebenen Quellen/Hilfsmittel nicht benutzt, und die den benutzten Quellen wörtlich und inhaltlich entnommene Stellen als solche kenntlich gemacht habe.

Ort	Datum	Unterschrift

Acknowledgments

I would like to thank all people who have supported me over the last six years. First, I want to thank my supervisor Prof. Arnold Baca, who continuously supported my PhD thesis. He guided me, offered me the opportunity to follow my ideas, and steadily motivated me to conduct my work at the highest possible standard.

Furthermore, I want to express my deepest gratitude to Prof. Jay Kapellusch. He introduced me to his ergonomic network, supported me in publishing data and encouraged my ergonomic research. Despite the substantial geographical distance, he always cared about my concerns.

My sincere thanks are also extended to Prof. Marc Streit and Barbara Nussbaumer-Streit who continuously influenced my research in a positive way. As personal friends and mentors, Marc and Barbara showed me the correct way to work through scientific projects. Their scientific success was an everyday motivator for me and prevented me from publishing data at a too early stage.

I also want to honestly thank my partner, Adela Nemcova, who steadily supported my PhD thesis. Although this PhD project led to a long-distance relationship for four years, her emotional support during stressful periods never stopped. Despite this circumstance, she often sacrificed leisure time for proof reading my articles.

I want to thank all my colleagues and friends who helped me to stay positive during these six demanding and labor-intensive years as well as my brother Roland Schwartz for supporting my PhD thesis in many ways.

Finally, I want to express my gratitude to all people supporting this PhD thesis in a technical way. I want to thank Joseph Gloeckl for donating the all height-adjustable desks used in the course of this research. His enormous interest in scientific studies was a constant source of motivation. I want to thank the Upper Austrian health insurance for allocating participants in the medium-term study. Lastly, I want to thank Christian Ecker for donating all ECG recorders used in this study. Without the support of these three parties, the successful completion of this PhD thesis would not have been possible.

Some working packages related to this thesis (<25%) were funded by the Austrian Research Promotion Agency (FFG) through the BRIDGE program (Project: "Active Office", grant number: 834185). Research abroad (in part) as well as open access fees were funded by the University of Vienna.

Content

List of Figures

Abbrevation

ANOVA	Analysis of variance
BCT	Behavior change technique
BMI	Body mass index
CAR	Cortisol awakening response
CEO	Chief executive officer
ECG	Electrocardiogram
EEG	Electroencephalography
ELISA	Enzyme-linked Immunosorbent Assay
EU	European Union
H	Hypothesis
IPAQ	International Physical Activity Questionaire
MET	Metabolic equivalent of task
NASA	National Aeronautics and Space Administration
NASA TLX	NASA Task Load Index
OECD	Organization for Economic Co-operation and Development
OSPAQ	Occupational Sitting and Physical Activity Questionnaire
PA	Physical Activity
SH	Secondary hypothesis
SITBRQ	Workplace Sitting Breaks Questionnaire
UK	United Kingdom
US	United States of America
WHO	World Health Organisation

1 Introduction

In modern societies alterations in domestic activities, transportation methods, and social life, as well as a shift from agricultural and manufacturing occupations to service jobs (Figure 1), has led to increased time spent in sedentary or prolonged seated postures (Brownson et al., 2005; Church et al., 2011; Ng and Popkin, 2012). In particular, the annual amount of sedentary time spent in the United States and in parts of Europe grew by more than 1.3 percent over the last decades (Ng and Popkin, 2012). Nowadays, as a consequence, US citizens spend about 55 percent of their daytime in a sedentary way, with noticeably higher values for elderly people (Matthews et al., 2008). As sedentary behavior is strongly related to sitting time, a dramatically high prevalence of sitting time can be observed in today's societies.

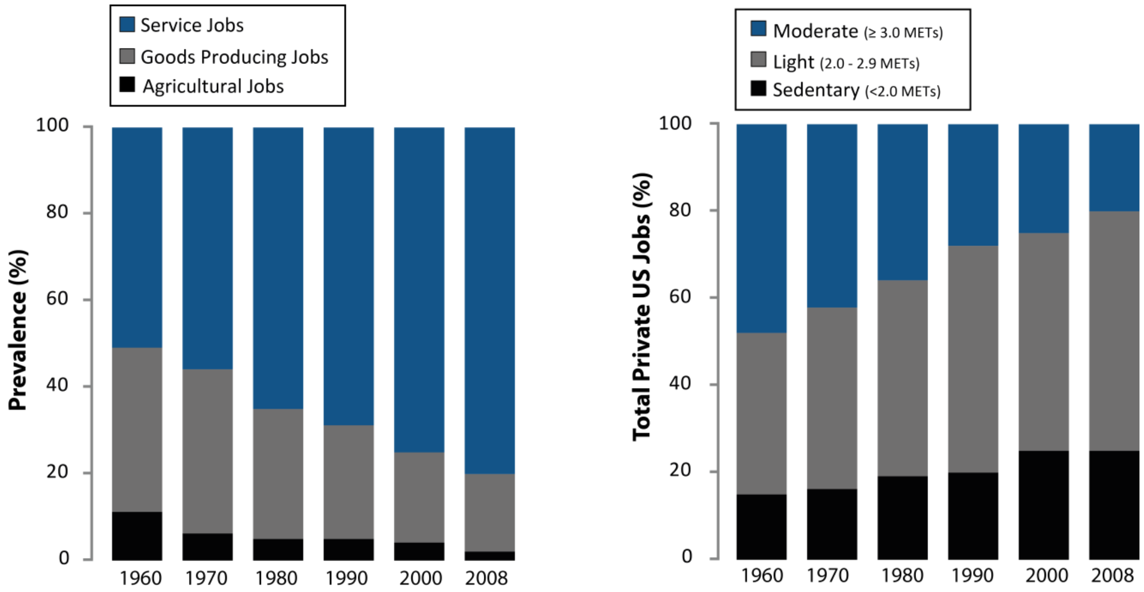

Figure 1: Service, manufacturing and agricultural jobs in the US (left) and trends in the prevalence of sedentary, light, and moderate activity occupation from 1960 to 2008 according to (Church et al., 2011)

1.1 Sitting time

Currently, 18.5 percent of all EU-citizens sit more than 7.5 hours per day (Loyen et al., 2016). There are huge inter-country variations of between 8.9 and 32.1 percent, and these are mainly based on the type of occupations (Eurobarometer & European Commission, 2014; Loyen et al., 2016) and a north-south disparity within the EU (Figure 2). For example, it is estimated that approximately one third of white-collar workers spend more than 7.5 hours per day seated, this is five times more than workers in manual occupations (Loyen et al., 2016). Moreover, it is assumed that working adults sit for up to two-thirds of their working time on average, with some office-based occupations (e.g. call center employees) requiring workers to sit for more than 80% of their working day (Alkhajah et al., 2012; Chau et al., 2014; Straker et al., 2013).

Interestingly, compared to leisure days approximately 2 hours more were spent sitting on working days (McCrady and Levine, 2009), and one quarter of sitting time is in periods of longer than 55 minutes (Ryan et al., 2011).

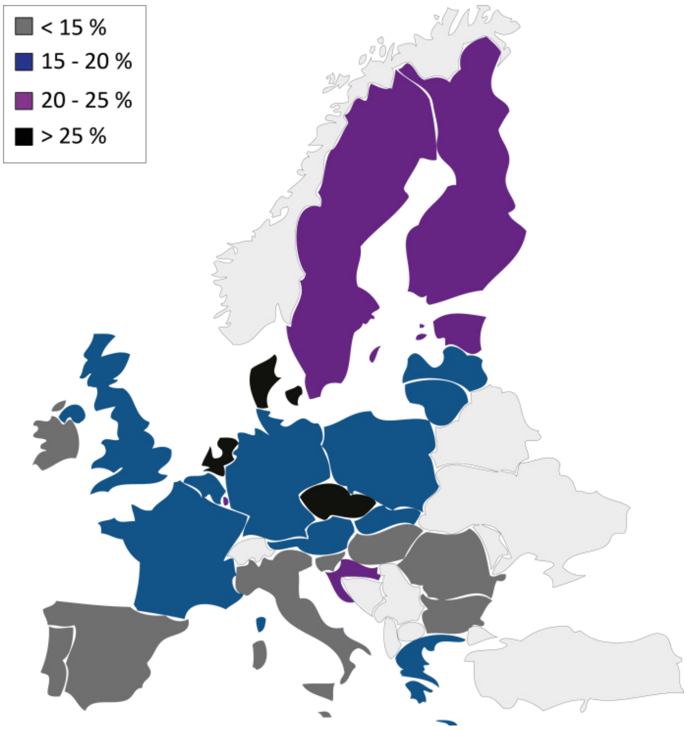

Figure 2: The distribution of the proportion of European adults reporting more than 7.5 h per day spent sitting according to (Loyen et al., 2016)

1.2 Physical activity

Simultaneously with the increment of sitting time, a significant decrease in physical activity, mainly driven by a growing prevalence of modern technologies, can be observed (Church et al., 2011; Ng and Popkin, 2012). Cars, robots, and other technical aids support users facing high physical demands, and lead to almost universal comfortable conditions in daily life. This development has resulted in a dramatical decrease in occupational physical activity (Figure 3) and energy expenditure, especially in working environments (Church et al., 2011; Ng and Popkin, 2012). Since the 1960s, industrialization and computerization, as well as social change, has diminished the annual occupational physical activity by more than 1.0 percent (Ng and Popkin, 2012). Related to this, the daily energy consumption, based on an overall physical activity decrease of approximately 40 percent over the last decades (Ng and Popkin, 2012), has dropped by more than 100 calories per day (Church et al., 2011).

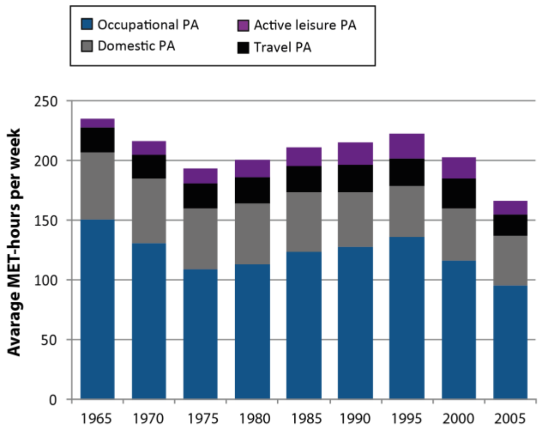

Figure 3: US (left) and UK (right) adults´ metabolic equivalents of task (MET)-hours per week of physical activity according to (Ng and Popkin, 2012)

1.3 Health issues

Although the decline in physical activity helped to reduce physical overload and the accompanying risks (Straker and Mathiassen, 2009), ongoing activity pattern changes are relevant factors in the development of health-related problems (Hill et al., 2003). Sedentary and sitting time are both risk factors for several diseases, such as obesity, depression and all-cause mortality (Brown et al., 2003; Peeters et al., 2013; Van Der Ploeg et al., 2012; Van Uffelen et al., 2013). Several types of cancer, mainly localized in lower body areas (Gierach et al., 2009; Patel et al., 2006), as well as musculoskeletal diseases (Lis et al., 2007; Peeters et al., 2013) are also related to prolonged sitting. Long bouts of uninterrupted sitting increase these risks (Lis et al., 2007) and further affect cognitive performance and comfort (Karakolis et al., 2016). Interestingly, risks of prolonged sitting are independent of physical activity levels (Healy et al., 2008a; Kerr et al., 2016; Peddie et al., 2013; Van Uffelen et al., 2010). On the other hand, regular sitting time interruptions have positive effects on waist circumference, triglycerides, postprandial plasma insulin (Healy et al., 2008a; Peddie et al., 2013), and daily energy consumption (MacEwen et al., 2015; Swartz et al., 2011).

1.4 Recommendations

Due to the aforementioned reasons it seems evident that increasing daily physical activity as well as reducing sitting time are key elements in current preventive medicine. As health issues such as obesity and overweight are related to socioeconomic costs of up to 2.8 % of the national gross product (Maniadakis and Gray, 2000; Tremmel et al., 2017), it is clear why this situation is also reflected in several national and international guidelines (Garber et al., 2011; World Health Organization, 2010). According to current WHO recommendations, people of working age should perform at least 150 minutes of moderate-intensity aerobic physical activity or at least 75 minutes of vigorous-intensity aerobic physical activity per week. In addition, doubling the amount of physical activity can elicit further additional health benefits (World Health Organization, 2010). Although it is possible to reach the physical activity recommendations by combining both intensity levels, only 30.3% of EU and 23.0% of global citizens aged 18+ years attained this level between 2002 and 2010 (Global Health Observatory (GHO) Repository, 2010). Furthermore, age (older adults are less active than younger ones) and level of income (high income countries have more than twice the prevalence of insufficient physical activity of low income countries) are main causes for physical activity disparities around the globe.

In contrast to physical activity recommendations, recommendations for sitting time are mainly based on expert consensus rather than robust scientific evidence (Ryan et al., 2011). Although there is no consistent global consensus about sitting time values, the pillars of all recommendations are similar: to reduce sitting time regardless of physical activity (Garber et al., 2011) and to avoid prolonged sitting periods by inserting periods of standing or moving around (e.g. 5 min every hour) (Hamilton et al., 2008; Owen et al., 2009; Scott et al., 2009; Shrestha et al., 2016).

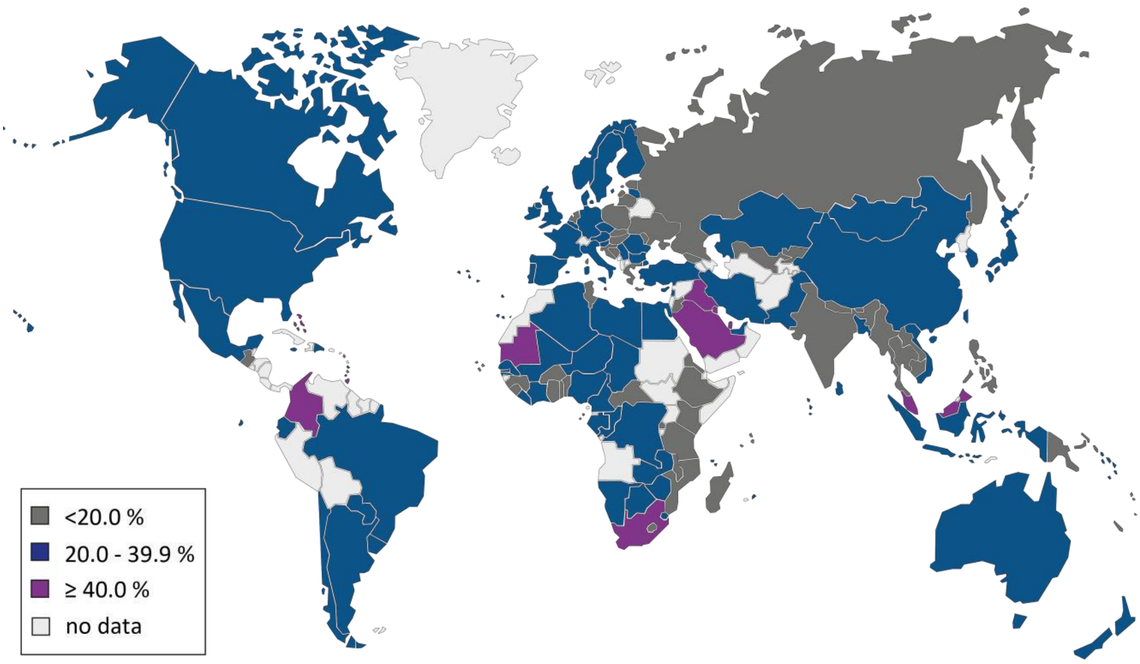

Figure 4: Prevalence of people aged 18+ not reaching the WHO physical activity recommendations according to (Global Health Observatory (GHO) Repository, 2010)

1.5 Interventions

In 2014, within the OECD countries the amount of time spent at work ranged from 1366 to 2228 hours per year (Figure 5), and the number of working hours dropped during the past 15 years by more than 4 percent (Global Health Observatory (GHO) Repository, 2010). It is estimated that on a worldwide scale working adults spend nearly one third of their adult life at work (Alkhajah et al., 2012). In addition, in developed countries more than two thirds of the working population spend the majority of their waking hours at work (OECD, 2015). Subsequently, it seems clear that workplace based interventions are central to reducing sitting time, increasing physical activity, and subsequently fulfilling current recommendations.

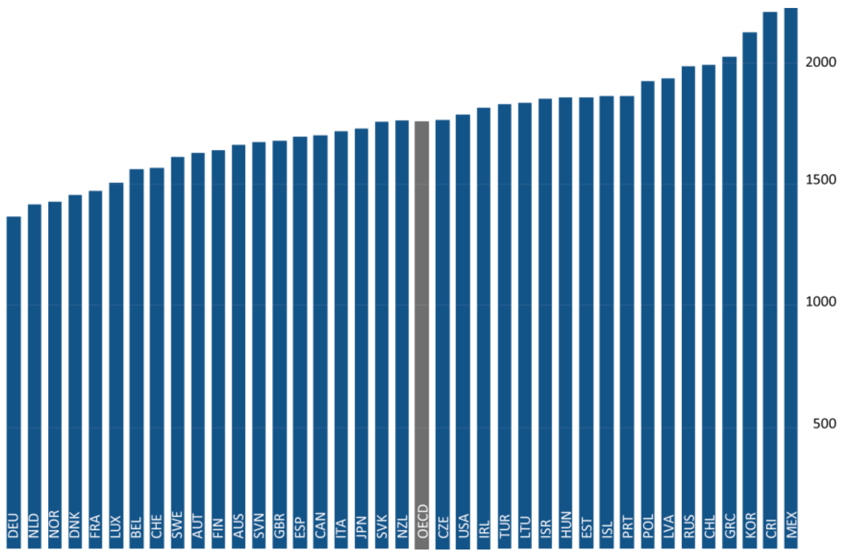

Figure 5: Annual hours worked in OECD countries in 2014 according to (OECD, 2016)

Workplace based physical activity interventions can be implemented in several ways (Dubuy et al., 2013; Gilson et al., 2009). They can include guided workouts during the working hours containing predefined goals e.g. 10,000 steps per day (Dalager et al., 2016) often accompanied by workshops (Hendriksen et al., 2016), as well as regular reminders (Fournier et al., 2016) to enhance the intervention's effectiveness. Additionally, workplace based sitting time interventions can be implemented in three different ways: physical changes in workplace environments (e.g. moving printers away from workstations to promote postural changes), policy changes regarding the organization of work (e.g. regular exercise breaks in the working process), as well as professional counseling (Shrestha et al., 2016). The implementation of height-adjustable desks, sit-to-stand workstations and active workstations (Figure 6) has received particular scientific interest in recent years.

1.5.1 Active workstations

Active workstations, usually consisting of working desks paired with fitness devices like elliptical trainers (Commissaris et al., 2014; Rovniak et al., 2014), cycling workstations (Elmer and Martin, 2014) or treadmills (Commissaris et al., 2014; Koepp et al., 2013) enable employees to take physical activity while working. Positive effects regarding sitting time, physical activity and energy consumption (Neuhaus et al., 2014a; Torbeyns et al., 2014), as well as neutral or positive impacts on obesity and other health-related outcomes, reaffirm the usefulness of such interventions, although more rigorously controlled studies with sufficient statistical power and long-term follow-ups are needed to clearly identify health-related benefits (Neuhaus et al., 2014a). Nevertheless, due to high acquisition costs, space requirements, and logistical problems active workstations are rarely implemented.

1.5.2 Sit-to-stand workstations

Sit-to-stand workstations (Figure 6), mainly realized by implementing height-adjustable desks or side tables in regular working environments, provide an incentive for people to work in either a sitting or standing posture and facilitate regular sit-to-stand transitions.

Figure 6: Occupational sitting time intervention based on physical changes in workplace environments - height-adjustable desks (left), sit-to-stand workstations (mid) and active workstations (right)

Despite the global increase in incidence rates, the majority of office workers in Austria are still not working on this kind of workstation because of concerns about utilization rates (i.e. how often do employees work while standing), loss of productivity, and higher purchasing costs. When sit-to-stand concepts do not fulfill users' requirements or workflow, utilization rates can be especially low (Wilks et al., 2006). In this regard, environmental conditions (i.e. working desk size), intervention type (desk only vs. multicomponent set-up), as well as user friendliness (i.e. type of height adjustments) can noticeably increase the feasibility and performance of sit-to-stand workstations (Neuhaus et al., 2014b; Straker et al., 2013; Wilks et al., 2006).

1.6 Cognitive performance

Within the last decade several studies have investigated the effect of active workstations (Commissaris et al., 2014; Koren et al., 2016; Ohlinger et al., 2011), sit-to-stand workstations (Russell et al., 2015; Straker et al., 2013), and physical activity interventions (Conn et al., 2009), on cognitive performance, coming to the conclusion that the workstation type (e.g. sit-to-stand, recumbent elliptical, cycling or treadmill workstations) as well as physical activity (i.e. working while executing slow or fast body movements) can alter performance.

Working in motion can result in reduced performance for motor tasks like mouse moving or finger tapping (Koren et al., 2016; Ohlinger et al., 2011; Straker et al., 2009), additionally triggered by the level of physical activity (Funk et al., 2012; Straker et al., 2009). In contrast, non-motor cognitive skills like reading (Commissaris et al., 2014; John et al., 2009), attention (John et al., 2009; Ohlinger et al., 2011), and working memory (Bantoft et al., 2015) seem to be unaffected. Positive and negative effects on accuracy (Commissaris et al., 2014; Ghesmaty Sangachin et al., 2016) and arithmetic performance can also be observed for working in motion (John et al., 2009).

When compared to sitting, standing did not influence reading skills (Commissaris et al., 2014), working memory (Bantoft et al., 2015; Russell et al., 2015) or arithmetic problem solving (Karakolis et al., 2016). In contrast, standing can alter performance in motor tasks (Ghesmaty Sangachin et al., 2016; Karakolis et al., 2016; Straker et al., 2009) and attention (Schraefel et al., 2012).

1.7 Workload

Workload, highly related to physical and mental health (Bakker et al., 2009; Chandola et al., 2010; Chida and Steptoe, 2009; Pope et al., 2002), is a term that represents the cost of accomplishing tasks (Hart, 2006) and its importance in ergonomics changed during the last years (Straker and Mathiassen, 2009). In the past, the focus was put on reducing physical workloads to prevent overuse symptoms and related physical impairments such as herniated discs as a result of a high amount of occupational physical activity. Nowadays, due to altered occupational requirements (i.e. lower physical effort, higher mental effort) this focus shifted towards determining and optimizing mental workloads to facilitate healthy and productive working flows.

Mental workload is linked to mental and physical effort, job satisfaction and well-being (Hart et al., 1988; Lindfors et al., 2006; Proctor et al., 1996; Sonnentag and Zijlstra, 2006). People working in occupations involving prolonged sitting or standing periods often exhibit high musculoskeletal discomfort (John et al., 2009; Neuhaus et al., 2014a). In contrast, regular changes in working posture can positively influence physiological well-being (Grunseit et al., 2013; Karakolis et al., 2016; Karakolis and Callaghan, 2014) and improve mood-states (Pronk et al., 2012), which in turn improves work satisfaction and productivity (Garrett et al., 2016).

1.8 Aims and hypotheses

Although sit-to-stand workstations facilitate interruptions in sitting periods (Neuhaus et al., 2014a; Pronk et al., 2004) and subsequently lead to improvements in bodyweight (Koepp et al., 2013), waist circumference (Carr et al., 2013), blood glucose (Healy et al., 2013) and lower extremity blood pressure (Thosar et al., 2015), their effect on mental parameters (i.e. concentration, attention) has rarely been investigated. Currently, there are only a few studies investigating the short-term effect of sit-to-stand transitions (Karakolis et al., 2016). Apart from a small number of studies investigating productivity (Garrett et al., 2016), there are no randomized controlled trial experiments determining the medium term effect of a sit-to-stand workstation on cognitive parameters.

Subsequently, the primary aim of this PhD thesis was to execute two randomized controlled trials to determine the short and medium-term influence of sit-to-stand transitions on cognitive performance (working speed, reaction time, concentration performance, accuracy) and workload. Furthermore, as existing sit-to-stand workstations often exhibit relatively small utilization rates (Gilson et al., 2012; Mansoubi et al., 2016; Straker et al., 2013), another primary aim of this thesis was to investigate the sitting time reduction potential for a novel user-friendly two-desk sit-to-stand workstation concept (Figure 7).

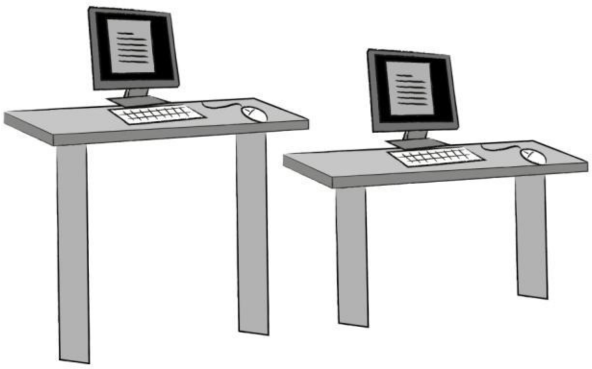

Figure 7: Two-desk sit-to-stand workstation concept

The following primary hypotheses (H) can be derived from the aforementioned aims:

H1: Working in alternating postures (sit/stand) affects cognitive performance on a short-term (1 day) basis.

H2: Working in alternating postures (sit/stand) positively influences workload on a short-term (1 day) basis.

H3: Working in alternating postures (sit/stand) over a long period (23 weeks) positively influences parameters of cognitive performance on a medium-term basis.

H4: Working in alternating postures (sit/stand) over a long period (23 weeks) positively influences workload on a medium-term basis.

H5: Sit-to-stand workstations consisting of two identical height-adjustable desks cause a significant sustainable (23 weeks) reduction in sitting time when implemented in occupational office environments.

2 Studies

Two randomized controlled trials were conducted within this PhD thesis. Study details, including study protocol, design and results have already been published (Schwartz et al., 2017, 2016). A graphical abstract is illustrated in Figure 8.

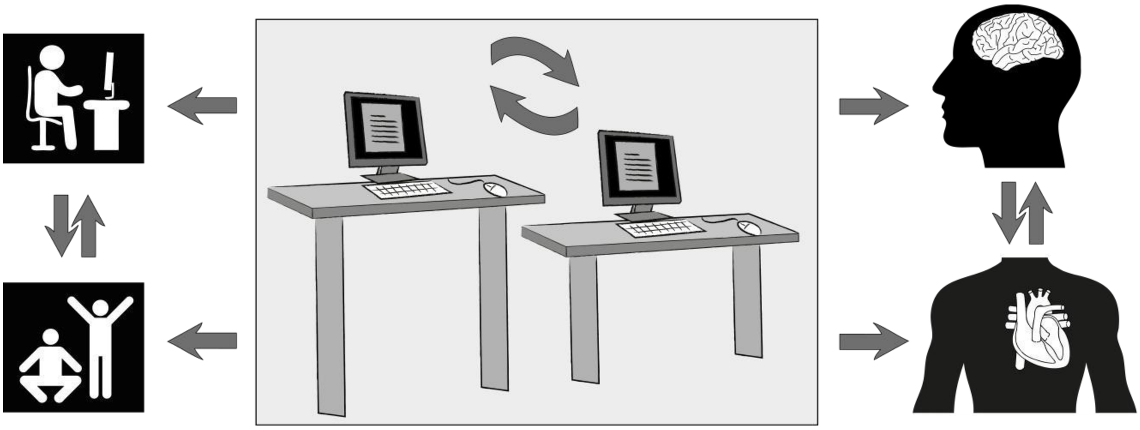

Figure 8: Graphical abstract - PhD thesis – adapted from Schwartz et al., (2017)

2.1 Study I (short-term)

The aim of the first study was to investigate the short-term effect of alternating working postures (sit/stand) on cognitive performance and perceived workload (hypotheses H1 & H2). Furthermore, it was designed to verify the study protocol for medium-term use (hypotheses H3&H4). The study was approved by the Ethics Committee of the University of Vienna (Reference number: 00052) and was retrospectively registered at ClinicalTrials.gov (Identifier: NCT02863731, July 2016). Study protocol, details, and results have been published together (Schwartz et al., 2017).

2.1.1 Publication 1 (Schwartz et al., 2017)

This publication entitled "Effect of alternating postures on cognitive performance for healthy people performing sedentary work" describes a randomized controlled cross-over trial investigating the effect of alternating (sit/stand) body postures on cognitive performance and perceived workload. Within this study, 45 healthy (free from chronic or acute disease) university students (age: 25.4 ± 3.3 years; 46.7 % women) with sedentary behaviour (sitting time: 660 ± 159 min/day) were recruited at the University of Applied Sciences, Upper Austria. They were randomly allocated to either an intervention or a control arm and executed a predefined study protocol in either alternating (sit/stand) or sitting only postures under laboratory conditions (see CONSORT diagram, Figure 9).

Overall, each subject participated in two assessment days with 7 days in between. The study protocol – similar to the one in the medium-term study of this PhD thesis (Schwartz et al., 2016) – consisted of three different cognitive tasks (Stroop-test, d2R test of attention, text editing task) as well as two questionnaires estimating workload (NASA TLX) and sedentary behavior (IPAQ).

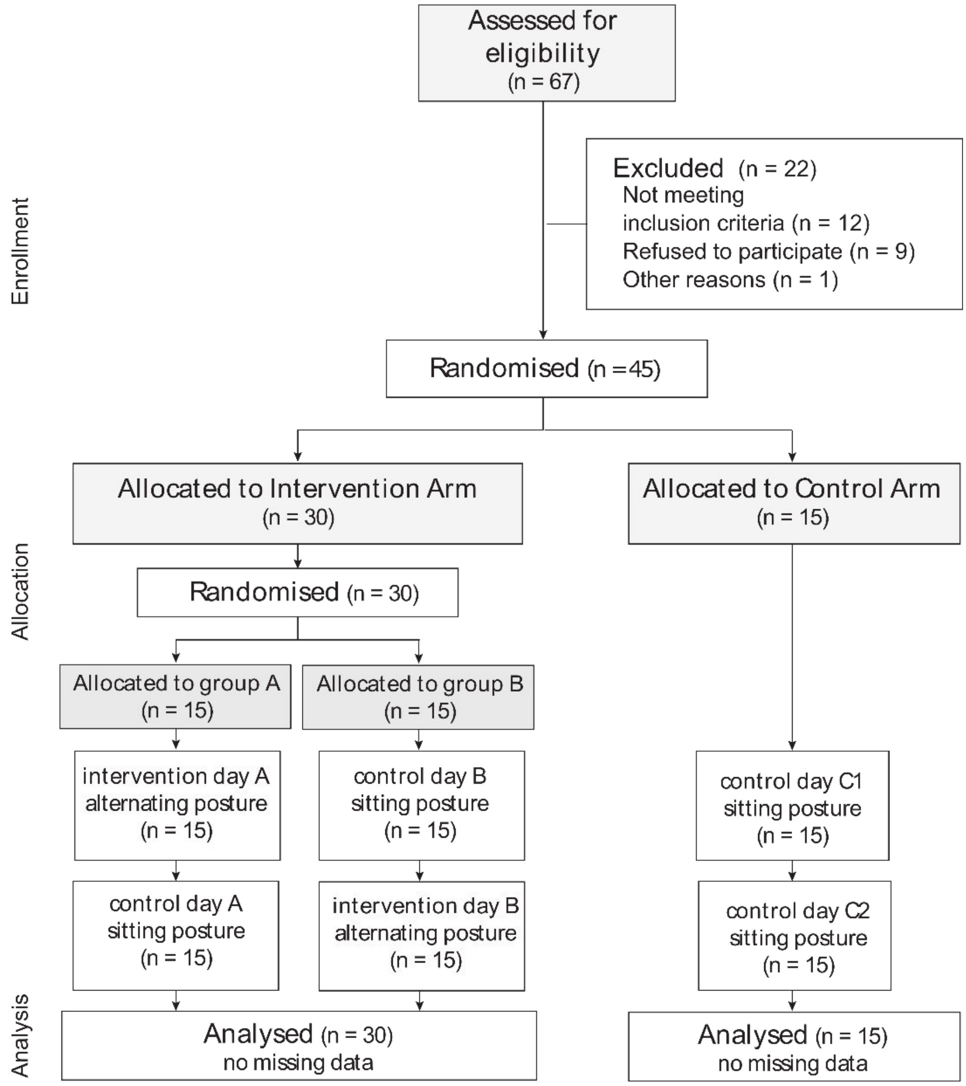

Figure 9: Short-term study CONSORT diagram by Schwartz et al. (2017)

Neither multivariate analysis of variance (Wilk's Λ=0.964, $F_{(6,170)}$ 0.530, p=0.785, partial η^2=0.018) nor one-way ANOVA (p>0.05) found a significant difference in cognitive performance parameters (working speed, concentration performance, reaction time) between people working in alternating (sit/stand) or sitting-only postures. Nevertheless, there were between-group differences for perceived workload ($F_{(2,87)}$=4.417, p=0.015, partial η^2=0.092), most likely driven by a nocebo effect. In addition, repeated measures ANOVA and Friedman-test found a strong difference in time for concentration performance ($F_{(2.505,\ 217.966)}$=39.252, p<0.001, partial η^2=0.311), working speed ($F_{(2.217,\ 192.905)}$=18.418, p<0.001, partial η^2=0.175) and text editing accuracy (χ^2=38.757, p<0.001).

2.2 Study II (medium-term)

The aim of the second study was to investigate the medium-term effects of two-desk sit-to-stand workstations on cognitive performance under controlled laboratory conditions (hypotheses H3 & H4). Further objectives of this study were to determine voluntary occupational sitting time reduction as well as postural change patterns among office-based employees after using a two-desk sit-to-stand workstation for 23 weeks (hypothesis H5). The study was approved by the Ethics Committee of the University of Vienna (Reference number: 00052) and was retrospectively registered at ClinicalTrials.gov (Identifier: NCT02825303, July 2016). The study protocol, details and results are published in three publications (Schwartz et al., 2018a, 2018c, 2016). Two of them (Schwartz et al., 2018a, 2018c) are currently under journal review.

2.2.1 Publication 1 (Schwartz et al., 2016)

This publication entitled "Effect of a novel two-desk sit-to-stand workplace (ACTIVE OFFICE) on sitting time, performance and physiological parameters: protocol for a randomized control trial" describes a study protocol for investigating the medium-term effects of working at a sit/stand workstation on cognitive performance, workload, physiological stress and sedentary behavior. Besides participant requirements (inclusion and exclusion criteria), this paper describes statistical considerations, the randomization and recruiting process, the study and intervention type, as well as the implemented measuring methods.

The study protocol followed a two-arm design with an intervention (2 subgroups) and a control arm (1 subgroup). To avoid recruiting bias, participants were recruited via a regional health insurance provider from a pool of companies in Upper Austria and were allocated to one of these arms by means of a covariate adaptive randomization (intervention to control, 2:1). For the intervention arm, study participants used a two-desk sit-to-stand workstation for 23 weeks either in the first or second half of the study (cross-over design), while for the remaining time of the study as well as for the control arm, participants used their traditional sitting only workstation. The intervention consisted of two equally furnished (i.e. same type and number of screens and computer hardware), height-adjustable desks adjusted to participants´ sitting and standing height to avoid hardware driven preferences.

Participants were healthy (no acute or chronic disease), caucasian, sedentary office workers of working age (18-60 years) with a body mass index (BMI) below 27.5 kg/m². They further were fluent German speakers who did not want to change their physical activity level within the study duration. They were regular computer users without any uncorrected visual impairments and were neither color blind nor regular smokers (< 1 cigarette/day). Furthermore, their total number (n=18) was estimated based on a pilot study (which exhibited a 105 minutes drop of sitting time for an 8-h work day) considering a 20% loss to follow-up.

In addition to participants´ baseline characteristics (e.g. age, body weight, gender, working hours per week, occupation), physiological (physical activity, sedentary behavior, salivary cortisol level, heart rate) and cognitive (reaction time, working speed, attention, workload) parameters were estimated according to the study protocol (see Figure 10) on four assessment days before and after each (intervention/control) 23-week interval.

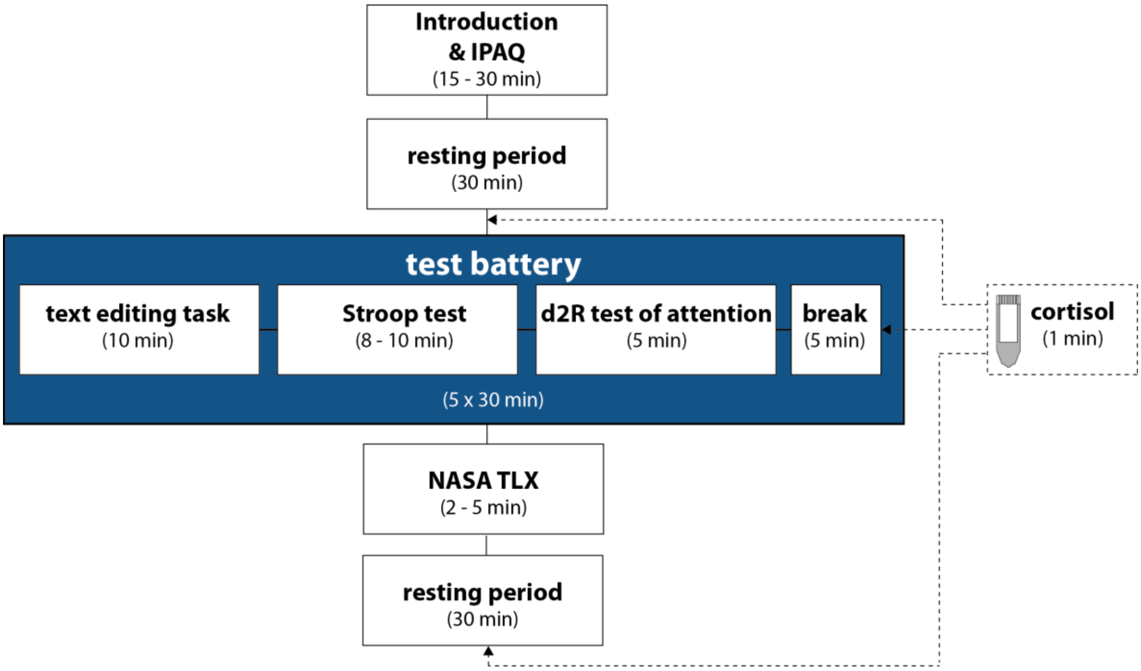

Figure 10: Study protocol for short-term and medium-term study. Medium-term study's supplements indicated with dashed lines (Schwartz et al., 2016)**.**

To estimate working speed, reaction time and concentration performance a self-developed text editing task was used, as well as the digital Stroop-Color-Word-Conflict-test (Stroop, 1935) and the d2R-test of attention (Brickenkamp et al., 2010) which are both validated tests, characterized by high test-retest reliability (Brickenkamp et al., 2010; Franzen et al., 1987) and commonly used in cognitive science (Bates and Lemay, 2004; Duschek et al., 2009; MacLeod, 2005; Mead et al., 2002; Van der Elst et al., 2006; Wassenberg et al., 2008). These were combined in one test battery (see Figure 10). Within each assessment day, participants executed this battery 5 times in alternating postures in a predefined order (sit/stand/sit/stand/sit). Due to this, and as the first trial was ruled out from analysis as a preparation trial, it was possible to ensure that the same number of test batteries were executed in sitting or standing postures.

To estimate sitting time, physical activity and workload the International Physical Activity Questionnaire – IPAQ (Hagströmer et al., 2008, 2007) and the NASA Task Load Index – NASA TLX (Hart, 2006; Hart et al., 1988) were used. In addition, physiological covariates for cognitive performance, salivary cortisol measurements, heart rate and body movements were determined by means of a mobile ECG recorder and cortisol ELISA. A self-developed logging tool was installed on participants´ workstations for quantitative estimation of time spent sitting and standing, as well as daily sit-to-stand transitions, within the whole study duration.

To ensure equal test conditions and subsequently reduce environmental bias, all assessment days were executed in the same laboratory room under equal environmental conditions (temperature, air flow, humidity, lighting conditions, noise). The measurements started at the same day time to avoid daily fluctuations on performance and cortisol level, and test instructions were given by the study leader only to avoid instruction bias. Finally, exercise, stress, and caffeine and alcohol intake were prohibited 24 hours prior to the assessment days.

2.2.2 Manuscript 1 (Schwartz et al., 2018c)

This manuscript entitled "Mid-term effects of a two-desk sit/stand workstation on cognitive performance and workload for healthy people performing sedentary work: A secondary analysis of a pilot randomized controlled trial" describes a randomized controlled cross-over trial investigating the medium-term effects of alternating (sit/stand) body postures on cognitive performance and perceived workload.

Within this study, 18 healthy (free from chronic or acute disease) office workers (age: 36.3 ± 10.3 years; 44.4 % women) with sedentary behaviour (sitting time: >600 min/day) were recruited by a governmental health insurance (Upper Austrian Regional Health Insurance "OOE GKK") and randomly allocated to either an intervention (2 subgroups) or a control arm (1 subgroup). Allocation to study arm and sub groups was executed by covariate adaptive randomization procedure. In the intervention arm (cross-over design), participants were equipped with either a traditional or a two-desk sit-to-stand workstation in either the first or the second half of the study, while control arm participants were equipped with traditional workstations only. The interventional workstation consisted of two equally furnished desks (i.e. same number and type of screens, mice and keyboards) standing next to each other and adjusted to users´ desired sitting and standing heights.

To investigate the effect of a 23 weeks usage of sit/stand workstations, each participant underwent four one-day assessment days, executed prior to (baseline) and after (follow-up) the 23 week intervention period (see CONSORT diagram, Figure 11).

The study protocol, described in detail by Schwartz et al. (2016), consisted of three different cognitive tasks (Stroop-test, d2R test of attention, text editing task), two questionnaires estimating workload (NASA TLX) and sedentary behaviour (IPAQ), and two physiological parameters (heart rate and salivary cortisol level) to estimate physiological stress.

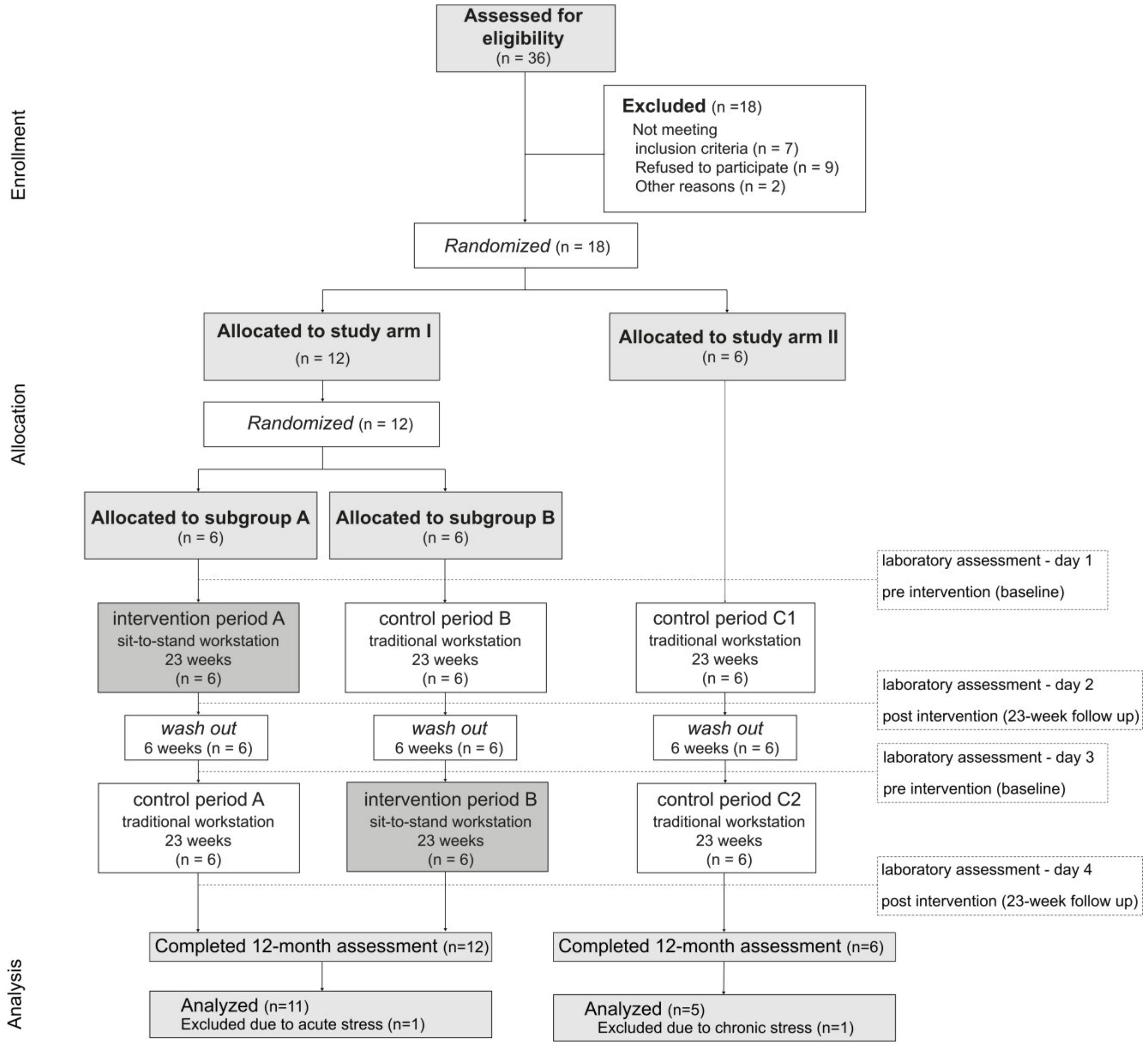

Figure 11: Medium-term study CONSORT diagram by Schwartz et al. (2018c)

A two-way multivariate analysis of variance showed no significant differences in cognitive performance (reaction time, working speed, concentration performance) between the groups (Wilk's Λ=0.918, $F_{(3,38)}$=1.131, p=0.349, partial η^2=0.082), the assessment days (Wilk's Λ=0.951, $F_{(3,38)}$=0.658, p=0.583, partial η^2=0.049), or the interaction assessment day (baseline vs. follow-up) x group (Wilk's Λ=0.991, $F_{(3,38)}$=0.113, p=0.952, partial η^2=0.009). However, repeated measures ANOVA found significant between-day differences (baseline vs. follow-up) for working speed, reaction time and concentration performance (all p<0.006), likely caused by practice effects. Baseline between-group differences (intervention vs. control arm) in reaction time and workload also occurred, mainly caused by a different study collective and a missing weighting procedure of the NASA TLX. Although accuracy rates (which were not part of the

ANOVA due to a violation of normality) did not differ between groups for reaction time and concentration performance tasks ($p>0.05$), they significantly improved post-intervention in the sit-to-stand workstation group ($p=0.033$). Finally, although heart rate and salivary cortisol were only measured to detect possible bias on cognitive performance caused by physiological stress, repeated measures ANOVA results for salivary cortisol at the 23 week follow-up exhibited a significant time (pre-testing/testing/post-testing) x group interaction ($F_{(4,58)}=4.033$, $p=0.006$, partial $\eta^2=0.218$). This was characterized by a significant baseline/follow-up difference in post-testing cortisol for the sit-to-stand workstation users only ($p=0.027$). Except for pre-testing/testing/post-testing differences in heart rate and cortisol level (all, $p<0.006$), repeated measures ANOVA for heart rate and cortisol level did not find any further interaction effects (time x group) or between-group differences (all, $p>0.42$).

2.2.3 Manuscript 2 (Schwartz et al., 2018a)

This manuscript entitled “Influence of a two-desk sit-to-stand workstation on sitting time: A randomized controlled pilot trial under real world conditions” describes the medium-term effect of sit/stand workstations on sitting time, physical activity and body mass found in the aforementioned medium-term study (Manuscript 1 (Schwartz et al., 2018c)). The results were deliberately divided and discussed in two manuscripts to ensure the readability of each article (Focus: I – Sedentary Behaviour, II – Cognitive Performance).

As described before, 18 healthy (free of chronic or acute disease) office workers (age: 36.3 ± 10.3 years; 44.4 % women) with sedentary behavior (sitting time: >600 min/day) participated in this study. They were recruited by a governmental health insurance (Upper Austrian Regional Health Insurance “OOE GKK”) and were randomly allocated to either an intervention (2 subgroups) or control arm (1 subgroup). Allocation to study arm and subgroups was executed by a covariate adaptive randomization procedure. In the intervention arm (cross-over design) participants were equipped with either a traditional or a two-desk sit-to-stand workstation in either the first or the second half of the study, while control arm participants were equipped with traditional workstations only (see CONSORT diagram, Figure 11). The interventional workstation consisted of two equally furnished desks (i.e. same number and type of screens, mice, and keyboards) standing next to each other and was adjusted to users´ desired sitting and standing heights. In addition, a logging tool for detecting body postures for the whole study duration was installed on each sit-stand workstation.

As described in the study protocol (Schwartz et al. 2016), sedentary behavior, physical activity and body mass were estimated by means of questionnaires (IPAQ) prior (baseline) and after the 23 weeks (follow-up) intervention period. In addition, postural change patterns (i.e. postural changes per day, mean duration of sitting or standing intervals) were determined continuously during the period between the baseline and the follow-up assessment days (23 weeks) by means of a self-developed posture recognition software.

Mixed-design ANOVAs (time x group) showed very strong interaction effects (time x group) for sitting time on occupational days (p=0.002, partial η^2=0.309), weekend days (i.e. Saturday and Sunday, p=0.017, partial η^2=0.219), and the whole week (7 days, p=0.002, partial η^2=0.321). These effects were characterized by significant -3.07 (CI: -4.92, -1.21; p=0.004) and -14.22 (CI: -25.15, -3.30; p=0.015) hour changes in occupational and overall week sitting time for sit-to-stand workstation users, respectively. They were further characterized by a significant decrement in sitting time on weekend days (mean: 2.75 h, CI: 0.35, 5.15; p=0.027), and over the whole week (mean: 11.06 h, CI: -3.18, 25.30, p=0.121) for users of sit/stand workstations compared to traditional workstations. Furthermore, there was a strong within-group difference on body mass (p=0.044, partial η^2=0.117). However, mixed-design ANOVAs did not find any further between-group or within-group (baseline/follow-up) interaction (time x group) effects for sitting time, physical activity or body mass (all, p>0.05).

3 Discussion

Over the last several years, changes in physical activity and sitting time were jointly responsible for a high prevalence of diseases such as back pain (Gallagher et al., 2014; Heneweer et al., 2009; Jussila et al., 2014), obesity (Hu et al., 2003, 2001; Must and Tybor, 2005) or diabetes (Hamilton et al., 2007; Wilmot et al., 2012). Although these can be found in several domains (travelling, domestic, and leisure time), a majority of them can be observed in occupational environments (Church et al., 2011; Ng and Popkin, 2012). People spend more than one third of their working life at work (Alkhajah et al., 2012). This explains why worksite based interventions focusing on occupational physical activity (e.g. "10.000 steps per day") and sitting time (e.g. active or sit-to-stand workstations) received increasing popularity within the last years (Carr et al., 2013; Elmer and Martin, 2014; Healy et al., 2013; Kerr et al., 2016). Furthermore, as negative effects based on prolonged sitting cannot be fully compensated by physical activity (Healy et al., 2008a; Kerr et al., 2016; Peddie et al., 2013; Van Uffelen et al., 2010), a substantial reduction of sitting time, especially for areas exhibiting prolonged sitting periods (e.g. offices), should become a socioeconomic objective (Garber et al., 2011).

A promising approach to achieve this goal are sit-to-stand workstations. These workstations are mainly based on height-adjustable desks and table-tops enabling their users to work either in a sitting or standing posture (Shrestha et al., 2016). Depending on their conceptual design they can achieve higher or lower degrees of utilization (Karakolis and Callaghan, 2014). As valid scientific findings, especially related to cognitive performance or utilization levels, can help to a counter the increased acquisition costs of these workstations, this PhD thesis provides results of two randomized controlled trials determining the effect of alternating body postures on cognitive performance in the short- and a medium-term. Furthermore, it reveals findings about the sitting time reduction of a novel two-desk sit-to-stand workstation concept.

3.1 Study protocol suitability

The study protocols in this PhD thesis contained questionnaires, resting periods, physiological measurements as well as validated physiological tests and simulated working tasks to estimate cognitive performance (Figure 10). These measuring methods, commonly used in ergonomic research (Commissaris et al., 2014; Koren et al., 2016; Ohlinger et al., 2011; Russell et al., 2015; Straker et al., 2009), enable performance-related between-study comparisons.

3.1.1 Questionnaires (assessment)

Questionnaires are commonly used in clinical studies to assess general (e.g. socio-demographic, work, and health characteristics) or specific (e.g. physical activity) parameters. Although quantitative measuring methods (e.g. double-labeled water or accelerometers) are recommended for assessing parameters such as physical activity or sitting time (Shrestha et al., 2016), questionnaires can also be considered for these cases. In particular, when these parameters are not primary study targets, validated questionnaires with sufficient reliability represent a simple and inexpensive way to collect data (Sylvia et al., 2014).

In this PhD thesis, the German version of the International Physical Activity Questionnaire (IPAQ) was used to estimate sitting time and physical activity (Putz and Elmadfa, 2009). Study results did not show any missing data in the IPAQ measurements (Schwartz et al., 2018c, 2017). This can be explained by the administration type of the questionnaire. Contrary to self-administration, the chance to overlook, forget, or not understand certain items (e.g. omitting the reverse side of a page) in interview-administered questionnaires is negligibly small (Craig et al., 2003). Although ambiguous points within the questionnaire (e.g. "Is rock climbing a moderate or vigorous leisure time activity?") can be clarified by the study leader as objectively as possible (e.g. by considering the Compendium of Physical Activity (Ainsworth et al., 2000, 1993)), it should be noted that the administration might also influence study results (Chu et al., 2015; Craig et al., 2003; Healy et al., 2011a). Furthermore, it should also be considered that there are several questionnaires suitable for estimating sedentary behaviour, especially in occupational environments. Commonly used ones are the Occupational Sitting and Physical Activity Questionnaire (OSPAQ, (Grunseit et al., 2013; Pedersen et al., 2016; Russell et al., 2015; Wick et al., 2016)) or the Workplace Sitting Breaks Questionnaire (SITBRQ, (Pedisic et al., 2014)) which, in contrast to the IPAQ, additionally delivers information regarding standing time (OSPAQ) and sitting breaks (SITBRQ). OSPAQ (Chau et al., 2012a) and SITBRQ (Pedisic et al., 2014) cannot determine leisure time or domestic physical activities, which could be important in estimating physical activity compensation in non-occupational hours. Therefore, the IPAQ, given its good reliability (Craig et al., 2003; Hagströmer et al., 2008, 2007), seems to be an appropriate solution to estimate physical activity and sitting time easily and without substantial cost. Nevertheless, as comparisons of quantitative and qualitative estimation of sedentary behaviour showed under- and overestimated sitting times, sit-to-stand transitions, and body postures (Healy et al., 2011a; Júdice et al., 2015; Sudholz et al., 2018; Wick et al., 2016), future studies should, as recommended by Healy et al. (2011a), additionally implement measuring devices based on quantitative methods such as Actigraph (Hall et al., 2015; Kozey-Keadle et al., 2012; Wick et al., 2016) or ActivPal (Alghaeed et al., 2013; Janssen et al., 2014; Júdice et al., 2015). The simultaneous use of two measuring methods (quantitative and qualitative) in parallel would deliver a better insight into the relationship between questionnaire driven and objectively measured sedentary behaviour, which would further improve the comparisons between prior studies. As objective measuring methods like Actigraph and ActivPal can provide additional and valid information regarding time spent in each individual posture (Júdice et al., 2015; Mansoubi et al., 2016; Sudholz et al., 2018), as well as the duration and intensity (i.e. sedentary: <100 count/min, light PA: 100-1951 count/min) of physical activity per day (Chau et al., 2012a; Kozey-Keadle et al., 2012; Vik et al., 2015), the additional implementation of acceleration-based measuring methods would also offers the possibility to classify users´ sedentary behaviour in more detail and allows more precise relationships between sedentary behavior and other parameters like cognition or workload to be established.

In complement to the IPAQ, the unweighted version of the NASA Task Load Index (NASA TLX) called NASA RTLX (NASA Raw Task Load Index) was implemented to measure workload perception of the users (Schwartz et al., 2016). Workload baseline similarities across both studies and interventional intervals (Schwartz et al., 2018c, 2017) confirmed the suitability of the RTLX for within-group differences and are in line with previous findings (Hart, 2006). In addition, as only 3 out of 162 workload ratings were following an artificial pattern (i.e. all items on the lowest, highest or mid-point level), the resulting high acceptance rate for the RTLX further accentuates its suitability. In contrast to this, significant between-group differences (intervention vs. control), possibly due to the missing weighting procedure, occurred in both studies (Schwartz et al., 2018c, 2017). Therefore, future studies should always consider this bias when interpreting between-group differences or should implement a weighting procedure for non-cross-over study designs. Nevertheless, the RTLX seemed to be a good method of measuring workload perception. In contrast to EEG based measuring methods (Berka et al., 2007), it is easy to implement and does not require cost-intensive hardware. Compared to other subjective methods like the Subjective Workload Assessment Technique (SWAT, (Reid and Nygren, 1988)) or the Modified Cooper-Harper (MCH, (Cooper and Harper, 1986)) scale, the NASA TLX has higher validity and acceptance rates (Hill et al., 1992).

As mentioned by Schwartz et al. (2018a), data determined by questionnaires should always be interpreted with care. There is always a possibility that statements, in order to "strengthen" research results (Hróbjartsson et al., 2012), have been consciously or unconsciously manipulated. Nearly all of the study participants critically questioned the high prevalence of sitting in modern societies (Schwartz et al., 2018a). In fact, most of them participated in this study to take part in discovering a new way to work. Although all participants were instructed to rate as objectively as possible, the risk remains that they might have manipulated their ratings to "strengthen" study results and subsequently facilitate the usage of novel workstations. A nocebo effect that occurred for the workload perception in the short-term study (Schwartz et al., 2017) confirms this estimation and further emphasizes the necessity to add objective measurement methods for future studies.

3.1.2 Cognitive performance (assessment)

In the course of estimating occupational performance, several systematic problems occurred. Depending on occupational background, the classification of performance can differ in various ways (Karakolis and Callaghan, 2014). In general, occupational performance is commonly estimated in two ways: executing work-related tasks, or standardized cognitive tests. Both have specific advantages and disadvantages.

Work-related tasks (e.g. faxes or telephone calls per minute) can be used to estimate specific work-related outcomes. They can be interpreted easily, although, general statements are hard to make. Moreover, test cofactors, validity, and reliability are often unknown. Cognitive test batteries, on the other hand, can help to estimate specific neural parameters like reaction time (Kane et al., 2007; Lemay et al., 2004; Schatz and Putz, 2006), memory (Buehner et al., 2006; IOM (Institute of Medicine), 2015; Kipps and Hodges, 2005) or attention (Duschek et al., 2003; Lemay et al., 2004; Lufi et al., 2011; Proctor et al., 1996). They are well validated, often used in neurological studies, and show high reliabilities (Lemay et al., 2004; Strauss et al., 2005; Wassenberg et al., 2008). Nevertheless, their relationship to specific work-related tasks is often unclear (Karakolis and Callaghan, 2014) and might be difficult to interpret for people not familiar with science.

Psychological tests for healthy people are mainly conducted while sitting. Although only minor changes can be expected for testing in different postures (Commissaris et al., 2014; Karakolis et al., 2016), validity parameters (e.g. test-retest reliability) are still unknown for different postures. In contrast, conducting physiological tests in untypical postures (e.g. carrying out a test while sitting when the subject is used to working in alternating postures) might also bias test results. Frequent repetition of cognitive tests can further bias results (Lemay et al., 2004). Depending on the cognitive tests' construction, these repetitions can lead to unintentional learning/practice effects (MacEwen et al., 2015; Schraefel et al., 2012), which can confound improvements caused by interventions and distort the findings (Lemay et al., 2004).

To compensate for practice effects the first trial of each assessment day was eliminated in the studies within this PhD thesis (Schwartz et al., 2017, 2016). To ensure similar conditions (i.e. practice effects are generally more pronounced in the beginning) both studies followed a crossover design. Nevertheless, despite the tests' high test-retest reliabilities (Brickenkamp et al., 2010; Franzen et al., 1987) practice effects were strong for "d2R-test of attention" in each group and assessment day (Schwartz et al., 2018c, 2017). This undesirable effect (fewer repetitions in longer time intervals did not illicit such marked practice effects) can be explained by the construction of the test. The d2R-test is the revised version of the original "d2-test of attention" (Brickenkamp et al., 2010). It is a pen and paper based test, consisting of 14 lines of 57 randomly assigned letters ('d' and 'p', surrounded by 1 to 4 dashes). Participants must mark specific letters, for example 'd' surrounded by 2 dashes. As the test sheet does not change between each testing trial, graphical patterns (e.g. 4 'd's surrounded by 2 dashes in a row) can be recognized by test subjects and subsequently lead to shorter processing times.

As strong practice effects may have confounded interventional effects, future studies should implement non-pattern based cognitive tests. Memory tests, such as the n-back test, are possibilities for repeatable use (Lawlor-Savage and Goghari, 2016), but their acceptance for the general population should always be considered. Discouraging (i.e. tests with low success rates) or incomprehensible tests could increase dropout rates and jeopardize study results (Lawlor-Savage and Goghari, 2016; Nuechterlein et al., 2008). Nevertheless, as participants from both studies were outstanding performers in comparison to their age cohorts (Schwartz et al., 2018c, 2017), it can be expected that the learning curve for the general population will be flatter (IOM (Institute of Medicine), 2015).

3.1.3 Physiological parameters (assessment)

Room temperature (Pilcher et al., 2002; Sellaro et al., 2015), lighting conditions (Hygge and Knez, 2001; Knez, 1995; Knez and Hygge, 2002), noise (Furnham and Strbac, 2002; Jahncke et al., 2011), mental stress (LeBlanc, 2009; Marin et al., 2011) and emotional states (Chepenik et al., 2007; Davis, 2009) can negatively influence cognitive performance (Figure 12). To minimize these effects, cognitive performance should be investigated under similar environmental and mental conditions. Mental stress is related to several physiological parameters such as heart rate variability (Hjortskov et al., 2004; Taelman et al., 2011; Thayer et al., 2010) or cortisol level (O’Connor et al., 2009; Oosterholt et al., 2015) and in addition to subjective questionnaire-based approaches, the determination of these parameters can help to estimate mental stress levels in an objective way.

Within this PhD study heart rate variability (HRV) as well as salivary cortisol were measured to assess mental stress (Schwartz et al., 2018c, 2017). To ensure similar stress levels and emotional states participants were asked to avoid stress on assessment days and watched documentaries for a 30 minutes resting period prior to the cognitive test battery. Study results confirmed the necessity for these breaks. In contrast to the beginning of the resting period, heart rate was homogenous between participants and groups at the end of the resting period (not published). Furthermore, salivary cortisol levels did not significantly differ from the baseline (Schwartz et al., 2018c). These findings are in line with previous research that stated stable HRV values after 10 minutes resting periods (Martinmäki and Rusko, 2008; Perini and Veicsteinas, 2003). As cortisol levels can be influenced by emotional states (Merrifield and Danckert, 2014; Stalder et al., 2010), as well as by body postures to up to 20 minutes after postural changes (Hennig et al., 2000), stable cortisol values at baseline further reinforce the necessity for these breaks.

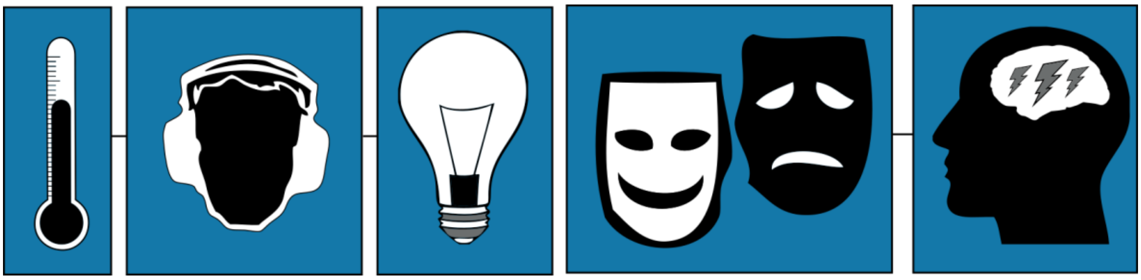

Figure 12: Excerpt from environmental factors influencing cognitive performance (room temperature, noise, lighting conditions, mood and stress)

In addition to the high one-off acquisition costs for HRV-recorders, the expenses for analyzing saliva samples (cortisol measurement) might limit the operational feasibility of these measuring systems. Increasing the number of participants, directly affects the costs and subsequently makes it these measuring methods unaffordable for small budget research projects. Furthermore, the acceptance rates of these measurement methods limit their applicability. Changes in daily habits (e.g. abstinence from caffeine) and restrictions to personal freedom (e.g. shaving chest hair for the Holter electrodes) can increase dropout rates (Schottenbauer et al., 2008). The necessity for these measures should always be carefully explained to the participants to minimize their effect on the study results. Providing well-prepared individual reports, as in the PhD studies, might help to reduce dropout rates. In individual interviews at the end of both studies, the majority of participants stated they experienced the physiological measurement methods as slightly uncomfortable but worth the effort. They further reported that receiving high-value test results strengthened their motivation to stay in the study. Based on the structure of the study protocol, the implemented objective physiological measurements enable the investigation of the relationship between stress-related parameters and cognitive performance (not part of this PhD thesis).

3.2 Cognitive performance

In addition to the previously stated environmental conditions (Furnham and Strbac, 2002; Hygge and Knez, 2001; Jahncke et al., 2011; Knez, 1995; Knez and Hygge, 2002; Pilcher et al., 2002; Sellaro et al., 2015), working in different physical states such as walking (John et al., 2009; Straker et al., 2009) or cycling (Commissaris et al., 2014; Koren et al., 2016), as well as the physical activity level during work (Koren et al., 2016; Straker et al., 2009), and the grade of self-estimation (i.e. self-paced walking (Funk et al., 2012)), can impact cognitive performance. Nevertheless, the effect of alternating postures on cognitive performance has hardly been investigated. There are only a few studies which show unaltered typing and mouse tasks, (Karakolis et al., 2016) and increased productivity (Garrett et al., 2016), in the short and medium term, respectively. Although it could be expected that performance for alternating postures might be similar to either sitting or standing (as it consists of both postures), there is currently a gap in our knowledge of how working in alternating postures affects cognitive performance. Therefore, two studies investigating the short- and medium-term effect of alternating body postures on cognitive performance have been carried out.

3.2.1 Possible Pathways (cognitive performance)

Although the connection between cognitive performance and the use of sit/stand workstations has not been clarified until now, several pathways for positive (Figure 13) and negative (Figure 14) relationships between those parameters are conceivable.

Working at sit-to-stand workstations can reduce sedentary time (Shrestha et al., 2016), promote sitting breaks (Danquah et al., 2017), and increase energy expenditure (Barone Gibbs et al., 2017; Júdice et al., 2016). These parameters related to positive impacts on hip circumference (Healy et al., 2011b), triglycerides (Healy et al., 2011b), fasting glucose (Healy et al., 2017), and postprandial plasma insulin (Peddie et al., 2013). Additionally, as even small changes (e.g. 100 kcal per day) can influence the development of obesity (Beers et al., 2008; Church et al., 2011), these parameters are important predictors for the development of obesity or overweight. Especially as sedentary behavior is a risk factor for obesity independent of physical activity (Chau et al., 2012b), implementing sit-to-stand workstations can be sufficient to prevent obesity. Overweight, obesity and sedentary behaviour are characterized by impaired physical functioning (Doll et al., 2000), and low body satisfaction and self-esteem (Wardle and Cooke, 2005), independent of the level of physical activity (Atkin et al., 2012; Dempsey et al., 2014), are related to psychological distress (Atkin et al., 2012), mental health (Gibson et al., 2017) and compromised wellbeing (Dempsey et al., 2014; Doll et al., 2000; Gibson et al., 2017; Wardle and Cooke, 2005). Wellbeing can be improved by weight loss (Doll et al., 2000), which in turn is related to the level of exercise, age, the prevalence of depression (Allerhand et al., 2014), or mental fatigue (Engberg et al., 2017). It further affects blood pressure, heart rate, and dopamine levels (Allerhand et al., 2014), and is therefore a protector against chronic stress (Llewellyn et al., 2008). As wellbeing and chronic stress are related to cognitive performance even after variance control of covariates (Allerhand et al., 2014; Llewellyn et al., 2008; Marin et al., 2011; McCormick et al., 2007), improvements in wellbeing caused by less sedentary time and reduced obesity prevalence may lead to improvements in cognitive performance for sit-to-stand workstation users.

As already mentioned by Schwartz et al. (2018c, 2017), changes in physical activity induced by sit-to-stand environments (e.g. reduced prevalence of back pain) can alter cognitive performance as well. The will to engage in physical activity is related to several parameters such as age (Brodersen et al., 2007; Eurobarometer & European Commission, 2014; Thibault et al., 2010), sex (Eurobarometer & European Commission, 2014; Salmon et al., 2003), socioeconomic status (Federico et al., 2013; Juneau et al., 2015; Thibault et al., 2010), occupation (Wu and Wu, 2000), sedentary behavior (Matthews et al., 2012), or the prevalence of musculoskeletal disorders (Morken et al., 2007; Schaller et al., 2017; Vlaeyen and Linton, 2000). Hence, reduced back pain (Agarwal et al., 2017; Karakolis et al., 2016), less discomfort (Agarwal et al., 2017; Waongenngarm et al., 2018), and reduced sedentary behavior (Shrestha et al., 2016) for sit/stand workstation users may result in enhanced physical activity. The short, medium and long-term potential of physical activity to improve executive functions, attention, concentration or memory (Colcombe and Kramer, 2003; Hillman et al., 2011; Loprinzi et al., 2013; Ratey and Loehr, 2011) is induced by higher prefrontal activities, greater cortical volumes and higher cerebral blood volumes (Loprinzi et al., 2013; Ratey and Loehr, 2011). Improvements in cognitive performance can be therefore be evoked by an increase in physical activity. Furthermore, as pain can directly affect cognitive performance due to its capacity to impose behavioral priority and disturb attention (Attridge et al., 2015; D. J. Moore et al., 2012), the reduction in musculoskeletal pain induced by the usage of sit/stand workstations might also influence cognitive performance.

The reduction of sedentary time (Graves et al., 2015; Healy et al., 2013; Shrestha et al., 2016) as well as shorter sitting intervals induced by the usage of sit/stand workstations (Danquah et al., 2017) might also affect cognitive performance as a result of decreased mental fatigue (Wennberg et al., 2016). Fatigue, as well as pain, has the potential to influence cognitive performance (Attridge et al., 2015; Barwick et al., 2012; Ishii et al., 2014; R. D. Moore et al., 2012). Although there is no generally applicable definition of fatigue, it has previously been described as an unpleasant state, a decreased capacity to perform physical and mental work, an enduring, subjective feeling of tiredness or exhaustion, or a lack of energy (Mota and Pimenta, 2006; Trendall, 2000). In general, fatigue, characterized by reduced activation in the central nervous system, leads to reduced reaction times (R. D. Moore et al., 2012), accuracy rates (Faber et al., 2012), alertness (Barwick et al., 2012) and well-being (Engberg et al., 2017). It can be induced by uninterrupted (>30min) working periods (Hockey and Earle, 2006; Käthner et al., 2014) and, especially for difficult tasks, it can impair subsequent executive functions (Grillon et al., 2015; Hockey and Earle, 2006), attention, or response inhibition (Ishii et al., 2014). Although motivation can help reduce fatigue-induced drops in performance (Ishii et al., 2014; R. D. Moore et al., 2012), this compensation process can further induce greater mental fatigue when it occurs over long periods (Ishii et al., 2014). Sedentary time, independent of a correction of covariates like age, sex or socioeconomic status (Engberg et al., 2017), is related to fatigue (Dempsey et al., 2014; Van Roekel et al., 2016). Hence, as sit/stand workstations (Ellegast et al., 2012; Pronk et al., 2012; Sheahan et al., 2016; Wennberg et al., 2016) as well as sitting breaks (Thorp et al., 2014; Wennberg et al., 2016) can positively influence fatigue, reduced fatigue induced by sit/stand workstations might also improve cognitive performance. A positive trend for memory improvements in people having active sitting breaks underpins this pathway (Wennberg et al., 2016). Furthermore, as fatigued people are less likely to participate in physical activity (Engberg et al., 2017), a possible increase in physical activity as described in the aforementioned pathways might improve cognitive performance, too.

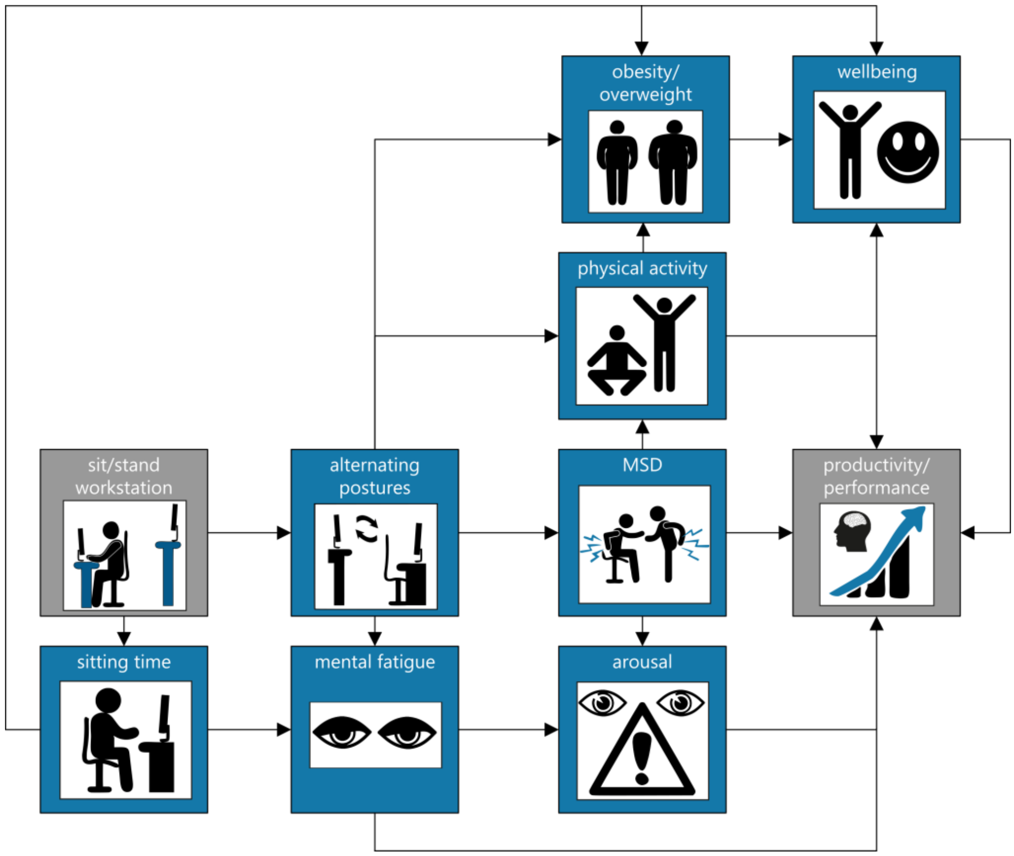

Figure 13: Concept of pathways between working at sit/stand workstations and cognitive performance (positive relationships)

Attention overloads induced by non-sitting postures might also influence cognitive performance (Figure 14). Compared to sitting, postural control requirements are increased when standing (Barra et al., 2015). Postural control and several cognitive performance parameters recruit attention resources (Barra et al., 2015). Especially for cognitive testing under enhanced postural control conditions, this can be problematic (Fraizer and Mitra, 2008). Due to a limitation of neuronal capacities and the neuronal competition between postural control and cognitive tasks (Barra et al., 2015), increased recruitment of attention induced by standing can reduce attention capacity and subsequently lead to poorer performance in attention-related cognition tasks (Schwartz et al., 2017).

Finally, a pathway towards cognitive performance reduction based on increased discomfort and physical exhaustion is conceivable. People not used to standing on a regular basis can experience greater discomfort and physical exhaustion (Beers et al., 2008; Drury et al., 2008; MacEwen et al., 2015), especially in the lower extremities (Lin et al., 2012a, 2012b; Reid et al., 2010). Nevertheless, as several previous studies did not find any consistent relationship between discomfort and cognitive performance (Drury et al., 2008; Karakolis et al., 2016; Karakolis and Callaghan, 2014; Liao and Drury, 2000), and as the additional amount of exhaustion in terms of metabolic effort needed for regularly alternating sitting by standing periods is considerably smaller than the physical exhaustion induced by physical activities (Ainsworth et al., 2000; Koren et al., 2016), these negative effects are unlikely for sit/stand workstations in office environments.

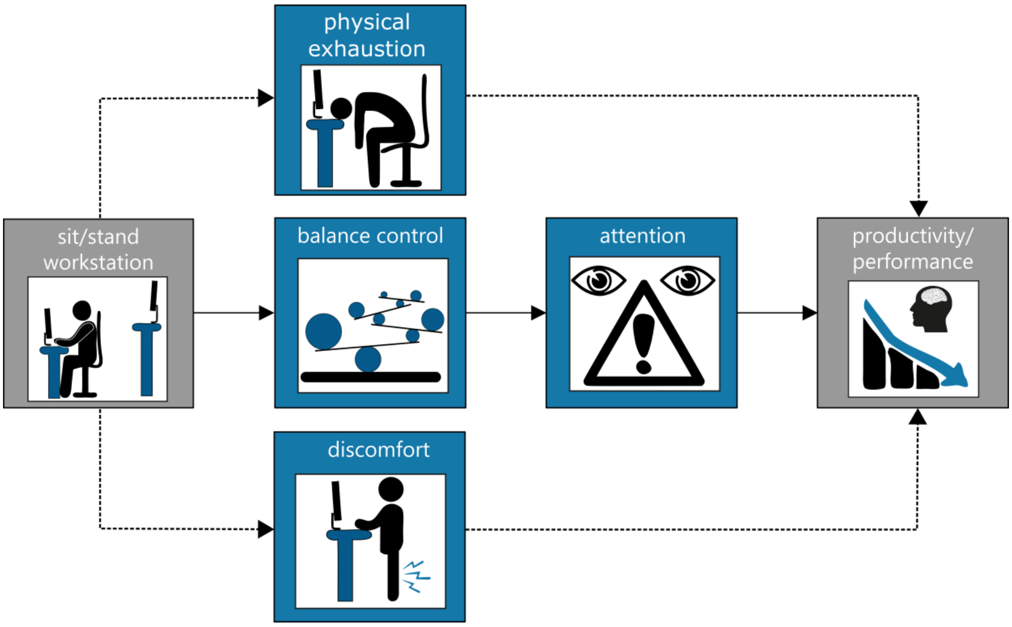

Figure 14: Concept of pathways between working at sit/stand workstations and cognitive performance (negative relationships)

3.2.2 Short-term study findings (cognitive performance)

Opposed to hypothesis H1, short-term study results showed no difference in cognitive performance for working in alternating body postures compared with sitting (Schwartz et al., 2017). Furthermore, no difference in cognitive performance has been found for test series conducted in sitting or standing postures. These findings are in line with prior studies which demonstrated unaffected cognitive performance for sit/stand (Bantoft et al., 2015; Russell et al., 2015; Straker et al., 2009) or sit/alternating posture comparisons (Karakolis et al., 2016), but are in contrast to those showing altered mouse dexterity for standing (Commissaris et al., 2014; Ghesmaty Sangachin et al., 2016).

As discussed by Schwartz and colleagues (Schwartz et al., 2017), a possible explanation for the these dexterity differences might be that only motor tasks are affected by a standing position. Compared with higher cognitive tasks like reading (Commissaris et al., 2014; John et al., 2009), selective attention (Bantoft et al., 2015; John et al., 2009; Ohlinger et al., 2011) and memory (Bantoft et al., 2015), motor tasks are more likely to be affected by physical activity (Commissaris et al., 2014; John et al., 2009; Straker et al., 2009), while the intensity of the physical activity plays a major role in the degree of influence (Koren et al., 2016; Straker et al., 2009). Although the intensity level for standing is only marginally higher than sitting (Júdice et al., 2016; Levine and Miller, 2007), it is possible that there is still an influence on motor tasks. In contrast to previous studies demonstrating reduced motor task dexterities (Commissaris et al., 2014; John et al., 2009; Straker et al., 2009), the short-term study (Schwartz et al., 2017) as well as comparable studies (Karakolis et al., 2016; Russell et al., 2015), did not show any impediment of fine motor tasks. Nevertheless, unaffected reaction times, concentration performance, as well as working speed, for alternating body postures (Schwartz et al., 2017) suggest that fears concerning decreased cognitive performance after implementing sit-to-stand workstations are baseless.

3.2.3 Medium-term study findings (cognitive performance)

Contrary to hypothesis H3, medium-term study results showed no difference in cognitive performance for working in alternating body postures over a 23-week period (Schwartz et al., 2018c). As mentioned by Schwartz et al. (2018c), these findings are consistent with prior studies on sit/stand comparisons (Knight and Baer, 2014; Russell et al., 2015) as well as with short-term study findings (Schwartz et al., 2017). Nevertheless, although multivariate ANOVA results did not find significant differences in cognitive performance, accuracy and working speed significantly improved for sit/stand workstation users after the 23-week intervention period.

As mentioned by Schwartz et al. (2018c), several factors might explain unaffected cognitive performance for sit/stand workstation users. The relatively small increase in physical activity (Barone Gibbs et al., 2017; Júdice et al., 2016; Levine and Miller, 2007) paired with a small number of postural changes for sit/stand workstation users, together with the unaffected body mass found in this study (Schwartz et al., 2018c), might not have been strong enough to induce changes (see Possible Pathways (cognitive performance)) in cognitive performance driven by physical activity, postural change or body mass. As there is a close-relationship between physical activity and cognitive performance (Koren et al., 2016), it seems likely that the small increase of metabolic effort caused by a shift towards longer standing times was not sufficient to induce performance changes. Nevertheless, unaffected cognitive performance for sit-to-stand workstation users opens up the question of why the expected pathways did not change cognitive performance, based on the relationship between sedentary behaviour and MSD, wellbeing, and attention, and their subsequent relationship with cognitive performance (Allerhand et al., 2014; Engberg et al., 2017; D. J. Moore et al., 2012; Thorp et al., 2014; Wennberg et al., 2016).

Similar to the short-term study, medium-term study participants were free of acute or chronic disease and did not suffer from regular back pain. As all participants declared high occupational sitting time prior to the study (inclusion criteria), it is likely that most of them can be classified as non-pain developers (i.e. if they were pain developers, they would have already suffered from back pain prior to the study). As a result, a zero increase in pain scores for non-pain developers (Gallagher et al., 2014) in both traditional and sit/stand workstation groups resulted in no between-group differences. Hence, MSD driven and, due to the relationship between MSD and well-being (Allerhand et al., 2014; Llewellyn et al., 2008), wellbeing driven changes (see Possible Pathways (cognitive performance)) were absent. Although a connection between pain and cognitive performance cannot be demonstrated due to a lack of pain estimation data within the medium-term study, the unaffected workload (Schwartz et al., 2018c) reinforces this approach.

Lastly, the mental fatigue driven pathway (see Possible Pathways (cognitive performance)) cannot be easily supported or rejected. Although MANOVA showed no difference in overall performance, text editing accuracies (which were not part of the MANOVA due to violation of normality) significantly improved and a positive trend ($p=0.05$) towards improved d2R-test accuracies was observed for regular sit/stand workstation users. As short-term study findings (Schwartz et al., 2017) also showed improved accuracies for text editing tasks (i.e. a battery-based approach showed significant alternations in accuracy after the third battery-trial), it is possible that the use of a sit/stand workstation might increase accuracy due to improved mental states.

For both the short-term and the medium-term studies, participants had to perform cognitive tests for a long period of time. Performing long lasting tests induces mental fatigue (Faber et al., 2012), which, in line with short-term study findings (Schwartz et al., 2017), can lead to fatigue-driven reduction in cognitive performance parameters (e.g. accuracy) until the end of the testing procedure (Faber et al., 2012). However, as mentioned before (Possible Pathways (cognitive performance)), sitting breaks as well as sit/stand workstations can be beneficial in reducing mental fatigue (Ellegast et al., 2012; Pronk et al., 2012; Sheahan et al., 2016; Thorp et al., 2014; Wennberg et al., 2016). Therefore, it seems possible that working in alternating body postures on a regular basis reduces mental fatigue and improves accuracy. The changes in cortisol slopes for sit-to-stand workstation users found in the medium-term study (see Medium-term study findings (physiological stress)) of this PhD thesis (Schwartz et al., 2018c) would support this approach. As prior studies showed that interventions often affect specific attention resources while others remain stable (D. J. Moore et al., 2012), unaffected Stroop-test accuracies do not contradict this pathway. Nevertheless, the missing estimation of fatigue within the short-term and the medium-term studies makes it impossible to confirm this proposal.

3.3 Workload

Workload, a parameter describing the effort people expend to accomplish a task (Hart, 2006), is commonly used to evaluate novel working concepts or working conditions (Bridger and Brasher, 2011; De Croon et al., 2005; Lan et al., 2010; Rolo et al., 2010). It can be affected by pain (Ratzon et al., 1998), musculoskeletal disorders (Byström et al., 2004), physical activity (Ghesmaty Sangachin et al., 2016), job satisfaction (De Croon et al., 2005), time pressure (Groenewegen and Hutten, 1991) and several environmental conditions such as noise, space or room temperature (De Croon et al., 2005; Lan et al., 2010; Rolo et al., 2010). When several influencing factors occur simultaneously (e.g. time pressure and noise), workload can increase significantly (Ghesmaty Sangachin et al., 2016; Lan et al., 2010; Smith-Jackson and Klein, 2009).

High workload, regardless of sleep duration, increases fatigue and sleepiness and produces longer sleep onset latencies (Goel et al., 2014). Increased workloads are strongly related to impaired wellbeing (Bridger and Brasher, 2011), as well as to a drop in cognitive performance (Lan et al., 2010; Smith-Jackson and Klein, 2009) and accuracy (Hockey and Earle, 2006; Käthner et al., 2014; Smith-Jackson and Klein, 2009). Hence, it seems clear that evaluating working concepts regarding workload is a very useful way to prevent the development of physiological or cognitive disorders induced by occupation.

Nevertheless, although the effect of some workstation concepts (e.g. open plan offices) on workload has already been investigated (Bridger and Brasher, 2011; De Croon et al., 2005), the effect of a two-desk sit/stand workstation on workload is still unclear. To address this, both studies implemented in this PhD thesis investigated the short and medium-term effect of working at a two-desk sit/stand workstation on perceived workload.

3.3.1 Possible Pathways (workload)

Several pathways for the relationship between working at sit/stand workstations and workload, mainly based on an association of workload with musculoskeletal disorders, are conceivable (Figure 15 & Figure 16). Musculoskeletal disorders (MSD) and back pain are common problems in sedentary working environments such as offices (Cho et al., 2012; Jiménez-Sánchez et al., 2010; Sheahan et al., 2016; Statistik Austria, 2014). These problems are related to the long-term use of computers in prolonged static sitting postures (Lis et al., 2007), prolonged sitting or standing periods (John et al., 2009; Neuhaus et al., 2014a) as well as stress and diminished job satisfaction (Cho et al., 2012; Groenewegen and Hutten, 1991). In addition, due to some bipolar correlations between these covariates (i.e. higher stress leads to lower job satisfaction (Groenewegen and Hutten, 1991), improvement in one of these parameters can influence the prevalence and intensity of pain and MSD.

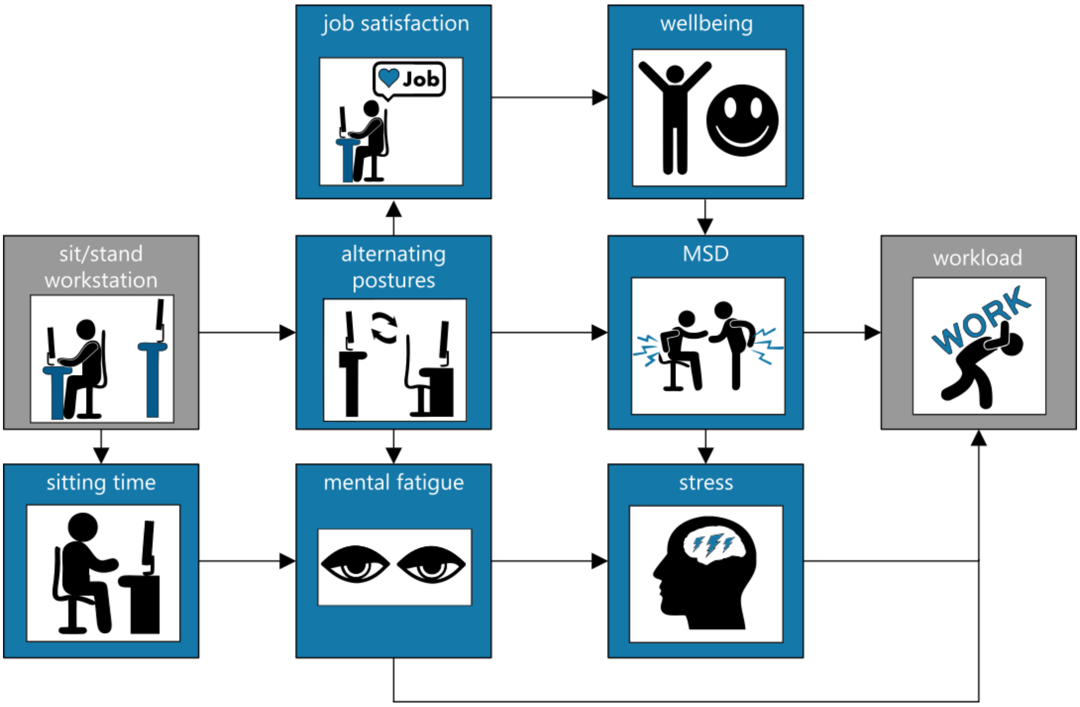

Figure 15: Concept of pathways between working at sit/stand workstations and workload (positive relationships)

In general, pain and MSDs are related to increases in workload (Cho et al., 2012). Pain and MSDs can be improved by sit-to-stand transitions or regular sitting breaks (Agarwal et al., 2017; Gallagher et al., 2014; Sheahan et al., 2016), and reducing sedentary time (Byström et al., 2004; Ratzon et al., 1998). Therefore, as the implementation of sit-to-stand workstations can initiate these kinds of behaviour changes (Alkhajah et al., 2012; Chau et al., 2014; Schwartz et al., 2018a; Shrestha et al., 2016), their implementation might positively influence the perceived workload, as well. In addition, there is a general wish to reduce sitting time and augment time spent standing for office workers (Wallmann-Sperlich et al., 2017). Since sit/stand workstations address this need (Schwartz et al., 2018a; Shrestha et al., 2016), their implementation could lead to increased job satisfaction (Garrett et al., 2016) and wellbeing (Grunseit et al., 2013; Karakolis et al., 2016; Karakolis and Callaghan, 2014), as well as fewer MSDs and decreased workload. Lastly, sit-to-stand workstations can also affect mental fatigue (Jerome et al., 2017; Wennberg et al., 2016). Mental fatigue (described in more detail in the chapter “Possible Pathways (cognitive performance)") is associated with a fall in cognitive performance and wellbeing (Barwick et al., 2012; Engberg et al., 2017; Faber et al., 2012). So, if performance is to be maintained, an extended mobilization of additional efforts to reduce stress and workload is required (Hockey and

Earle, 2006) and sit-to-stand workstations may provide a positive impact on perceived workload due to reduced mental fatigue.

However, the implementation of sit-to-stand workstations might also increase perceived workload (Figure 16). As described before, people not used to standing on a regular basis can suffer from greater discomfort or increased physical exhaustion (Beers et al., 2008; Drury et al., 2008; MacEwen et al., 2015). Working while standing compared to sitting requires additional cognitive resources to ensure sufficient posture control (Barra et al., 2015). Due to the neuronal competition between postural control and cognitive tasks, people have to apply greater mental effort to maintain performance (Hockey and Earle, 2006), and this can lead to increased workload (Hockey and Earle, 2006) in line with previous studies which showed increased workload under alternating environmental conditions (Lan et al., 2010; Smith-Jackson and Klein, 2009).

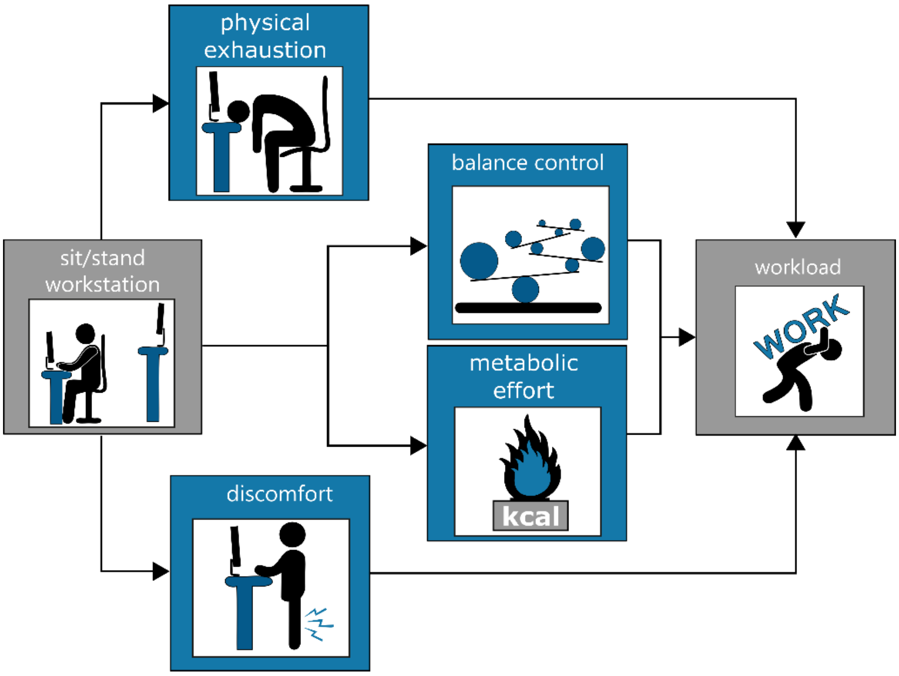

Figure 16: Concept of pathways between working at sit/stand workstations and workload (negative relationships)

Furthermore, additional metabolic efforts (i.e. walking while working at a computer) can also affect workload (Ghesmaty Sangachin et al., 2016). In summary, although the metabolic effort for standing is considerabely smaller than for walking or cycling, the increase in energy expenditure when standing might also negatively affect workload.

3.3.2 Short-term study findings (workload)

Contrary to hypothesis H2, short-term study results indicated no difference in perceived workload for working in alternating (sit/stand) body postures (Schwartz et al., 2017). As discussed by Schwartz et al. (Schwartz et al., 2017), these findings are in line with previous investigations which demonstrated no difference in workloads for working in standing postures (Drury et al., 2008) or for low levels of physical activity during work (Ohlinger et al., 2011; Russell et al., 2015). Only one study showed lower workloads for alternating postures, and these were estimated with less rigorous measurement methods (Hasegawa et al., 2001). Nevertheless, the reason for workloads to be unaffected in the short-term study cannot be attributed to the study's design. It seems possible that either a) the workload was not influenced by changing postures or b) positive and negative effects caused by changing postures canceled each other out. Nevertheless, due to the relatively small increase in metabolic effort, as well as the relatively short standing time, it seems unlikely that the extra energy expenditure caused by standing influenced the overall workload. On the other hand, long-term changes in job satisfaction, wellbeing and pain reduction, which positively influence workload (Garrett et al., 2016; Grunseit et al., 2013; Karakolis et al., 2016; Karakolis and Callaghan, 2014), can be ruled out due to the short-term study duration. As a result, it seems possible that the effects of mental fatigue or MSDs were too small to make a significant impact on workloads in the short-term study. Furthermore, since a high level of work control has a positive effect on workload (Hockey and Earle, 2006), the fixed posture schedule of the short-term study, which did not fulfill participants' preferences (Sheahan et al., 2016), could have had a negative impact on workload and might have negated any positive effects caused by other marginal factors. Medium effects with insufficient statistical power indicate limited validity of this short-term study (Schwartz et al., 2017), but would also support this approach.

Lastly, short-term study results showed baseline between-group differences in workload and untypical workload patterns for the counterbalanced trials. According to Schwartz et al. (2017), these findings could be caused by the absence of a weighting procedure of the NASA-TLX Questionnaire as well as nocebo effects (Olshansky, 2007; Vase et al., 2016). This statement is also supported by the fact that the perception of workload, especially with regard to marginal factors, is very personal (Smith-Jackson and Klein, 2009).

3.3.3 Medium-term study findings (workload)

Contrary to hypothesis H4, the medium-term study results revealed no differences in workload for people working in alternating postures for a 23-week period. In line with short-term findings (Schwartz et al., 2017), these results open up the question of why a two-desk sit-to-stand workstation, rated mainly as very positive and useful (see chapter "Medium-term study findings (sitting time)"), did not influence the perceived workload in a positive way.

As described before, there are many environmental factors influencing workload in office environments (De Croon et al., 2005; Lan et al., 2010; Rolo et al., 2010). For example, in open-plan offices, it was shown that the restriction of space, impairment of privacy, or noise disturbance can reduce job satisfaction, increase stress, reduce wellbeing, and increase workloads

(Bridger and Brasher, 2011; De Croon et al., 2005). Furthermore, as shown under controlled laboratory conditions, environmental factors such as high room temperatures (e.g. 28°C) can also increase workload (Lan et al., 2010).

The influence of room temperature, room volume, space, noise or lighting conditions can be excluded with a high degree of certainty because of the stringent inclusion criteria (i.e. measurements being taken in the same room under the same environmental conditions) for both studies in this PhD thesis. In addition, increased physical exhaustion induced by working in alternating postures can also be discounted because the medium-term study participants were used to this kind of working during their 23-week intervention period. Nevertheless, although the effect on workload due to long-term changes in job satisfaction, wellbeing and pain cannot, contrary to the short-term study, be automatically excluded for medium-term study participants, it is not clear why workload did not change for regular sit-to-stand workstation users.

According to Schwartz et al. (Schwartz et al., 2018c), several reasons for the lack of differences in workload are possible. Although physical activity and workload are related (Ghesmaty Sangachin et al., 2016), the small difference in physical activity or metabolic effort between sitting and standing (Barone Gibbs et al., 2017; Júdice et al., 2016) might not be strong enough to induce changes in workload. Furthermore, improvements in musculoskeletal disorders which have already been shown for sit/stand working schedules (Gallagher et al., 2014; Sheahan et al., 2016) might also be negated by unfamiliar sit/stand ratios. However, as medium-term study participants were free of pain and discomfort under to the inclusion criteria, musculoskeletal disorder and pain have not been investigated in this study. As a result, these suggestions are very speculative.

Similar to the short-term study results, between-group differences in workload were found (Schwartz et al., 2018c). As these differences occurred only between intervention and control arm participants, this circumstance can be attributed to a lack of weighting. This further highlights the need for weighting within the NASA TLX for non-crossover trials.

3.4 Physiological stress

Physiological stress (i.e. preparation for a flight-or-fight situation) is known as a risk factor for obesity (Stachowicz and Lebiedzińska, 2016), hypertension (Dimsdale, 2008; Schneiderman et al., 2005; Stachowicz and Lebiedzińska, 2016) and cardiovascular events (Dimsdale, 2008) and can occur for short-term events (acute stress) or long lasting periods (chronic stress). While acute stress can help to manage hazardous situations by allocating additional physiological resources (e.g. faster and greater energy supply), long lasting periods of stress, often induced by high demands and low control at work (Dimsdale, 2008; Schneiderman et al., 2005), can lead to several negative outcomes. In general, chronic stress is related to elevated blood pressure

(Dimsdale, 2008; Schneiderman et al., 2005), heart rate (Schneiderman et al., 2005) and endocrinological activity (Schneiderman et al., 2005) as well as risk of depression (Marin et al., 2011). It further leads to an acceleration of autoimmune diseases, increased vulnerability to viral infections, reduced wound healing, antibody response and insulin resistance (Schneiderman et al., 2005; Stachowicz and Lebiedzińska, 2016).

Beside the physiological responses to chronic stress, it is also known to be a cofactor for cognitive performance (McCormick et al., 2007) due to the enhancement of endocrinological activity (i.e. higher glucocorticoid release). Glucocorticoids initiate brain maturation, remodel axons and dendrites, and affect cell survival (Lupien et al., 2009), and higher glucocorticoid levels (Lupien et al., 2009) associated with chronic stress can lead to a reduced hippocampal volume (Marin et al., 2011) and impaired brain development (Lupien et al., 2009). It can further lead to several psychological disorders such as sleep disturbance, depression, and impairment of cognitive functions such as learning (Marin et al., 2011), memory (Marin et al., 2011; Shields et al., 2015), attention (Lupien et al., 2009), task shifting (Goldfarb et al., 2017), and hippocampus-related tasks (Marin et al., 2011).

3.4.1 Pathways physiological stress (Salivary cortisol & heart rate)

Cortisol, the prevailing hormone in the glucocorticoid group (Stachowicz and Lebiedzińska, 2016), and its collection in mediums such as saliva or blood, is commonly used to determine the level of stress (Almela et al., 2011; Bakke et al., 2004; Goldfarb et al., 2017; Lupien and Lepage, 2001). Due to its simplicity (i.e. non-invasive, user-friendly) and its high correlations with serum cortisol (Aardal and Holm, 1995; Sumioka et al., 2013), salivary cortisol measurement has received increased interest in non-medical research applications (Almela et al., 2011; Diez et al., 2011; Hennig et al., 2000), even though stress-induced cortisol responses occur faster (i.e. equilibrium between saliva and serum cortisol takes up to 5 minutes) in serum than in saliva (Aardal and Holm, 1995).

In general, independently of stress-related changes, cortisol levels can be influenced by age (Aardal and Holm, 1995), genes (Marin et al., 2011), physical activity (Hill et al., 2008), gender (Marin et al., 2011; Nater et al., 2007), meal consumption (Stachowicz and Lebiedzińska, 2016), coffee intake (Stachowicz and Lebiedzińska, 2016), sleep loss (Leproult et al., 1997), and emotions (Merrifield and Danckert, 2014; Sumioka et al., 2013) (see Figure 17). In addition, there are strong daytime related variations in cortisol levels, characterized by a dramatic increase in the morning hours (cortisol awakening response) and a decrease in the evening (Chida and Steptoe, 2009; Leproult et al., 1997; Nater et al., 2007; O'Connor et al., 2009; Oosterholt et al., 2015). It therefore seems clear that cortisol measurements similar to those executed within this PhD thesis

(Schwartz et al., 2018c, 2016) should always be conducted under stringent environmental conditions to ensure unbiased results.

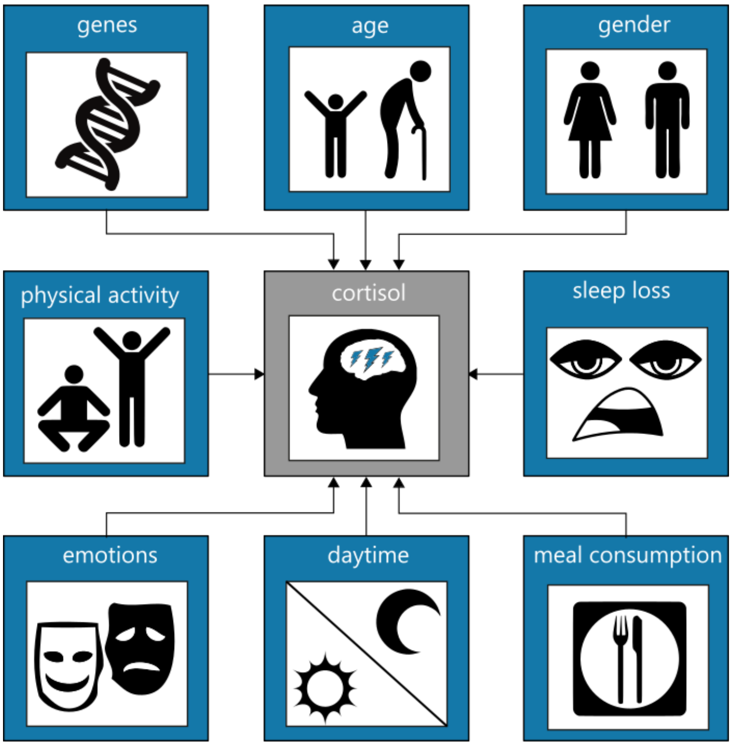

Figure 17: Stress-independent factors influencing cortisol level

Furthermore, as physiological parameters such as heart rate are also affected by stress (Hill et al., 2008; Hjortskov et al., 2004; Schneiderman et al., 2005), these parameters can help to identify possible variations in cortisol responses which did not appear under acute stress (i.e. meal consumption, which increases cortisol levels but does not influence heart rate).

3.4.2 Medium-term study findings (physiological stress)

Although the dose-response for cortisol on cognitive performance is still unclear (Shields et al., 2015) and subject to speculations suggesting an inverted U-shape relation between glucocorticoids and performance (Lupien et al., 2009), impairments of memory (Shields et al., 2015), switching tasks (Goldfarb et al., 2017) or accuracy rates (Marin et al., 2011) induced by cortisol increments made it necessary to measure the cortisol level within the medium-term study of this PhD thesis.

Even though cortisol measurements were mainly implemented to ensure that no baseline differences in cortisol levels exist, the medium-term study results exhibited different cortisol slopes between traditional workstation and sit/stand workstation users (Schwartz et al., 2018c). This unexpected difference, characterized by a non-significant drop in cortisol values during the testing procedure for sit-to-stand workstations users at the 23-week follow-up only, may have been caused by a number of factors.

Cognitive tests as well as cortisol measurements within the medium-term study were all executed during the evening hours (Schwartz et al. 2018c, 2016). Therefore, as stated by Schwartz et al. (2018c), it is likely that the drop in cortisol measured on most of the days can be partly explained by the natural evening drop of cortisol (Chida and Steptoe, 2009; Leproult et al., 1997; Nater et al., 2007; O'Connor et al., 2009; Oosterholt et al., 2015). Nevertheless, as the drop in salivary cortisol was less pronounced for the intervention period follow-up (Figure 18), it seems possible that there might be an additional overlapping effect.

First of all, performing cognitive tests can increase salivary cortisol levels (Goldfarb et al., 2017; Hill et al., 2008; Nater et al., 2007) and the natural evening drop in cortisol may have occurred simultaneously with the elevation of cortisol caused by cognitive testing. Hence, if the medium-term usage of sit/stand workstations led to higher stress responses during cognitive testing (i.e. higher cortisol levels), these levels would counteract the natural drop of cortisol, and further explain between-group differences found in the medium-term study. Nevertheless, as stress responses due to cognitive testing are characterized by increases in cortisol level and heart rate (Hill et al., 2008; Nater et al., 2007), and the latter did not differ between groups (Schwartz et al. 2018c), enhanced cortisol responses for regular sit-to-stand users seem to be unlikely. Reduced stress levels for sit/stand workstation users found in a previous study (Pronk et al., 2012) support this appraisal.

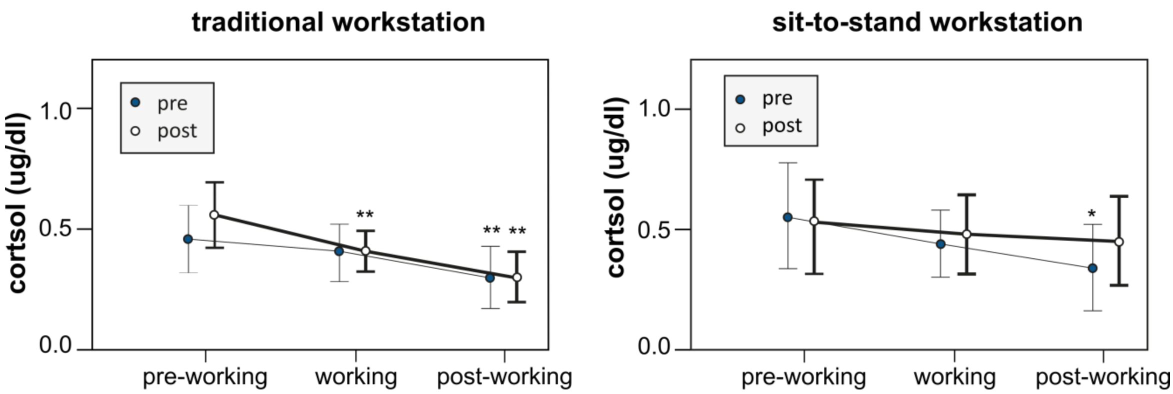

Figure 18: Illustration of the cortisol drop estimated during assessment days for pre-working, working and post-working conditions according to the data of Schwartz et al. (2018c)

Unlike changes based on stress responses due to cognitive testing, changes based on feelings seem to be more concrete. As described by Schwartz et al. (2018c), positive as well as negative feelings (e.g. fatigue or boredom) can affect cortisol levels (Merrifield and Danckert, 2014; Sumioka et al., 2013). Repetitive tasks, as demonstrated in the medium-term study, are related to mental fatigue and induce feelings of monotony (Hasegawa et al., 2001). These mental states can be positively affected by sit-to-stand transitions and the use of sit-to-stand workstations (Ellegast et al., 2012; Hasegawa et al., 2001; Pronk et al., 2012; Sheahan et al., 2016; Wennberg et al., 2016). Therefore, it seems possible that elevated levels of fatigue and boredom for traditional workstation users might have a cumulative effect on the natural evening drop of cortisol level. This would further explain between-group differences in the medium-term study (Schwartz et al., 2018c).

Lastly, and although all environmental conditions (e.g. room, light, noise, room temperature, etc.) were controlled in the medium-term study of this PhD thesis to avoid bias (Schwartz et al. 2018c, 2016), violations of the study protocol by some participants (e.g. coffee or food intake immediately prior to the assessments) might have occurred, but as mentioned earlier, seem unlikely as heart rates were unaffected.

3.5 Sedentary behaviour

A high prevalence of sedentary behaviour, especially in occupational environments (Eurobarometer & European Commission, 2014; Loyen et al., 2016), have led to an increased interest over the last few years in worksite-based interventions focusing on prolonged sitting (Conn et al., 2009; Neuhaus et al., 2014a; Shrestha et al., 2016). As a consequence, several novel workplace concepts encouraging postural changes or physical activity have been designed, realized and investigated (Carr et al., 2013; Elmer and Martin, 2014; Koepp et al., 2013; Straker et al., 2009). As previous scientific findings exhibited massive differences in efficiency and acceptance (Neuhaus et al., 2014a; Wilks et al., 2006), one aim of this PhD thesis was to investigate the effect of a novel two-desk sit-to-stand workstation on sitting time, physical activity and postural changes (Schwartz et al., 2018a, 2016).

3.5.1 Medium-term study findings (sitting time)

Study results showed substantial sitting time reductions and progressive time-dependent changes in sitting time patterns for the two-desk sit-to-stand workstation concept (Schwartz et al., 2018a), which were more pronounced than some previous interventions (Alkhajah et al., 2012; Evans et al., 2012; Wilks et al., 2006) and in line with hypothesis H5.

As already discussed by Schwartz et al., (2018a), the efficiency of a workplace can be influenced by different factors. It has been shown that interventions supplemented with additional support (Healy et al., 2013; Robertson et al., 2013) as well as those executed during paid working time (Conn et al., 2009) can increase efficiency. In contrast, interventions not fulfilling users´ requirements (e.g. too complex, impracticable, and noisy) as well as those reducing self-regulation (e.g. automatic height adjustments every 20 minutes) will reduce user acceptance and subsequently the intervention efficiency. As the workstation described by Schwartz et al., (2016) consisted of two desks individually adjusted to a user's sitting and standing height. No further adjustments were necessary for postural changes between sitting and standing. Thus the risks of wrong or insufficient adjustments by the user, which are related to awkward postures and musculoskeletal problems (Lis et al., 2007; Pope et al., 2002; Sitthipornvorakul et al., 2011), could be eliminated. Furthermore, there were no problems with adjustment times, noise (e.g. sounds from crank handles or electric motors), or technical issues (e.g. trapped cables) related to user acceptance of this workstation type.

Unexpected advantages, mainly reported by the participants at the end of the study, further enhanced the performance and user acceptance of the two-desk sit-to-stand workstation concept (Figure 19). Beside the quick and easy postural changes (i.e. just standing up or sitting down without the need for any adjustments to screens or desks) the workstation design (i.e. two equally furnished desks) allowed collaborative work on the same document. For example, user 1 could be working on a document using the keyboard at the sitting desk, while user 2 is highlighting mistakes by using the mouse at the standing desk. Moreover, the standing desk regularly reminded users to stand up by its presence. Unequal eye levels (e.g. user 1 is sitting, and user 2, who is standing, instructs user 1 to write a specific text) which rarely occurred with traditional workstations, proved to be less prevalent than expected for the novel workstation, as workers chose to communicate at equal eye levels. It is assumed that the aforementioned parameters, especially those related to behaviour change (Schwartz et al., 2018a; Shain and Kramer, 2004) known from behavioural science (Direito et al., 2014; Michie et al., 2009), are the main reason for the substantial sitting time reduction induced by the investigated workstation concept. Scientific recommendations indicating the enhanced effects of sit/stand workstations induced by behavior change theory elements (Agarwal et al., 2017; Danquah et al., 2017; Jerome et al., 2017; Wallmann-Sperlich et al., 2017), as well as previous investigations showing decreased sitting time after implementing behaviour change elements in existing sit/stand workstation offices, strengthen this perception (Danquah et al., 2017).

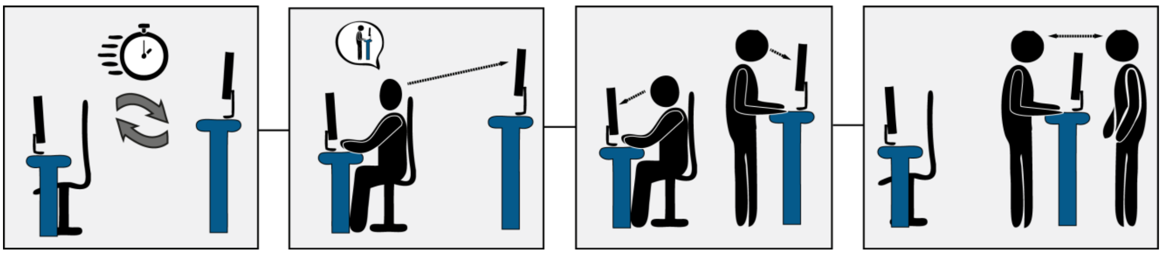

Figure 19: Unexpected advantages of the novel two-desk sit-to-stand workstation (fast switches, reminders, collaborative working, equal eye level)

Similar to previous workplace based interventions (Danquah et al., 2017; Mansoubi et al., 2016), a diminished effect on sitting time towards the end of the medium-term study (Schwartz et al., 2018a) demonstrated a need to develop long-lasting workplace based interventions (e.g. wearables or other forms of optional feedback systems (Schwartz and Baca, 2016a)).

However, contrary to the advantages of the novel workstation concepts, it should be noted that working on two equally furnished workstations might also cause problems regarding personal privacy. Personal privacy, a parameter highly related to user acceptance (Zweig and Webster, 2002), decreases when people feel they are being monitored (Zweig and Webster, 2003). Whenever people work on two equally furnished desks, the screens are not covered by the user (especially on the desk not in use) enabling external parties to follow the working process. Although it is possible to switch off unused screens, screen start up and shut off times may also influence user acceptance. A software which automatically darkens unused screens, also implemented in this study, might help to compensate for this.

3.5.2 Medium-term study findings (postural changes)

Contrary to substantial effects on the overall sitting time, the effect on postural changes per hour induced by the two-desk sit-to-stand workstation was relatively small (Schwartz et al., 2018a). Although this statement is based on findings in a small subsample of participants (i.e. only 3 out of 12 full data sets exist due to unpredicted events), and it does not imply causality, these findings should not be ignored, especially as, for the majority of the intervention period, the number of postural changes for each participant was distinctly smaller than stated in current recommendations (Gallagher et al., 2014; Owen et al., 2009) and in previous workplace-based interventions (Alkhajah et al., 2012; Straker et al., 2013).

Different estimation methods, as well as the workstation design, might explain this. Sit-to-stand transitions are commonly detected by means of accelerometers (Godfrey et al., 2011; Gorman et al., 2013; Kerr et al., 2016). In office ergonomics, they are usually mounted on the hip or near the person’s centre of mass (Júdice et al., 2015; Plasqui et al., 2013) to detect sitting, standing or lying postures. By counting acceleration peaks they can also estimate the intensity level of physical activity (Crouter et al., 2006; Healy et al., 2011a; Mailey et al., 2016). In contrast to this, postural changes in this PhD thesis were detected by a self-developed software installed on the personal workstation (Schwartz et al., 2016). Although it was not possible to detect postural changes outside of the work environment (e.g. during meetings or lunch breaks), or to estimate the level of physical activities, the logging tool, unlike accelerometers, was able to track workplace based body postures (sitting or standing) and their changes (sit/stand transitions) continuously over the whole study duration (Probst et al., 2013b). Missing data as a result of forgotten interactions (e.g. starting or closing the program manually) were excluded as the software was continuously running on users´ computers without any additional input. Nevertheless, missing postural information outside the workstation environments may have led to a lower number of recorded postural changes within the observation period. Subsequently, postural changes estimated by the logging tool are lower than those estimated by conventional methods.

Another explanation for the low number of postural changes might be the workstation design. As shown in previous studies, environmental conditions (spatial and technical facilities) can influence changes in posture (Alkhajah et al., 2012), even if this does not always happen voluntarily (e.g. when printers are placed in separate rooms). People might be forced to move back to the sitting desk to complete their work tasks, especially when standing desks do not provide sufficient space or equipment. In the two-desk sit-to-stand workplace concept investigated in this study both desks were equally furnished and took up the same amount of space. As a result, there was no necessity of changing back to the sitting desk for the aforementioned reasons. This could have led to fewer sit-to-stand transitions. Compared to previous investigations (Alkhajah et al., 2012; Carr et al., 2016; Neuhaus et al., 2014b), the relatively long sitting and standing intervals would also support this hypothesis; the minimum and maximum interval for sitting and standing ranged between 34 to 173 min and 5 to 57 min, respectively.

Nevertheless, as mentioned at the beginning, it should be noted that the dramatic loss of logging data (75%) limited their explanatory power. Further research is necessary to investigate the relationship between accelerometer and logging data as well as to detect parameters facilitating regular postural changes, especially as study results indicated postural change frequencies lower than stated in current recommendations (Gallagher et al., 2014; Owen et al., 2009).

3.5.3 Medium-term study findings (physical activity)

Physical activity is known as an important cofactor for cognitive performance (Esteban-Cornejo et al., 2015; Rasberry et al., 2011; Yaffe et al., 2001). It can be influenced by several environmental parameters such as weather (Klenk et al., 2012; Lewis et al., 2016), social support (Mendonça et al., 2014; Mendonça and Farias Júnior, De, 2015), or season (Atkin et al., 2016; Hagströmer et al., 2014) and, depending on its magnitude and volume, it can positively or negatively affect cognitive performance (Funk et al., 2012; John et al., 2009; Labelle et al., 2013). Executive functions such as reaction time are particularly affected by long-lasting changes in physical activity (Colcombe and Kramer, 2003; Galioto Wiedemann et al., 2014; Kramer et al., 1999).

Study results did not show any difference in overall physical activity (Schwartz et al., 2018a). These findings are in line with those by Mansoubi et al. (2016) who showed unchanged overall physical activity when sit-to-stand workstations were implemented. Contrary to Mansoubis results, this study did not show changes in leisure time and occupational physical activity. Although the reason for this situation is not fully clarified, it is hypothesized by Schwartz et al. (2018a) that seasonal fluctuations, which influence overall and leisure time physical activity (Atkin et al., 2016; Hagströmer et al., 2014) might have caused these differences. In contrast to Mansoubi´s studies, seasonal effects (which also occurred within the medium-term study) were eliminated due to the cross-over design of the medium-term study. Consequently, changes in physical activity habits due to varying environmental conditions (i.e. enhanced indoor activity during bad weather) might not have biased the medium-term study results. Nevertheless, as both studies did not indicate any changes in overall physical activity, it can be assumed that the influence of physical activity levels on cognitive performance is negligibly small.

3.5.4 Medium-term study findings (body mass)

Obesity and overweight, health issues directly connected with body mass, are associated with several physiological and mental impairments (Atkin et al., 2012; Dempsey et al., 2014; Doll et al., 2000; Gibson et al., 2017; Wardle and Cooke, 2005) and are possible covariates for cognitive performance (see chapter Possible Pathways (cognitive performance)). As risk factors for obesity can be influenced by workstation design (Dempsey et al., 2016; Hadgraft et al., 2015; Hawari et al., 2016; Healy et al., 2017; Koren et al., 2016; Owen et al., 2010b), body mass was examined in the medium-term study of this PhD thesis (Schwartz et al., 2018a).

Multivariate analysis did not show body mass differences within the medium-term study (Schwartz et al., 2018a). Although these findings are in line with previous studies (Carr et al., 2016; Healy et al., 2017), the question arises of why sit/stand workstations are not sufficient to provoke body mass changes.

In general, compared to sitting, working in standing or alternating body postures are both characterized by higher heart rates (Beers et al., 2008) and can increase occupational energy expenditure (Barone Gibbs et al., 2017; Beers et al., 2008; Júdice et al., 2016). Depending on the number of sit-to-stand transitions (each transition burns approx. 0.5 kcal (Hawari et al., 2016)) as well as the amount of standing time, this increase can reach up to 20 percent (Hawari et al., 2016). As working in alternating postures, as well as having less sedentary time, has a positive effect on obesity risk factors such as waist circumstance (Hamilton et al., 2008; Owen et al., 2010a), triglycerides (Hamilton et al., 2008; Healy et al., 2011b, 2008b), fat oxidation and carbohydrate oxidation (Hawari et al., 2016) as well as postprandial or fastening glycemia (Dempsey et al., 2016; Healy et al., 2017), and higher energy expenditure can help to promote energy balance and prevent weight gain (Beers et al., 2008), it is unclear why working at sit/stand workstations did not change body mass.

As mentioned by Schwartz et al. (2018a), there could be several reasons for this. In general, weight gain is associated with an energy gap of 15-50 kcal/day (Beers et al., 2008). In the medium-term study (Schwartz et al., 2018a), based on prior energy expenditure studies (Barone Gibbs et al., 2017; Beers et al., 2008; Júdice et al., 2016), the overall sitting time reduction of approx. 2.75 h led to an additional metabolic effort of approx. 14 kcal per day. Due to this relatively small amout of additional metabolic effort, it is likely that the impact of using sit/stand workstations might not be sufficient to induce body mass changes. Furthermore, only normal weight or slightly overweight healthy people were included in the medium-term study. As previous studies showed that, compared to obese people, the non-obese need even more physical activity during sitting breaks to improve physiological parameters (Dempsey et al., 2016), and as the effect on cardiometabolic biomarkers was mainly caused by a decrease in the control group rather than an increase in the intervention group (Healy et al., 2017), it seems clear why no weight loss occurred within the medium-term study. Furthermore, it is likely that the small, non-significant effects found by the univariate analysis of body mass can be explained by a Hawthorne effect combined with commonly underestimated body weights in the general population (Mummery et al., 2005).

3.6 Dropout

No dropout occurred during either studies. It seems that playful cognitive tests, well motivated and interested subjects, study participation within paid working time, and the participants' positive attitude to support a young researcher with his PhD thesis are predictors for high acceptance. These findings are consistent with other observations about improved success rates for workplace-based interventions during paid working time (Conn et al., 2009), higher interventional effects for motivated people (Boksem et al., 2006), and lower response rates for unpleasant measuring methods (Schottenbauer et al., 2008). Qualitative interviews conducted at the end of the study (not yet published) confirmed these expectations. Statements such as "Something has to be done to decrease prolonged sitting", "I cannot quit this study because if it fails nothing will change at work" or "I like doing the tests. Especially the d2R-test and the Stroop-test felt like playing a game. I wanted to achieve higher scores each time." are only a small number of typical responses.

3.7 Limitations and strengths

Although the studies in this PhD thesis were carefully designed, some limitations still occurred (Figure 20). The first and most significant one concerns the small sample size of both studies, mainly based on two conditions. First, to ensure similar testing conditions all assessment days were conducted in the same laboratory and accompanied by the author of the PhD thesis. Subsequently, because of the duration of one assessment day (6-7 h per subject, including preparatory and follow-up work) it was not possible to realize larger sample sizes. Second, the number of height-adjustable desks available was limited for the medium-term study. The desks were provided by Joseph Gloeckl, CEO of the company "Aeris Impulsmoebel GmbH", because of his scientific interest in this topic. As height-adjustable desks were not part of his company's portfolio, all desks had to be bought from an external company. The number of subjects within this study was therefore limited by the high costs of these desks. Although a priori sample size calculation confirmed sample size sufficiency for answering the PhD hypotheses, it was neither possible to stratify the results in an efficient way (i.e. gender stratification), nor to draw any conclusions about the long-term sustainability of the measured parameters. Multi-year, prospective studies are needed to test the efficacy of sit-stand technologies, devices, and administrative strategies.

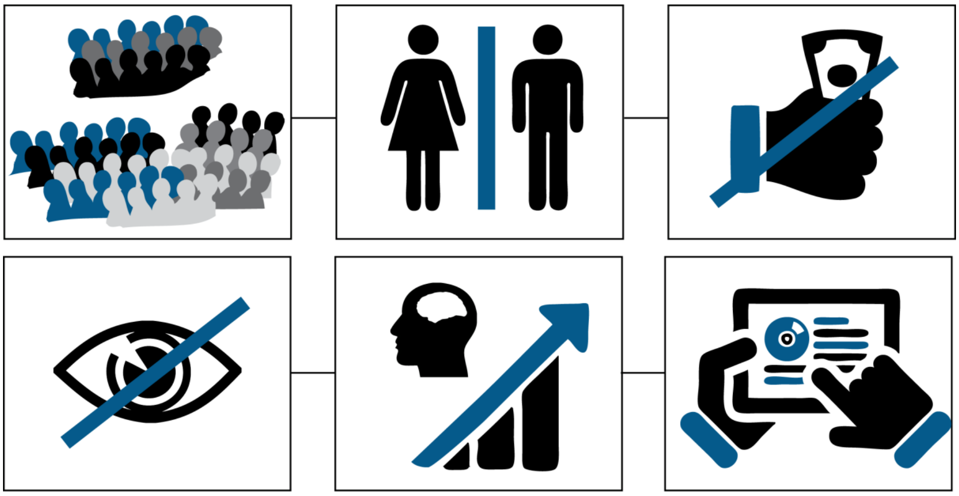

Figure 20: Study limitations graphical summary (study size, gender stratification, study reward, blinding, process, practice effects, software problems)

The second limitation concerns the study's blinding process. Due to the nature of the intervention it was not possible to blind the participants. However, to ensure the highest possible level of objectivity all participants were coded at the beginning of the study and all statistical analyses were conducted with coded data only.

An unexpected third limitation was the validity of the posture logging software data. Although the software had been thoroughly tested in a pilot study (Probst et al., 2013b), several unforeseeable circumstances, especially changes regarding Microsoft Windows (change from Windows XP to Windows 7) at several companies participating in this study dramatically reduced the amount of logging data (75% data loss). Although the results of the logging data correspond to those of data from the whole collective determined via questionnaire, all conclusions based on logging data should be handled with care.

Further limitations are the strong practice effects that occurred in both studies, as well as the participants´ motivational levels. The repetition of the tests led to practice effects which subsequently overlapped with cognitive changes and biased them. Furthermore, as study participants did not receive any financial compensation, it can be presumed they were highly motivated and interested. The fact that the study participants performed much better than their age cohort in previous studies appears to confirm this perception. Thus, estimations about the effects of alternating postures for the general population should be assessed with care.

Despite of these limitations, the studies in this PhD thesis possess many strengths (Figure 21). Both were randomized controlled trials with an independent recruiting and randomization process. Participants were neither within a relationship of dependency with the author, nor working in an ergonomics related field. The recruitment of participants for the medium-term study was totally detached from the study leader and conducted by a governmental health insurance group.

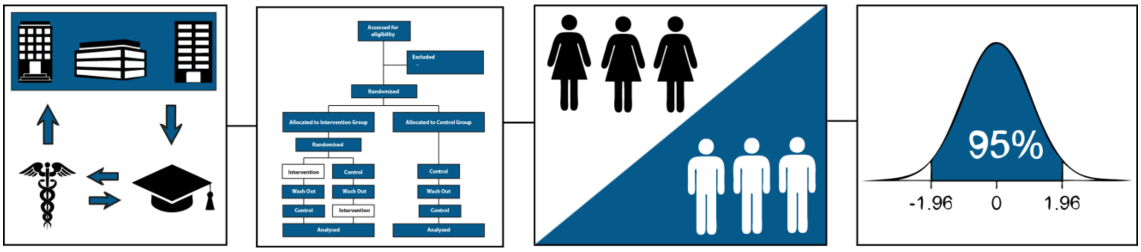

Figure 21: Study strengths graphical summary (recruiting process, study design, gender equality, statistical methods)

Furthermore, independent of the study type, participants were recruited from several Austrian universities for the short-term study and companies for the medium-term study. The studies' cross-over designs, as well as the gender equality of the studies, permit a compensation of the missing gender stratification and therefore render unisex statements possible. Valid, minimally biased quantitative measurements and appropriate statistical analyses also strengthen the studies´ findings. As the medium-term study subjects were allowed to participate in assessment days in their paid working time, this study did not have any dropouts.

3.8 Proof of hypotheses

Based on the results of both studies, the following answers to the hypotheses can be concluded:

H1: Working in alternating postures (sit/stand) affects cognitive performance on a short-term (1 day) basis.

The short-term study results demonstrated no difference in cognitive performance regarding working speed, concentration performance, and reaction time. Hypothesis H1 has to be rejected.

H2: Working in alternating postures (sit/stand) positively influences workload on a short-term (1 day) basis.

The short-term study results showed a trend towards lower workloads for people working in alternating postures compared to those who were only sitting. As the differences did not reach statistical significance, a greater sample size is needed to clarify this. Hypothesis H2 has to be rejected.

H3: Working in alternating postures (sit/stand) over a long period (23 weeks) positively influences parameters of cognitive performance on a medium-term basis.

The medium-term study results demonstrated no difference in overall cognitive performance, although certain cognitive parameters experienced significant improvements. H3 has to be rejected.

H4: Working in alternating postures (sit/stand) over a long period (23 weeks) positively influences workload on a medium-term basis.

The medium-term study results showed no difference in workload. H4 has to be rejected.

H5: Sit-to-stand workstations consisting of two identical height-adjustable desks cause a significant sustainable (23 weeks) reduction in sitting time when implemented in occupational office environments.

Medium-term study results indicate that sitting time reduction was more prominent for sit-to-stand workstations consisting of two identical height-adjustable desks compared to common one-desk solutions. Hypothesis H5 is supported.

4 Conclusion

In this PhD thesis two randomised controlled trials with healthy participants under laboratory environments were conducted. The first study investigated the short-term effect of alternating working postures (sit/stand) on cognitive performance and workload. The second one investigated the mid-term effect of a two-desk sit-to-stand workstation on cognitive performance, workload and sedentary behaviour. Both studies showed no difference in cognitive performance or workload for working in alternating body postures. Furthermore, medium-term study results showed post-working alternations in salivary cortisol level and improvements in accuracies for sit-to-stand workstation users. Hence, concerns about a loss in cognitive performance while working in alternating postures can be refuted, but changes in specific cognitive parameters, as well as changes in stress response rates, indicated that unknown causalities may exist. Further research implementing valid cognitive tests designed for multiple use, quantitative measuring devices for estimating sedentary behaviour and physical activity as well as methods for estimating musculoskeletal complaints, pain, discomfort and mental fatigue, especially on a long-term basis with large sample size, could help to clarify this.

Additionally, medium-term study results showed substantial sitting time reductions and progressive time-dependent changes in sitting time for two-desk sit-to-stand workstation users, without changes in leisure time and occupational physical activity or body mass. These substantial sitting time reductions and unexpected advantages related to behaviour change in sedentary behaviour reported by the sit/stand workstation users showed that further investigations on barrier-free sit-to-stand workstation concepts should be carried out. As this two-desk sit-to-stand workstations does not appear to promote postural changes in a recommended way, future interventions should also consider novel technologies such as wearables, mobile health applications or other technical aids to support people in modifying their activity patterns.

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6 Appendix

English documents

Publications

Manuscripts

Ethical committee approval

German documents

Study brochure (long version) - short-term study

Study brochure (short version) - short-term study

Form - consent to participate - short-term study

Form - personal data - short-term study

Study brochure (long version) - medium-term study

Study brochure (short version) - medium-term study

Form - consent to participate - medium-term study

Form - personal data - medium-term study

Form - body mass - medium-term study

Form - CAR measurement - medium-term-study

Form - general health status - both studies

Form - measuring protocol - both studies

NASA-TLX questionnaire - German translation

IPAQ questionnaire - German translation

Figure copyright statement

Schwartz et al. BMC Public Health (2016) 16:578
DOI 10.1186/s12889-016-3271-y

BMC Public Health

STUDY PROTOCOL Open Access

Effect of a novel two-desk sit-to-stand workplace (ACTIVE OFFICE) on sitting time, performance and physiological parameters: protocol for a randomized control trial

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Abstract

Background: Prolonged sitting is ubiquitous in modern society and linked to several diseases. Height-adjustable desks are being used to decrease worksite based sitting time (ST). Single-desk sit-to-stand workplaces exhibit small ST reduction potential and short-term loss in performance. The aim of this paper is to report the study design and methodology of an ACTIVE OFFICE trial.

Design: The study was a 1-year three-arm, randomized controlled trial in 18 healthy Austrian office workers. Allocation was done via a regional health insurance, with data collection during Jan 2014 – March 2015. Participants were allocated to either an intervention or control group. Intervention group subjects were provided with traditional or two-desk sit-to-stand workstations in either the first or the second half of the study, while control subjects did not experience any changes during the whole study duration.
Sitting time and physical activity (IPAQ-long), cognitive performance (text editing task, Stroop-test, d2R test of attention), workload perception (NASA-TLX) and physiological parameters (salivary cortisol, heartrate variability and body weight) were measured pre- and post-intervention (23 weeks after baseline) for intervention and control periods. Postural changes and sitting/standing time (software logger) were recorded at the workplace for the whole intervention period.

Discussion: This study evaluates the effects of a novel two-desk sit-to-stand workplace on sitting time, physical parameters and work performance of healthy office based workers. If the intervention proves effective, it has a great potential to be implemented in regular workplaces to reduce diseases related to prolonged sitting.

Trial registration: ClinicalTrials.gov Identifier: NCT02825303, July 2016 (retrospectively registered).

Keywords: Postural changes, Standing, Sitting, Cognitive performance, Reaction time, Concentration, Workload, Office, Stroop-test, d2R-test of attention

Background

Prolonged sitting is ubiquitous in modern society and the amount of physically inactive people is rising in many countries [1, 2]. Ongoing computerization is a main cause for changes in physical activity and sitting time patterns [3, 4]. Screen time, which is commonly associated with sitting, has been dramatically increased by a rising prevalence of computers in school and occupational environments [4]. Duration of sitting time has also been shown to increase with age [5].

In 2013, 11 % of all European citizens (aged 14 years and older) spent more than 8.5 h per day in a sitting posture [6]. In the working age population, white-collar workers are most frequently affected by this amount of sitting time (21 %) and exhibit a more than four times higher risk of being exposed to prolonged sitting in comparison to manual occupations [6]. Especially office

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workers and call center employees are affected by prolonged sitting periods. The total amount of sitting in these occupations can exceed more than 80 % of the working day [7, 8].

Prolonged sitting is a risk factor for cardiovascular and musculoskeletal diseases, diabetes, several types of cancer and all-cause mortality [9–14]. In combination with static and awkward postures, the prevalence of musculoskeletal diseases (e.g. back pain, chest pain) can increase further [14]. As additional physical activity cannot fully compensate the effects of prolonged sitting [15, 16], standing between prolonged sitting periods and reduction of sedentary pursuits should be a goal for adults, irrespective of their exercise habits [17].

Given that most of the world's population spend averagely one third of their adult life at work [18], it seems clear that worksite based interventions for reducing sitting time are key elements of daily sitting time reduction. Generally, worksite based recommendations in offices contain "*Sit less", "Stand up", "Move more" and "Change postures regularly*" [16, 19, 20]. In order to fulfill postural recommendations different types of worksite based interventions have been started. Besides numerous activity promotion programs, which typically replace sitting time with low-intensity physical activity [21], the implementation of sit-to-stand or active workstations is commonly used to diminish occupational sitting time [22].

Large differences in sitting time reduction have been found for different types of sit-to-stand workstations [22]. While non-significant changes in sitting time for sit-to-stand desk users in open plan offices occurred [23], meta-analysis showed an average reduction in sitting time of 77 min per 8-h workday for activity-permissive workstations [22]. Multi-component interventions (e.g. management consultation) can further enhance this effect [24].

Although the implementation of sit-to-stand or active workstations can help to reduce sitting time, improve physical activity at work and promote health benefits [25–27], it might also lead to changes in cognitive functions such as productivity [22]. Even though non-significant changes in attention have been found [28], fine motor functions (e.g. mouse moving) as well as mathematical problem solving can be negatively influenced by additional body movements [29]. As studies reporting deterioration of work-related outcomes were all of short duration, studies using long-term follow-up were recommended [22].

The occupational hazards associated with prolonged sitting are receiving renewed attention, and new technologies, devices, and workplace controls to help reduce sitting time are being developed and introduced regularly. It would benefit researchers, practitioners, and employers if these devices and controls were evaluated and studied using consistent and reproducible methods. Reliable and comparable information produced from similarly designed studies would help to separate fact from fiction in the efforts to reduce chronic sitting in the workplace.

Objectives

The primary objective of this paper is to describe and discuss the methods of a study designed to evaluate the long-term effect of a novel two desk sit-to-stand workplace on sitting time as well as physiological and cognitive parameters for healthy people of working age in comparison to their traditional workplace (control). A secondary objective is to propose methods for future studies of sit-to-stand equipment and intervention programs.

Hypothesis

The primary hypothesis of the described study is that the ACTIVE OFFICE two-desk sit-to-stand workplace are more effective in reducing occupational sitting time than conventional one desk solutions. Secondary hypotheses are that people using the ACTIVE OFFICE setup will experience positive long term effects on physiological and cognitive skills. The experimental groups received a two desk sit-to-stand workstation in their regular office environments.

Methods/Design

ACTIVE OFFICE is a three-arm randomized control trial with two intervention and one control group (Fig. 1). After the baseline assessment was completed, the participants were randomly allocated to either the intervention or the control arm in a 2:1 ratio. The experimental group subjects received a novel two desk sit-to-stand workstation in their regular office environments, while the control group subjects did not encounter any change in their regular office environments. A 6-week wash out phase was implemented to encourage similar starting conditions for each participant (i.e. using a traditional workplace prior to pre-intervention measurements).

Participants

A convenience sample of participants was recruited from companies in Linz (Austria) and the surrounding area. A general letter requesting collaboration and providing study descriptions was sent to employers. To reduce recruiting bias, partner-company allocation was randomly done via a regional health insurance provider between August and September 2013. Study details were provided to companies that accepted collaboration in the form of information seminars located at the respective company sites. Separate interviews with people

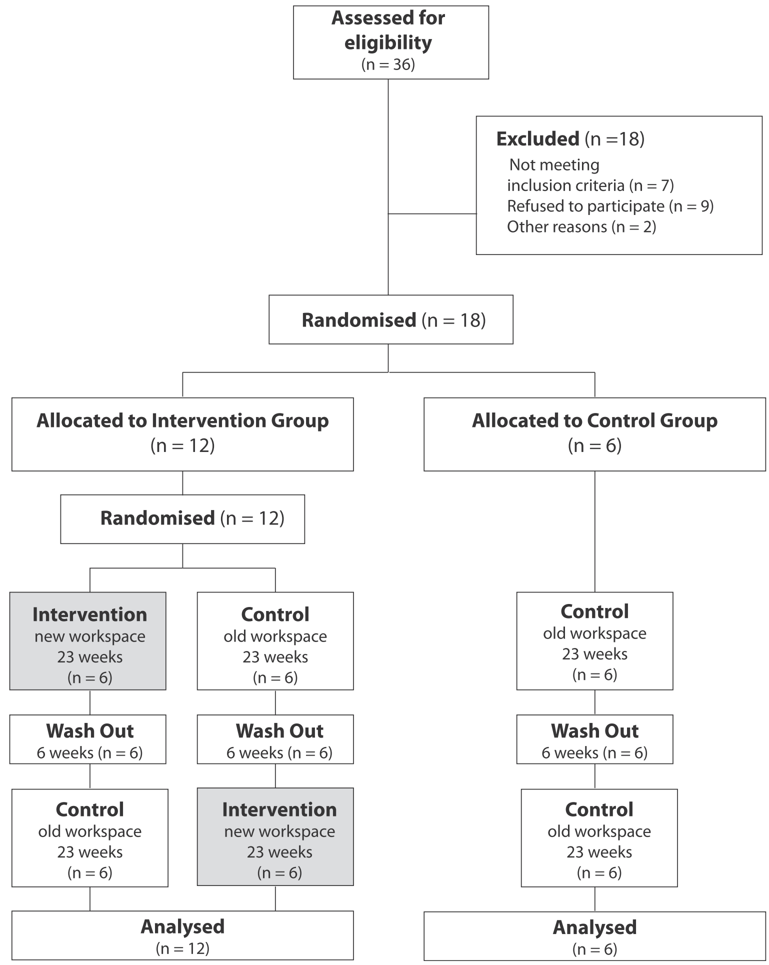

Fig. 1 ACTIVE OFFICE study design flow chart

interested in participating in the study took place after the seminars to ascertain the potential subjects' suitability for study purposes. After exclusion criteria were applied, participants were allocated randomly either to intervention or control groups.

Subject inclusion criteria

Included subjects were: a) healthy caucasian (no acute or chronic diseases); b) normal weight or slightly overweight (BMI: 18.5–27.5 kg/m^2); c) aged: 18–60 years; d)regularly working in sedentary office environments; e) regular computer users; f) fluent German speakers; and g) consented to participate.

Subject exclusion criteria

Excluded subjects had or were: a) heavily overweight & Obesity (BMI >27.5 kg/m^2); b) short office stay duration (<8 h / day or <20 h / week) c) experience in sit-to-stand workstations; d) acute or chronic diseases; e) inability to stand; f) visual impairments that had not been corrected; g) color blindness h) women who are pregnant or plan to become pregnant within 12 months; i) people planning to change their physical activity level; j) regular smokers (> 1 cigarette /day); or k) not consented to participate.

Randomization and blinding

After the baseline assessment was completed, the participants were randomly allocated to either the intervention or the control (no intervention) arm in a 2:1 ratio (Fig. 1) by means of a covariate adaptive randomization [30]. Based on previous findings [31], 'company' has been determined as a stratum and thus participants were balanced across companies (i.e., 3 participants for each company). On a second level, intervention participants were assigned to either the first (intervention first) or the second (control first) intervention group. Due to the nature of the intervention, participants were not blind to their allocation.

Sample size

A pilot study with 5 participants, performed in order to estimate the potential of the two-desk setup, found a 22 % reduction of sitting time [32]. Converted to a regular 8-h work day this results in 105 min of sitting time reduction. As this effect was noticeably higher than the effect shown by existing meta-analysis [22] we decided to detect a value between those limits. Therefore, 12 subjects would be needed to detect 90 min differences in sitting time, assuming an alpha risk of 0.05 and beta risk of 0.20 in a two-sided test, and with 20 % loss to follow-up.

Screening

Study eligibility was determined in private interviews prior to the study. Age, body weight, stature, gender, physical and mental well-being, smoking habits, chronic and acute complaints, pregnancy, medical limitations, medication, working hours per day and week, main occupation and company affiliation were collected via a self-administered questionnaire.

Intervention for experimental Group

Figure 2 shows the ACTIVE OFFICE two desk sit-to-stand intervention setup. It consists of two equal height-adjustable desks standing next to each other. Precise table arrangements (e.g. 90, 135 and 180°) were self-determined by the participants. To ensure equal conditions, every desk was furnished with the same amount and style of mice, keyboards and screens. Depending on their pre-intervention working conditions, the participants used either one or two screens per desk. The ACTIVE OFFICE was installed 1 day prior to the intervention period at the location of the old desk. Together with the study leader, desk heights were adjusted to the desired sitting and standing heights. Additional software tracking hardware inputs on the standing or sitting desk were installed. The traditional desks were moved to storerooms at the local facility for the duration of the intervention period. During the control phase for the experimental group, both desks were fixed to the sitting height to simulate regular sitting environments. This strategy was used to reduce reconstruction work efforts when the experimental group switched from intervention to control, or vice versa. Reasonable care was been taken to ensure that both desks were equally furnished to avoid preferential effects during both the intervention and control phases (e.g. comparable construction and style of desk, identical equipment and furnishings).

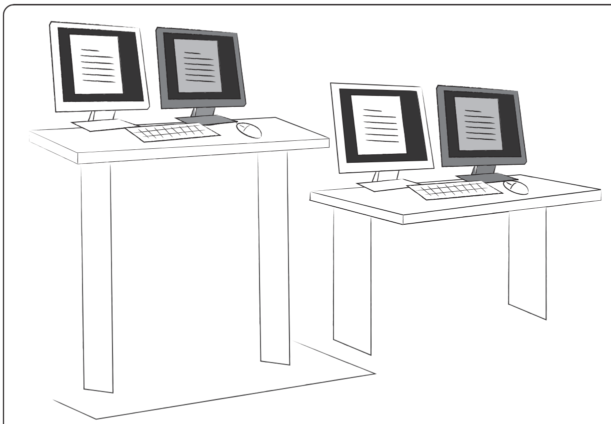

Fig. 2 ACTIVE OFFICE two desk sit-to-stand intervention setup

Control group

Control group subjects did not encounter any changes in their regular office environments.

Outcome measures

Measurements were made both in the field and in a laboratory. Field measurements were made and processed continuously over the 23-week intervention period. Laboratory measurements were made on two different days, 1 day prior to intervention, and 1 day following intervention (due to cross-over design, each subject underwent 4 total days of laboratory measurements). Field measurements were collected automatically at the participants' workstation in their working office. Laboratory tests were conducted in a controlled, simulated work-space located at the University of Applied Sciences Campus Linz.

Outcomes

Primary outcomes were changes in sitting time after 23 weeks in the experimental group compared with its own control period and the control group.

Secondary outcomes within the experimental group were changes in: reaction time, working speed, level of attention, workload perception, physical activity and postural changing pattern for the intervention phase as compared to the control phase.

Tertiary outcomes were changes in salivary cortisol level and heartrate variability (HRV) within the experimental group.

Experimental group: field measurements

Logging-software was installed on each participant's computer. By recognizing hardware (mouse, keyboard) inputs on either the sitting or standing desk, the software could determine the proportion of time that a subject was standing versus sitting during the 23-week intervention period.

Experimental group: laboratory measurements
All laboratory measurements were made in a controlled laboratory at the campus site Linz of the University of Applied Sciences Upper Austria. Temperature, air flow, humidity, lighting conditions (artificial light only) and noise level were controlled and set to be consistent with the subjects' typical working environment.

Participants were asked to refrain from exercise, caffeine and alcohol and undue stress for 24 h prior to laboratory testing. Food intake 90 min prior to the experiment was prohibited. Subjects were instructed to pursue their usual professional activity in the morning, followed by a laboratory visit in the early evening. To avoid daily fluctuations on performance all measurements started between 1:30 and 2:45 pm.

During the laboratory measurements, subjects either stood or sat upright in an ergonomic office chair, according to the study protocol. Subjects were encouraged to work as fast and as accurately as they could. To ensure identical testing conditions between subjects and to not unduly influence physiological parameters such as salivary cortisol level or heart rate variability, subjects were required to minimize excessive movement (e.g. standing up during the sitting periods). During regular breaks subjects were allowed to visit the toilet. Minor body movements, which typically occur under normal working conditions, were allowed.

Reaction time, attention & working speed
Physical efforts when performing standardized tests (e.g. standing or walking) can negatively influence cognitive parameters [28, 29]. As studies reporting deterioration of work-related outcomes were all of short duration [19] and there are indications that these are caused by non-familiar working conditions, long-term effects on cognitive performance remain to be identified. Within the study protocol, three different performance-related tests were implemented:

A digital text editing task encouraging participants to fill in spaces in an ergonomic guideline text for 10 min was used. A Stroop-Color-Word-Conflict (Stroop) test, used to measure selective attention and processing speed [33–35] as well as a "d2R-test of attention" (d2R), commonly used in the European area to determine concentration performance [36–38], were implemented.

The simplicity of the text editing task (that did not require any disciplinary knowledge) enabled working speed measurements and simulated typical low effort office work. The implemented digital Stroop-test version contained 190 congruent, incongruent and neutral tasks and required approximately 10 min to simulate long-lasting monotonous office screen work. The d2R-test was executed as a pen and paper version. Therefore, it enabled screen breaks during the test protocol and simulated paper-related office work.

The Stroop-test and the d2R-test are both characterized by a high test-retest reliability ($r = 0.77–0.95$) and do not require any specific previous knowledge except of rudimentary language skills [39, 40]. Normative values for the d2R-test are available for different countries [39].

Workload perception
Sit-to-stand workstations can evoke positive as well as negative associations [22]. While additional physical efforts caused by standing can lead to higher discomfort especially in the lower extremities (e.g. leg swelling) [22], novel working environments can improve mental well-being [41]. A common method to rate workload perception is the NASA-TLX questionnaire [42]. For reasons of simplicity and unmodified sensitivity [42], the short version of this questionnaire (RTLX), consisting of six major items, was used. Influences on workload perception based on unweighted items in the RTLX were negated due to the cross-over design.

Salivary cortisol level
Although there are new findings related to the metabolic risks associated with postural changes (breaks in sedentary time) [16, 43, 44], the effect on stress-related parameters is still unclear. Modified cortisol levels after implementing a novel workplace have been shown but the effect of postural changes on cortisol level is not yet known [41]. Therefore, salivary cortisol level was measured during the study protocol and on the following morning in order to detect the cortisol awakening response (CAR) [45].

Heartrate variability
Heartrate variability (HRV) can be used for predicting all-cause mortality and characterizing cardiovascular health [46, 47]. Improvements of HRV caused by additional physical effort have been shown mainly in physical training programs with medium or vigorous intensity [48–50]. Additional weekly metabolic efforts around 1000 METmin at low intensity level (walking) have also demonstrated positive changes in HRV [51]. Since additional standing (caused by occupational sitting time reduction) should lead to the same level of physical effort (assumption 20–30 % standing), any effect on HRV would be detectable. The 30 min breaks within the study protocol as well as nocturnal periods were used to compare HRV under bias reduced conditions. According to the HRV guideline [46], 24 h Holter monitoring measurements have been implemented. HRV will be analyzed using the software Kubios [52].

Controlling for outside of work physical activity and sedentary behavior

Physical activity and sedentary behavior are related to physiological and cognitive changes [53, 54]. To avoid bias these parameters have to be determined. The International Physical Activity Questionnaire (IPAQ) has been shown to be reliable and valid for estimating physical activity and sitting time without any further measuring device [55–57]. The long version of this questionnaire (IPAQ-long) additionally enables it to distinguish between occupational and non-occupational activity. To adjust for outside of work sedentary behavior and/or physical activities, the IPAQ-long was interview administered at the beginning of each laboratory measurement day.

Body movements

Body movements can alter physiological parameters and cognitive performance [28, 58]. Especially small movements during longer time intervals are very hard to classify my means of personal observations. Therefore, a three-dimensional accelerometer – placed on the sternum via a neoprene breast belt – was used to objectively measure body movements. Upper body placements of accelerometers have been shown to reliably detect body movements, and sit-to-stand as well as stand-to-sit transitions [59, 60]. To reduce the total number of sensors, a HRV-recorder with integrated 3D-accelerometer was used (model: medilog AR12 plus, Schiller AG, Baar, Switzerland).

Measurement protocols

To test the study hypotheses, several parameters were defined and/or measured under standardized (laboratory measurements) and real life (field measurements) conditions (Table 1). Whereas body postures as well as postural changes were collected continuously during the 23-week intervention period, all further parameters were selectively measured before and after the intervention. To guarantee similar test sequences for each participant, a study protocol for laboratory measurements was developed (Fig. 3), consisting of three phases collecting physiological and cognitive parameters.

In the first (initial) phase, participants were familiarized with the study protocol. Sitting time and weekly physical activity were determined via the IPAQ-questionnaire. Examples of each cognitive test implemented in the cognitive phase were executed according to their guidelines [39]. A 30 min break in a sitting posture was used to ascertain baseline heart-rate and cortisol level. Baseline heart-rate was calculated after a 20 min rest for a 5 min interval and saliva samples were collected at the end (30 min) of the break.

In the second (cognitive) phase subjects participated in a test battery containing five blocks. Each block consisted of a working speed test (text editing task), an attentional test (d2R-test of attention) and a reaction time test (Stroop-test). These tests lasted for 30 min to fulfill recommendations regarding postural changes [24]. To simulate "common" working conditions (computer based and non-computer based tasks), digital

Table 1 Parameters measured within the ACTIVE OFFICE study

Measurement			Location		Data points	Sampling rate
Parameter	Method	Performed by	Laboratory	Office	d^{-1} (overall)	s^{-1}
Physiological						
Sitting time	IPAQ-long	questionnaire - interview	x		1 (4)	n.a.[d]
Physical activity	IPAQ-long	questionnaire - interview	x		1 (4)	n.a.[d]
Mental workload	NASA-TLX	questionnaire	x		1 (4)	n.a.[d]
Salivary cortisol	saliva collection	Salivette + cortisol ELISA	x[a]		8 (32)	n.a.[d]
Heart-rate	ECG	ECG recorder	x[b]		n.a.[c]	250
Body movements	acceleration	ECG recorder	x[b]		n.a.[c]	250
Cognitive						
Working speed	text editing task	computer software (matlab)	x		5 (20)	>1000
Reaction time	Stroop-test	computer software (matlab)	x		5 (20)	>1000
Attention	d2R-test	test sheet	x		5 (20)	n.a.[d]
Office based						
Body postures	logging tool	computer software (C#)		x	n.a.[c]	>1000
Postural changes	logging tool	computer software (C#)		x	n.a.[c]	>1000

[a]Seven measurements in the laboratory followed by one measurement at home on the following morning
[b]Measurement starts in the laboratory and ends at home on the following morning
[c]Data points depending on duration of measurement
[d]Non-digital measuring method (pen & paper)

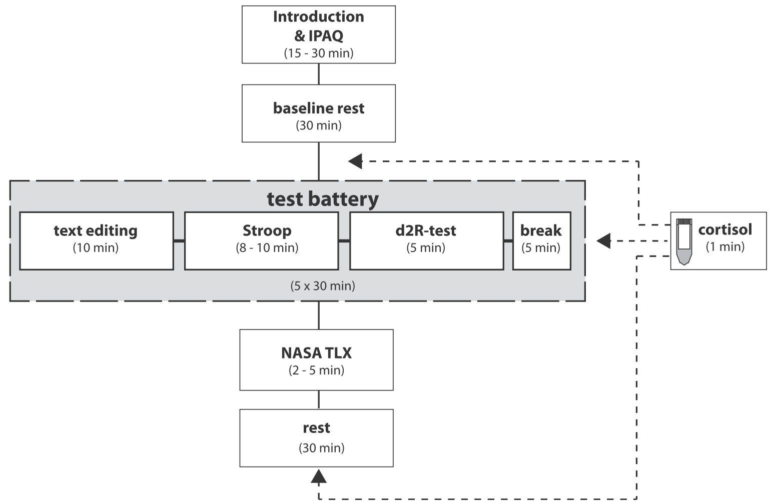

Fig. 3 ACTIVE OFFICE study protocol (laboratory measurement)

(text editing task, Stroop-test) as well as pen & paper (d2R-test) versions of the implemented tests were used. All blocks were executed in alternating postures (sit – stand – sit – stand – sit) and at the end of each block – after a 5 min break – salivary samples were collected. The order of posture was not changed within groups or time.

In the third (final) phase participants were asked to estimate their workload by means of the NASA-TLX questionnaire followed by a 30 min resting phase in a sitting posture. During both 30 min resting phases (initial & final) participants watched documentaries and were encouraged not to talk.

Salivary samples were collected after each break during the study protocol and on the following morning, 20 min after waking up, to ascertain cortisol awakening response (CAR). Salivary samples were centrifuged and stored at -80 °C for subsequent testing using a chemiluminescent immunoassay.

Heart-rate was measured from the start of the study protocol until the CAR measurement.

Statistical analysis

Statistical analyses will be conducted using SPSS version 21 for windows (SPSS, Chicago, IL). Standard statistical methods will be used for calculations for means and standard deviations. Pre- and post- intervention differences will be calculated for sitting time and physical parameters. Paired t-tests will be used to show differences between pre- and post- conditions when the normality condition is satisfied. If not, Mann-Whitney-U tests will be used for pre-post comparison. For cognitive parameters, ANOVA with repeated measures will be used to test whether the different conditions have any effects on the outcome parameters assessed. To reduce learning effects the first block of the test-battery will be ruled out for analysis. When appropriate, post-hoc analyses will be conducted. The effects of time, group and interaction between both variables will be evaluated. To test for normality and homogeneity of variance, Shapiro-Wilk-test and Levene-test will be used, respectively. In general, two-sided tests with an alpha risk of 0.05 and a beta risk of 0.2 are to be accepted.

Discussion

The ACTIVE OFFICE study evaluates the effects of a novel two desk sit-to-stand workplace on occupational sitting time for healthy office workers. Secondary and tertiary outcomes will deliver insights in physiological and performance-related changes. To our knowledge, a workplace intervention consisting of two equally furnished height-adjustable desks has not been investigated to date.

This study design and approach has several strengths, including the randomized controlled trial design, statistical power analysis, strong inclusion criteria, identical environmental measurement conditions and objective assessment of the primary outcome based on a pilot study.

The study includes recruitment of several different companies to convey a greater pool of people with ergonomic ideas and provide insights into typical Austrian office workplaces. The resulting multisite bias has been reduced by a randomization stratum. The study's inclusion criteria support a homogeneous collective and will fortify findings. The robust nature of this study design is expected to provide insights into benefits of a two desk sit-to-stand setup. These methods could be employed to study other specific sit-stand interventions or strategies in a robust way.

There are some noteworthy limitations of this study design. For example, as a result of the nature of the intervention it was not possible to blind subjects, although the researcher responsible for the statistical analyses will be blinded. Another limitation is the repeatability of the implemented cognitive tests. Although evaluations regarding short-term reliability have been executed [39, 61], the learning effect resulting from multiple repetition of the "d2R-test of attention" is unknown. Furthermore, as the implemented tests were evaluated in sitting postures only [39], the short-term effect of alternating postures on the performance (e.g. less performance caused by unfamiliar working posture) creates an additional bias. To reduce this bias, a short-term study implementing the ACTIVE OFFICE study protocol has been performed, but data have not yet been analyzed.

There are some additional limitations that are specific to the ACTIVE OFFICE study but these could be easily overcome for future studies. First, due to limitations of hardware input detection, worker idle time (e.g. reading a document or leaving the workstation for a break) could not be directly measured. Sophisticated algorithms can be used to determine whether gaps between hardware inputs should be classified as sitting or standing, but these are imperfect (e.g. 1 min idle time between two sitting periods leads to the conclusion that the subject was sitting the whole time period). Hence, proximity sensors are proposed to be used in future studies to identify associated working postures and idle times more precisely.

Second, the sample size for the ACTIVE OFFICE study is small, and thus statistical power might be limited. Researchers will be able to use the forthcoming results of the ACTIVE OFFICE study to determine appropriate sample sizes for future studies.

This study design is intended to quantify the short to mid-term benefits of using a sit-stand intervention device of strategy. As specified, the design cannot draw conclusions about the long-term sustainability of any measured differences in behavior or performance, nor any long-term health outcomes associated with the changes. Multi-year, prospective studies are needed to test the efficacy of sit-stand technologies, devices, and administrative strategies. Nevertheless, the study design described here provides a repeatable, minimally biased approach to determine what devices and/or strategies have the potential to alter worker behavior and provide positive health benefits.

If the ACTIVE OFFICE setup proves to be successful intervention, it has potential to be implemented in common workplaces. This is crucial since alternating postures as well as reduction in prolonged sitting can promote health benefits and prevent several diseases [16, 20, 43, 44]. Healthy individuals will likely also exhibit less absence time (increase in performance) which in turn leads to decreased health care system costs. If cognitive performance improvements can be shown, additional costs for a two desk setup will become more acceptable.

The methods used for the ACTIVE OFFICE study are generalizable and can serve as a common foundation upon which future studies can determine the potential efficacy of sit-stand devices and strategies. If future studies employ substantially similar methods, the results between studies would likely be directly comparable and this would help employers, practitioners, and future researchers to design appropriate sit-stand interventions.

Trial status

The recruitment for the "ACTIVE OFFICE" trials was initiated during August – September 2013. The baseline measurements and the post intervention measurements (23 weeks after baseline) were completed in September 2014 and April 2015, respectively. The study is currently at the stage of data analysis.

Acknowledgements

The authors thank all participants involved in this research as well as the Upper Austrian health insurance (*Oberoesterreichische Gebietskrankenkasse*) for allocating them. They further thank Joseph Gloeckl (*Aeris Impulsmöbel GmbH & Co. KG*) and Christian Ecker (*Schiller Medizintechnik GmbH*) for donating all height-adjustable desks and ECG-recorders used in this study. These companies had no role in the design, analysis or writing of this article.

Funding

This study is partly supported by the Austrian Research Promotion Agency (FFG, BRIDGE program, 834185, "ACTIVE OFFICE"). The funders had no role in the design, analysis or writing of this article.

Availability of data and materials

Data resulting from this study will be analyzed and published in the PIs' PhD-thesis and journal articles.

Authors' contributions

Corresponding and first author BS led the development of this manuscript. He contributed to the research design and collected and analyzed data. AS and MH initiated the project "ACTIVE OFFICE". KP developed the logging-software and was part of the ACTIVE OFFICE team. AB and AS contributed to the research design and played a major role in the study implementation. Authors AB and JK participated in the manuscript writing. All authors read and approved the final manuscript.

Authors' information

BS is a research associate at the University of Applied Sciences Upper Austria and a PhD-student at the University of Vienna. The study described in this article is part of his PhD-thesis.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

The study was conducted in accordance with the principles of the Helsinki Declaration and followed Austrian's best practice guidelines (Good Scientific

Practice). The protocol and all pertinent documents have been evaluated and approved by the *Ethics Committee of the University of Vienna (*Reference number: 00052*)*. Data confidentiality was guaranteed in accordance to the Austrian law governing the protection of personal data (*Bundesgesetz über den Schutz personenbezogener Daten (Datenschutzgesetz 2000 - DSG 2000), (165/1999 17 August)*). All study participants have given written consent to participate prior to involvement in the study.

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Received: 24 June 2016 Accepted: 7 July 2016
Published online: 15 July 2016

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Ergonomics

ISSN: 0014-0139 (Print) 1366-5847 (Online) Journal homepage: http://www.tandfonline.com/loi/terg20

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To cite this article: Bernhard Schwartz, Jay M. Kapellusch, Andreas Schrempf, Kathrin Probst, Michael Haller & Arnold Baca (2018) Effect of alternating postures on cognitive performance for healthy people performing sedentary work, Ergonomics, 61:6, 778-795, DOI: 10.1080/00140139.2017.1417642

To link to this article: https://doi.org/10.1080/00140139.2017.1417642

Accepted author version posted online: 13 Dec 2017.
Published online: 28 Dec 2017.

ERGONOMICS, 2018
VOL. 61, NO. 6, 778–795
https://doi.org/10.1080/00140139.2017.1417642

Effect of alternating postures on cognitive performance for healthy people performing sedentary work

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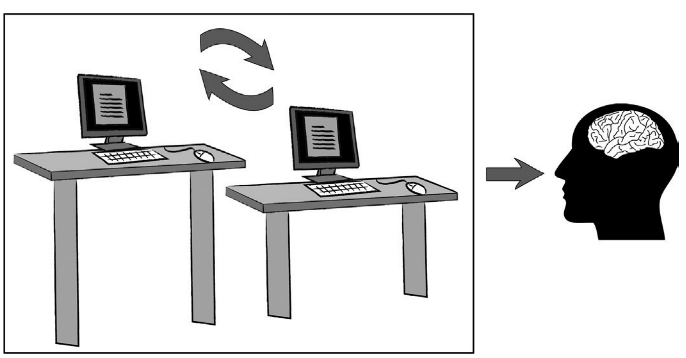
ABSTRACT
Prolonged sitting is a risk factor for several diseases and the prevalence of worksite-based interventions such as sit-to-stand workstations is increasing. Although their impact on sedentary behaviour has been regularly investigated, the effect of working in alternating body postures on cognitive performance is unclear. To address this uncertainty, 45 students participated in a two-arm, randomised controlled cross-over trial under laboratory conditions. Subjects executed validated cognitive tests (working speed, reaction time, concentration performance) either in sitting or alternating working postures on two separate days (ClinicalTrials.gov Identifier: NCT02863731). MANOVA results showed no significant difference in cognitive performance between trials executed in alternating, standing or sitting postures. Perceived workload did not differ between sitting and alternating days. Repeated measures ANOVA revealed significant learning effects regarding concentration performance and working speed for both days. These results suggest that working posture did not affect cognitive performance in the short term.

Practitioner Summary: Prior reports indicated health-related benefits based on alternated (sit/stand) body postures. Nevertheless, their effect on cognitive performance is unknown. This randomised controlled trial showed that working in alternating body postures did not influence reaction time, concentration performance, working speed or workload perception in the short term.



ARTICLE HISTORY
Received 4 May 2017
Accepted 8 December 2017

KEYWORDS
Alternating body postures; cognitive performance; sit-to-stand workstation; randomised controlled trial

Introduction

Over the last few decades, novel transport systems, technical aids and ubiquitous digitalisation have shifted populations from physically intensive jobs into computer-based jobs. This shift in work has reduced occupational physical activity and indirectly promoted prolonged sitting periods (Biddle et al. 2010; Church et al. 2011). The resulting increase in sedentary time has shown association with increased physical health problems (Brown, Miller, and Miller 2003; Gierach et al. 2009; Lis et al. 2007; Patel et al. 2006; Peeters, Burton, and Brown 2013; van der Ploeg 2012). Some of these health problems can be mitigated by

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regular breaks from sitting (Healy et al. 2008, 2011; Peddie et al. 2013) and/or interventions such as sit-to-stand workstations (Carr et al. 2013; Healy et al. 2013; Koepp et al. 2013; Neuhaus et al. 2014).

Recently, an increasing number of occupational performance-related studies have investigated the effects of sit-to-stand workstations (Russell et al. 2015; Straker et al. 2013); active workstations (Commissaris et al. 2014; Koren, Pišot, and Šimunič 2016; Ohlinger et al. 2011); or physical activity interventions (Conn et al. 2009) on cognitive performance. Commissaris et al. (2014) reported a small performance decrease in highly precise mouse-related tasks when standing; however, reading and cognitive tasks were not affected. These findings are consistent with other studies that found no significant difference in cognitive tasks when directly comparing sitting to standing (Russell et al. 2015; Straker, Levine, and Campbell 2009). Similarly, for active workstations, a decrease in motor skill-related parameters has been shown (Commissaris et al. 2014; Koren, Pišot, and Šimunič 2016; Ohlinger et al. 2011; Straker, Levine, and Campbell 2009), while cognitive parameters such as selective attention, working memory and working speed were not affected (Commissaris et al. 2014; Koren, Pišot, and Šimunič 2016; Ohlinger et al. 2011). It should be noted that there are some indications that the intensity level of physical activity is decisive for alterations of cognitive performance (Koren, Pišot, and Šimunič 2016; Straker, Levine, and Campbell 2009) and that office layouts influence workload (De Croon et al. 2005).

From physiologic and neurophysiologic perspectives, there are several mechanisms that could plausibly improve cognitive performance when using active or sit-to-stand workstations. For example, physical activities such as walking, cycling and standing are known to influence cognitive performance (Hillman, Kamijo, and Scudder 2011; Loprinzi et al. 2013; Rasberry et al. 2011; Ratey and Loehr 2011), and improve executive functions (Colcombe and Kramer 2003; Loprinzi et al. 2013; Ratey and Loehr 2011) due to higher prefrontal cortex activities (Budde et al. 2008; Loprinzi et al. 2013; Ratey and Loehr 2011). Short bouts of physical activity can also increase alpha activity in the precuneus which may increase concentration (Hillman, Kamijo, and Scudder 2011). Regular physical activity results in greater cortical volumes in the frontal, temporal and parietal lobes (Loprinzi et al. 2013) and the hypothalamus (Loprinzi et al. 2013; Ratey and Loehr 2011), which may contribute to improvements in attention and memory (Loprinzi et al. 2013). Further improvements in cognitive performance may be facilitated by reduced latency of neural activity due to the greater cardio-respiratory fitness and higher cerebral blood volumes resulting from long-term physical activity (Loprinzi et al. 2013; Ratey and Loehr 2011).

Conversely, there are also mechanisms that could plausibly decrease cognitive performance. For example, increased need for balance control results in competition for neuronal resources (Barra et al. 2015) between physical and cognitive tasks (e.g. computer work during walking) being performed in parallel. If the combination of both tasks becomes too difficult, an attention overload could be induced leading to a performance decrement in both tasks (Barra et al. 2015; Koren, Pišot, and Šimunič 2016). It should be noted, however, that body postures requiring enhanced balance difficulty (e.g. standing, walking) can induce physical modifications (e.g. increment on brain oxygenation) that provoke higher alert states that may positively impact cognitive performance (Barra et al. 2015).

A deleterious mechanism on cognitive performance is low-back and/or leg pain – an often occurring parameter in office environments. The primary function of pain is to disrupt attention and to impose behavioural priority (Attridge et al. 2015; Moore, Eccleston, and Keogh 2017). Thus, pain will typically override all cognitive demands and reduce cognitive performance (Moore, Eccleston, and Keogh 2017).

In summary, the positive effects of sit-to-stand workstations on physical health are well documented (Healy et al. 2008; Peddie et al. 2013). Similarly, the cognitive performance aspects of dedicated standing or sitting postures have been studied (Russell et al. 2015). By comparison, the effects of sit-to-stand transitions on cognitive performance have not been well investigated and the cognitive performance effects (positive or negative) of working in alternating postures remain unclear. Therefore, the primary aim of this study was to investigate the effects of alternating postures (sit-to-stand transitions) on cognitive performance and workload under controlled laboratory conditions. Based on the pathway mechanisms between physical activity, postural control, pain, workload and cognitive performance, we hypothesised that positive effects induced by working in alternating postures (higher physical activity, less pain development, higher alertness) would outweigh negative effects (working in uncommon postures, higher balance control) resulting in a net positive increase in cognitive performance and workload.

Methods

Participants

Participants were recruited via email and postings at the University of Applied Sciences Upper Austria and were screened by the study leader (BS) to determine their current health status. The study protocol and procedures were explained verbally.

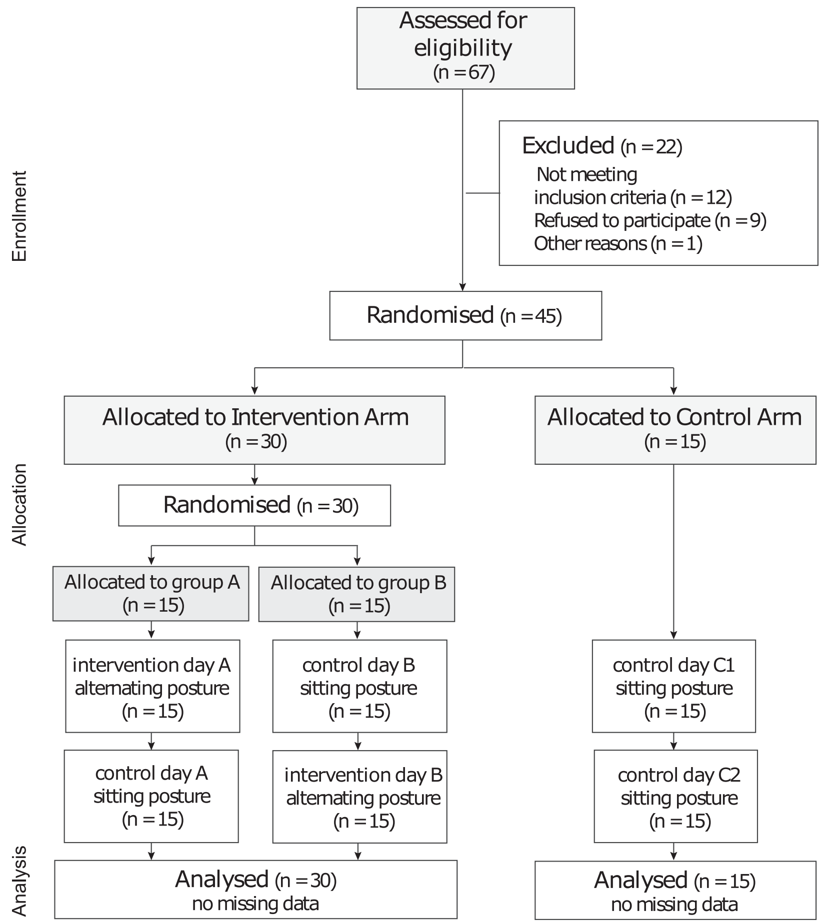

Figure 1. Allocation flow chart.

A total of 45 students between 20 and 32 years of age participated in this study (Figure 1) between January 2014 and March 2015. Participants were free of acute and chronic diseases, had at least a high school education, were used to computer work and were working in a sitting posture at their jobs at the time the study commenced.

This study was approved by the Ethics Committee of the University of Vienna (Reference number: 00052) and retrospectively registered (ClinicalTrials.gov Identifier: NCT02863731, July 2016). All study participants provided written, informed consent to participate prior to involvement in the study. Demographic information including age, sex, weekly sitting hours and physical activity was collected from each participant by questionnaire (Table 1).

Study design

After baseline assessment, a two-step covariate adaptive randomisation (Kang, Ragan, and Park 2008) process was executed. On the first level, participants were randomly allocated to either the intervention or the control (no intervention) arm (2:1 ratio, two-arm design see Figure 1) while on a second level, intervention participants were assigned to either the first (group A, intervention first) or the second (group B, control first) intervention group (1:1 ratio). Participants were blinded to the presence of multiple intervention groups and to their own group allocation, but were not blind to their treatments (i.e. they knew on which day they would execute the study protocol in sitting or alternating postures).

Participants underwent two, one-day assessments under laboratory conditions. Both assessment days were executed individually (one participant per day) in the same laboratory. The second assessment day was executed exactly 7 days after the first one (i.e. if the first assessment day was on Monday, the second one was on the following Monday). To avoid furniture shifts within the room (e.g. by the room cleaning service), the position of each desk was permanently marked on the laboratory floor. Temperature, humidity and air movement within the room were controlled. Participants were asked to refrain from exercise, caffeine and alcohol, and undue stress for 24 h prior to assessment day. To avoid fluctuations on performance due to time-of-day, all assessment days started between 1:30 pm and 2:45 pm.

Study protocol

The study protocol (Figure 2) – based on the one proposed by Schwartz and colleagues (Schwartz et al. 2016) – comprised of a preparation phase, followed by five repeated trials of a test battery (described below) that assessed: reaction time [digital Stroop test, (Stroop 1935)], working speed (text editing task, self-developed see Appendix 1) and attention [d2R-test of attention, (Brickenkamp, Schmidt-Atzert, and Liepmann 2010)]. The measurement day concluded with a closing questionnaire.

In the preparation phase, sitting time and physical activity were determined via the long version of the International Physical Activity Questionnaire [IPAQ-long, (Craig et al. 2003)]. The questionnaire was interview-administered to avoid missing values, and used to estimate the potential bias caused by between-subject differences in physical activity and sedentary time. The IPAQ-long has exhibited high validity and reliability in several countries (Craig et al. 2003).

The closing questionnaire was used to estimate each subject's workload by means of the NASA-TLX questionnaire (Hart, California, and Staveland 1988). For simplicity and unmodified sensitivity (Hart 2006), the short version of this questionnaire (RTLX) – consisting of six major items – was used. Influences on workload perception based on unweighted items in the RTLX were negated due to the cross-over design. To avoid missing values and to achieve a common understanding of every question, all questionnaires were interview-administered by the study leader (BS).

Participants were provided with a 30 min break, in a sitting posture, between the preparation phase and battery trials. This break was used to provide non-stressful baseline conditions for each participant.

Test battery

The battery consisted of three different tests determining working speed, reaction time and concentration performance (Figure 2). The target duration for each battery was approximately 30 min in order to fulfil recommendations regarding postural change frequency (Neuhaus et al. 2014). During each battery, subjects either stood or sat upright in an European Standard EN ISO 1335

Table 1. Participants' socio-demographic and health characteristics.

	Intervention arm ($n = 30$)	Control arm ($n = 15$)	All ($n = 45$)	p
Age (years)	25.3 (3.8)	25.5 (2.2)	25.4 (3.3)	0.805
Women	46.7% (14)	46.7% (7)	46.7% (21)	1.000
Caucasian	100.0% (30)	100.0% (15)	100.0% (45)	1.000
Bachelor's degree completed	26.7% (8)	73.3% (11)	42.2% (19)	0.003
Body mass index, kg/m^2	22.6 (2.0)	22.1 (1.5)	22.4 (1.9)	0.373
Left handed	10.0% (3)	26.7% (4)	15.6% (7)	0.158
Smoking habits				
Smoker	3.3% (1)	20.0% (3)	8.9% (4)	0.073
Chipper (<1 cigarette/day)	16.7% (5)	20.0% (3)	17.8% (8)	0.784
Stopped <3 years ago	6.7% (2)	20.0% (3)	11.1% (5)	0.194
Stopped ≥3 years ago	10.0 % (3)	6.7% (1)	8.9% (4)	0.705
Never smoker	63.3% (19)	33.3% (5)	53.3% (24)	0.056
Sitting time (min)				
Occupational day	679 (163)	657 (177)	660 (159)	0.261
Weekend	516 (162)	525 (191)	518 (152)	0.905
Overall	4424 (936)	4332 (1083)	4333 (912)	0.348
Physical acitivity (METmin wk^{-1})				
Work	0 [0, 2466]	0 [0, 10194]	0 [0, 10194]	0.990
Transport	0 [0, 1911]	537 [0, 2700]	396 [0, 2700]	0.158
Domestic	150 [0, 1740]	180 [0, 765]	170 [0, 1740]	0.961
Leisure	2544 [0, 6720]	1455 [0, 4400]	2040 [0, 6720]	0.054
Overall	3752 (163)	3859 (1811)	3621 (2145)	0.569

Note: Table represents means (SD), median [min, max] or % (*n*).

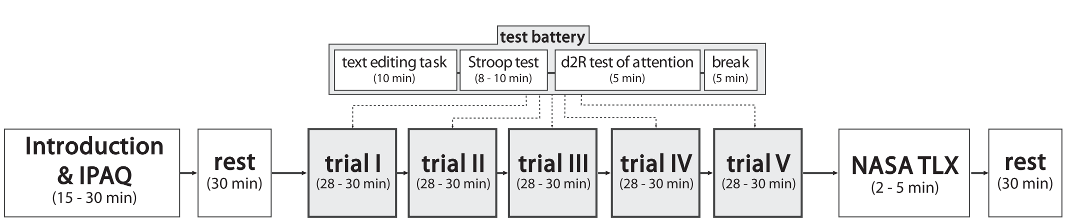

Figure 2. Adapted study protocol based on Schwartz et al. (2016).

(International Organization for Standardization 2010) compliant office chair (Kastel Kolor, Kastel s.r.l.) as specified by the study protocol. Each cognitive test in the battery was executed using its validated procedures (Brickenkamp, Schmidt-Atzert, and Liepmann 2010). To encourage real-world and similar between-subject effort, subjects were encouraged to work as fast and as accurately as they could during each battery.

Working speed

Working speed was assessed by a digital text editing task (see example in Appendix 1). Subjects were provided with a text document where all spaces between words and sentences were removed (different text documents were used for each battery). The task required participants to manually insert spaces between letters such that words and grammatically correct sentences were created (e.g. 'ergonomic guideline' instead of 'ergonomicguideline'). The task was performed for 10 min. Words created determined working speed; errors were any misplaced spaces (e.g. 'ergonomicgui deline' instead of 'ergonomic guideline') or missing spaces (e.g. 'ergonomicguideline' instead of 'ergonomic guideline'). Working speed (words created per trial) and relative errors (%) were calculated and analysed after the last assessment day (see Appendix 1).

Reaction time

Reaction time – a commonly measured parameter to describe mental states, fatigue or performance in ergonomics research (Commissaris et al. 2014; Ohlinger et al. 2011; Russell et al. 2015) – was determined using the Stroop–Colour–Word–Conflict–Test (Van der Elst et al. 2006; MacLeod 2005; Mead et al. 2002). This test, first described by Ridley Stroop (Stroop 1935), encourages participants to name the text colour of 'color words' written in the same (e.g. BLUE written in blue letters, congruent task) or different colour (e.g. BLUE written in red letters, incongruent task). The test measures reaction time as well as selective attention, and exhibits a high test–retest reliability (Lemay et al. 2004; Penner et al. 2012). For this battery, a digital Stroop test containing 190 congruent, incongruent and neutral (i.e. four crosses 'XXXX' written in different colours) items was used. The duration of this test was a minimum of 8, but not longer than 10 min, depending on participant reaction times. A fixed 5-min break occurred between successive batteries regardless of how long the subject took to complete the Stroop test portion of the battery.

Concentration performance

Concentration performance was measured using the 'd2R test of attention'. This revised version of the original 'd2-test of attention' (Brickenkamp, Schmidt-Atzert, and Liepmann 2010) is a pen and paper-based test, consisting of 14 lines of 57 randomly assigned letters ('d' and 'p', surrounded by 1 to 4 dashes) and encourages participants to mark specific letters ('d' surrounded by 2 dashes). The overall duration of the d2R-test is 4 min and 40 s (20 s for each line). The test is commonly used in Europe (Duschek et al. 2009; Wassenberg et al. 2008) and requires only rudimentary language skills (Brickenkamp, Schmidt-Atzert, and Liepmann 2010). The d2R-test is characterised by a high test–retest reliability (r = 0.77–0.95, (Brickenkamp, Schmidt-Atzert, and Liepmann 2010; Franzen et al. 1987)).

Intervention

The study protocol contained five consecutive battery blocks, each lasting 28–30 min depending on the time required to complete the Stroop test (Figure 2). For the intervention arm, the battery blocks were executed in alternating postures (sit - stand - sit - stand - sit) either on the first or the second day of measurement, depending on the subject's group allocation (cross-over design). For control periods (i.e. non-intervention day), all five battery trials were conducted in a sitting posture (sit - sit - sit - sit - sit). For the control arm, both days of measurement were conducted in a sitting posture only (sit - sit - sit - sit - sit).

Workstation design and experimental set-up

The experimental workplace used in this study was installed in a laboratory room at the University of Applied Sciences Upper Austria and consisted of two height-adjustable desks mounted next to each other (Figure 3). To ensure equal conditions, every desk was furnished with the same amount and type of mice, keyboards and screens. Temperature, air flow, humidity, lighting conditions (artificial light only) and noise level were controlled and identical for both desks and between days. Prior to the measurements, working heights for the sitting and standing desks (screen and desk) as well as office chair and hardware properties (e.g. keyboard distances, screen heights, screen angles) were adjusted by the study leader according to ergonomic recommendations (e.g. elbow height for the desks, screen heights for standing (15–45°) or sitting (20–50°) postures) while accommodating participants' personal preferences so long as those preferences did not markedly deviate from the aforementioned starting recommendations.

Data processing

To reduce learning effects biases for cognitive tests, the first tests within the first battery of each measuring day were excluded from statistical analysis. Reaction time and

Figure 3. Experimental workplace consisting of two equally furnished height-adjustable desks.

working speed were measured and recorded automatically using software. Results from the d2r-test were analysed and digitised manually by BS. During testing subjects would occasionally deviate from protocol (e.g. ask the investigator a question mid-test thereby missing their cue) and this would lead to false reaction times. To avoid biased means due to these inappropriately long reaction times, MATLAB (MathWorks, Inc) was programmed to mark outliers and remove all responses that were more than 3 standard deviations away from the subject's mean. In total, 1.4% of all reaction time trials (2.68 ± 1.35 items per trial per person – equally distributed between participants and ranging from 0 to 8 items per trial) were excluded during the automated outlier elimination procedure. Automated outlier removal was applied only to reaction time tests and thus text editing and d2R-trials were not altered.

Statistical analysis

SPSS version 23 for Microsoft Windows (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. Continuous variables were expressed by means and standard deviations or median and range for skewed variables. Multivariate analysis of variance (MANOVA) was performed to compare cognitive performance test scores by group. Additionally, when the normality condition was satisfied, repeated measures ANOVAs were used to estimate the learning effect caused by repetitions of the test batteries. Furthermore, one-way ANOVAs performing group comparisons were executed. When the assumption of sphericity was violated, the significance of F-ratios was adjusted according to the Greenhouse–Geisser procedure (Greenhouse and Geisser 1959). Friedman tests were used when normality conditions were not satisfied. Unpaired tests (normality: *t*-tests; violation of normality: Mann-Whitney-U tests) were used to show raw data differences between intervention and control conditions. Depending on normality, paired *t*-tests and Wilcoxon signed-rank tests were used to determine raw data differences between trials. To avoid alpha inflations, paired and unpaired tests were Bonferroni corrected. Normality and homogeneity of variance were estimated by Shapiro–Wilk tests and Levene tests, respectively. Common values of alpha and beta errors ($\alpha = 0.05$, $\beta = 0.20$) were accepted.

Results

Participants' characteristics

Table 1 shows participants' characteristics at baseline. There were no differences in ethnicity and gender between groups. In comparison to the intervention group, the control group exhibited more participants with a completed Bachelor's degree (73.3% vs. 26.7%, $p = 0.003$). Non-significant differences in smoking habits were also observed. Independent *t*-tests did not find any differences regarding age and body mass index (BMI) between groups.

Missing values

Outside of outlier removal described above, no data loss occurred during the study.

Performance (Alternating vs. Sitting)

MANOVA showed no statistically significant differences in working speed, concentration performance or reaction time between alternating sit/stand and sitting-only days (Wilk's $\Delta = 0.964$, $F(6,170) = 0.530$, $p = 0.785$, partial $\eta^2 = 0.018$).

When comparing the intervention arm to the control arm, one-way ANOVA and Kruskal–Wallis tests (Table 2) demonstrated no significant differences for any performance-related parameters ($p > 0.05$), except perceived workload ($F(2,87) = 4.417$, $p = 0.015$, partial $\eta^2 = 0.092$). Post hoc independent *t*-tests showed that workload differed between the control arm and the intervention arm sitting period ($p = 0.011$).

Repeated measures ANOVA for workload perception on a daily basis (Figure 4) showed significant differences regarding time ($F(1, 42) = 9.903$, $p = 0.003$, partial $\eta^2 = 0.191$), and the interaction between time and group ($F(2,42) = 5.710$, $p = 0.006$, $\eta^2 = 0.214$) but narrowly did not reach significance for group ($F(2,42) = 3.031$, $p = 0.059$, $\eta^2 = 0.126$).

Table 2. Cognitive performance comparison: intervention (alternating and sitting postures) and control group (sitting posture) on a daily basis (battery II to battery V).

	Intervention arm				Control arm	Group comparison	
	Alternating ($n = 30$)	Sit ($n = 30$)	Sit-alternating		Sit ($n = 30$)	F(2,87)	
	Mean (SD)	Mean (SD)			Mean (SD)		
Measure	Median [min, max]	Median [min, max]	Mean (95% CI)	*p*	Median [min, max]	$\chi^2(2, N = 90)$	*p*
Text editing task							
Working speed (words)	367.7 (49.6)	367.3 (55.5)	−0.4 (−27.5, 26.8)	0.979	363.0 (47.2)	0.081	0.922
Errors (%)	1.66 [0.07, 4.66]	1.44 [0.23, 7.29]	–	1.000	1.28 [0.00, 2.35]	2.174	0.337
Stroop test							
Reaction time (ms)	727.3 (104.9)	732.2 (105.1)	4.8 (−49.2, 58.8)	0.859	753.6 (90.3)	0.585	0.559
Errors (%)	1.23 [0.13, 4.33]	1.23 [0.13, 5.35]	–	0.496	0.91 [0.13, 5.22]	3.974	0.137
d2R test							
Concentration performance (a.u.)	216.2 (34.1)	219.0 (44.3)	2.7 (−17.7, 23.2)	0.790	222.9 (50.8)	0.177	0.838
Errors (%)	2.50 [0.00, 21.60]	1.78 [0.16, 17.77]	–	0.745	1.84 [0.08, 5.75]	1.883	0.390
NASA TLX							
Workload (a.u.)	42.0 (12.8)	46.9 (11.7)	4.9 (−1.5, 11.2)	0.130	37.0 (14.1)	4.417	0.015

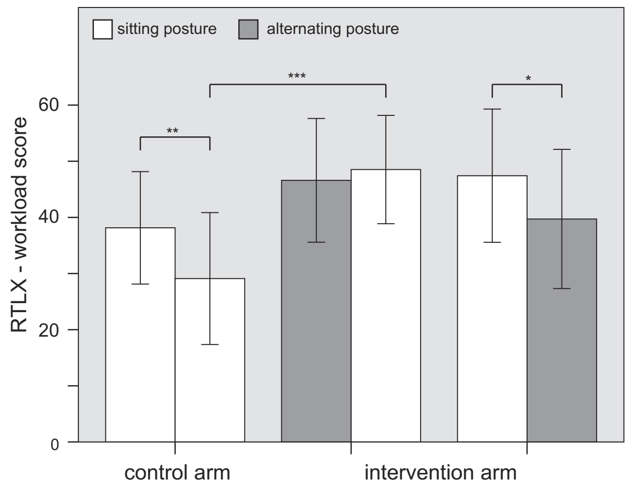

Figure 4. Workload perception on a daily basis.
Note: Asterisks representing significant differences – $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 3. Repeated measures ANOVA results for cognitive tasks (battery II to battery V).

	Time		Group		Time × group	
Measure	p	η^2	p	η^2	p	η^2
Working speed (words)	0.000	0.175	0.922	0.002	0.766	0.013
Reaction time (ms)	0.095	0.025	0.585	0.013	0.323	0.026
Concentration performance (a.u.)	0.000	0.311	0.838	0.004	0.181	0.034

Battery performance

Repeated measures ANOVA (Table 3) showed a significant difference in time (i.e. differences between the batteries) for working speed ($F(2.217, 192.905) = 18.418$, $p = 0.000$, partial $\eta^2 = 0.175$) and concentration performance ($F(2.505, 217.966) = 39.252$, $p = 0.000$, partial $\eta^2 = 0.311$), but not for reaction time ($F(2.636, 229.347) = 2.219$, $p = 0.095$, partial $\eta^2 = 0.025$). Furthermore, there were no significant differences for group and the interaction of group and time ($p > 0.05$).

Non-parametric Friedman tests of differences among repeated measures exhibited significant differences in text editing accuracy ($\chi^2 = 38.757$, $p = 0.000$), but not for Stroop ($\chi^2 = 2.980$, $p = 0.395$) and d2R-test ($\chi^2 = 2.708$, $p = 0.439$) accuracy.

One-way ANOVA did not demonstrate any significant group difference ($p > 0.05$) for working speed, reaction time or concentration performance (Table 4). Similarly, accuracy did not differ between groups (Friedman, $p > 0.05$).

Repeated measures analyses showed within-measurement day time dependencies (i.e. battery dependence) for several variables. For working speed, pairwise tests comparing the second battery to subsequent batteries showed significant differences for the third battery ($p < 0.0028$), in both the intervention and control arms (Table 4). Reaction time was statistically shorter for the fourth battery of the alternating day in the control arm. No further reaction time differences were observed (Table 4). Concentration performance differed between the second and all following batteries for the control arm and the alternating day of the intervention arm ($p < 0.003$). For the intervention arm's control day this statistical difference was observed only for the fourth battery (Table 4).

Text editing accuracy decreased significantly for the intervention arm, during the fourth (alternating day only) and fifth battery tests (Table 5), as compared to the second battery test. No battery-dependent changes in accuracy were observed for the Stroop and d2R-tests, nor for the any tests in the control arm (Table 5).

Performance (sit vs. stand)

MANOVA showed no significant difference between standing and sitting trials (Wilk's $\Delta = 0.958$, $F(6,170) = 0.616$, $p = 0.717$, partial $\eta^2 = 0.021$) for working speed, concentration performance or reaction time. Furthermore, paired tests did not demonstrate any difference in any cognitive parameter (Table 6).

Discussion

To our knowledge, this study represents the first randomised controlled trial examining the effect of alternating sit–stand postures on cognitive performance and workload. Contrary to our hypothesis, we found no significant difference in cognitive performance when comparing alternating sit-to-stand and sitting-only working strategies (Table 2). Neither were differences observed between standing and sitting performance for the alternating sit-to-stand approach (Table 6). These results are consistent with prior findings suggesting no cognitive performance or productivity affect from sitting vs. standing (Bantoft et al. 2015; Russell et al. 2015; Straker, Levine, and Campbell 2009) nor from alternating postures (Karakolis, Barrett, and Callaghan 2016).

Performance outcome

This study did not find a significant performance difference between alternating sitting–standing and sitting-only, a finding that is broadly similar to those of prior studies (Karakolis, Barrett, and Callaghan 2016; Russell et al. 2015). Text editing speed and errors, reaction time and concentration performance were all statistically comparable when standing vs. when sitting. However, contrary to our expectations, we found very small effect sizes (Cohen's d: 0.007–0.057) as compared to prior studies of cognitive parameters such as mouse dexterity (Commissaris et al.

Table 4. Battery-based working speed, reaction time and concentration performance: intervention (alternating and sitting postures) and control group (sitting posture) comparison.

	Intervention arm				Control arm		
	Alternating ($n=30$)	Sit ($n=30$)			($n=30$)	Group comparison	
	Mean (SD)	Mean (SD)	Sit-alternating		Mean (SD)	F(2,87)	
Measure	Median [min, max]	Median [min, max]	Mean (95% CI)	*p*	Median [min, max]	$\chi^2(2, N=90)$	*p*
Working speed (words)							
Battery I – pilot run	331.3 (48.5)	335.6 (58.8)	4.4 (−23.5, 32.2)	0.755	334.1 (40.5)	–	–
Battery II	361.0 (50.7)	360.5 (60.3)	−0.5 (−29.3, 28.3)	0.972	356.6 (48.3)	0.062	0.940
Battery III	373.3 (50.3)***	377.0 (57.4)**	3.7 (−24.2, 31.6)	0.790	371.4 (48.4)**	0.090	0.914
Battery IV	369.9 (51.7)	365.1 (52.0)	−4.8 (−31.6, 22.0)	0.721	362.1 (50.6)	0.174	0.841
Battery V	366.5 (50.2)	366.7 (56.9)	0.1 (−27.6, 27.9)	0.992	361.6 (47.3)	0.093	0.912
Reaction time (ms)							
Battery I – pilot run	774.2 (113.7)	781.5 (139.3)	7.3 (−58.4, 73.0)	0.292	764.2 [605.8, 1089.7]	–	–
Battery II	728.1 (103.2)	731.5 (103.6)	3.4 (−50.0, 56.9)	0.899	737.3 [584.1, 1020.8]	0.870	0.647
Battery III	737.2 (117.3)	738.3 (118.9)	1.1 (−60.0, 62.1)	0.972	748.6 [577.9, 1025.1]	0.818	0.664
Battery IV	712.1 (102.4)**	730.0 (111.3)	18.0 (−37.3, 73.2)	0.518	750.4 [599.2, 978.5]	2.476	0.290
Battery V	732.0 (106.7)	728.8 (98.8)	3.2 (−56.3, 50.0)	0.906	747.8 [591.6, 930.9]	1.072	0.585
Concentration performance (a.u.)							
Battery I – pilot run	186.8 (39.2)	188.0 (50.6)	1.3 (−22.1, 24.7)	0.914	193.8 (50.4)	–	–
Battery II	207.4 (34.8)	213.9 (46.2)	6.6 (−14.6, 27.7)	0.536	213.2 (52.8)	0.191	0.826
Battery III	215.3 (35.3)**	218.9 (46.5)	3.6 (−17.7, 24.9)	0.737	223.8 (50.1)***	0.279	0.757
Battery IV	221.3 (34.1)***	221.8 (42.8)*	0.5 (−19.5, 20.5)	0.960	226.4 (50.3)***	0.129	0.879
Battery V	220.9 (35.8)***	221.2 (44.3)	0.3 (−20.5, 21.1)	0.980	228.0 (51.6)***	0.249	0.780

Notes: Pilot runs were not part of the statistical analysis.
*$p < 0.05$ for between-battery change as compared to battery II (paired test, Bonferroni corrected); **$p < 0.01$ for between-battery change as compared to battery II (paired test, Bonferroni corrected); ***$p < 0.001$ for between-battery change as compared to battery II (paired test, Bonferroni corrected).

Table 5. Individual battery accuracy rates: intervention (alternating and sitting postures) and control group (sitting posture) comparison.

	Intervention arm			Control arm		
	Alternating ($n=30$)	Sit ($n=30$)		Sit ($n=30$)		
	Mean (SD)	Mean (SD)	Sit-alternating	Mean (SD)	Group comparison	
Measure	Median [min, max]	Median [min, max]	*p*	Median [min, max]	$\chi^2(2, N=90)$	*p*
Text editing task – errors (%)						
Battery I – pilot run	1.64 [0.00, 7.42]	1.40 [0.00, 5.24]	–	1.25 [0.00, 4.17]	–	–
Battery II	0.97 [0.00, 5.03]	1.20 [0.00, 5.24]	0.446	1.09 [0.00, 3.18]	1.620	0.445
Battery III	0.85 [0.00, 4.00]	0.95 [0.21, 8.13]	0.425	0.93 [0.00, 2.94]	0.668	0.716
Battery IV	1.83 [0.00, 5.36]*	1.26 [0.00, 8.70]	0.767	1.35 [0.00, 2.79]	0.665	0.717
Battery V	2.08 [0.00, 5.43]**	1.73 [0.00, 7.08]*	0.564	1.20 [0.00, 4.42]	4.209	0.122
Stroop test – errors (%)						
Battery I – pilot run	1.04 [0.00, 7.77]	1.04 [0.00, 9.52]	–	1.04 [0.00, 5.00]	–	–
Battery II	1.30 [0.00, 8.65]	1.55 [0.00, 6.40]	0.366	0.52 [0.00, 7.32]	4.824	0.090
Battery III	1.04 [0.00, 5.47]	1.04 [0.00, 4.52]	0.862	0.78 [0.00, 4.52]	0.665	0.717
Battery IV	1.04 [0.00, 5.00]	1.04 [0.00, 5.00]	0.560	1.04 [0.00, 5.00]	0.620	0.620
Battery V	1.30 [0.00, 4.52]	1.55 [0.00, 5.47]	0.586	0.78 [0.00, 5.00]	0.104	0.104
d2R test – errors (%)						
Battery I – pilot run	2.56 [0.00, 29.15]	2.77 [0.00, 27.78]	–	2.48 [0.00, 8.67]	–	–
Battery II	1.47 [0.00, 19.45]	2.09 [0.00, 18.14]	0.505	1.91 [0.00, 7.88]	0.728	0.695
Battery III	1.78 [0.00, 17.73]	1.74 [0.00, 25.00]	0.923	1.37 [0.00, 6.30]	1.074	0.585
Battery IV	1.75 [0.00, 16.33]	2.32 [0.00, 22.13]	0.859	1.36 [0.00, 6.42]	2.596	0.273
Battery V	2.27 [0.00, 22.97]	2.23 [0.00, 23.28]	0.756	1.27 [0.00, 5.70]	4.694	0.096

Notes: Pilot runs were not part of the statistical analysis.
*$p < 0.05$ for between-battery change as compared to battery II (paired test, Bonferroni corrected); **$p < 0.01$ for between-battery change as compared to battery II (paired test, Bonferroni corrected).

2014; Ghesmaty Sangachin, Gustafson, and Cavuoto 2016), typing performance (Funk et al. 2012) and typing speed (Straker, Levine, and Campbell 2009), all of which had strong effect sizes (Cohen's d > 1.2). This small effect size limited our statistical power to 0.06 and this alone might explain the negative findings.

Prior studies in occupational environments where physical activity during work (e.g. walking or cycling) is present have shown negative influences on motor tasks such as mouse dexterity (Commissaris et al. 2014; John et al. 2009; Straker, Levine, and Campbell 2009) and typing (Commissaris et al. 2014; John et al. 2009; Ohlinger et al. 2011). Physical activity intensity for standing is higher compared to sitting (Júdice et al. 2016; Levine and Miller 2007); however, it is considerably smaller than the intensity of slowly walking or cycling (Ainsworth et al. 2000).

Table 6. Cognitive performance comparison: sitting vs. standing posture.

	Stand ($n = 30$)	Sit ($n = 30$)	Sit–stand	
	Mean (SD)	Mean (SD)		
Measure	Median [min, max]	Median [min, max]	Mean (95% CI)	p
Text editing task				
Working speed (words)	365.5 (50.4)	362.8 (55.7)	−2.7 (−30.1, 24.8)	0.847
Errors (%)	1.59 (0.00, 5.20)	1.42 (0.11, 6.97)	–	0.848
Stroop test				
Reaction time (ms)	720.0 (100.6)	730.7 (105.0)	10.7 (−42.5, 63.8)	0.689
Errors (%)	1.04 [0.00, 6.35]	1.17 [0.26, 5.7]	–	0.386
d2R test				
Concentration performance (a.u.)	214.4 (33.9)	217.8 (44.2)	3.5 (−16.8, 23.9)	0.729
Errors (%)	2.52 [0.00, 20.14]	1.78 [0.00, 17.89]	–	0.679

Notes: Standing values: mean of batteries II and IV from alternating day of intervention arm.
Sitting values: mean of batteries III and V from alternating day of intervention arm.

Thus, it is possible that standing alone does not have a meaningful effect on motor performance. Alternatively, it is possible that this study's sole test requiring specific motor movements (digital Stroop test) was simply unable to detect fine motor skill decrements that might have been occurring. Had we measured parameters such as higher (Ghesmaty Sangachin, Gustafson, and Cavuoto 2016) or lower (Commissaris et al. 2014) mouse reaction times, it is possible that a statistical difference in performance between sit and stand and sit-only would have been observed. However, the results of this study suggest that such a difference would likely be small and perhaps not practically affect work outcomes in 'real-world' situations.

Studies have shown that learning effects are a common problem for repeated measures of cognitive test batteries (Nuechterlein et al. 2008; Russell et al. 2015) and thus we dropped the first battery from all analyses. To determine if there were potentially further time-dependent differences, we compared batteries III, IV and V to battery II (see Table 4 and Table 5). As expected, reaction time (assessed with the digital Stroop test) improved from battery I to II and then stabilised for all remaining batteries. A statistically significant decrease in reaction time was identified for battery IV of the alternating side of the intervention arm; however, the actual reaction time difference between battery II and IV was 16.0 ms or about 2.2%, a value which is likely caused by minor non-significant reaction times differences (10.7 ms or about 1.5%) while standing (see Table 6).

Working speed improved by about 8% from battery I to battery II, and then further improved by about another 4% from battery II to battery III, after which speed modestly reduced and stabilised for batteries III and IV. Percentage of errors for text editing (i.e. working speed) similarly decreased into battery III and then began to increase again (though the increases were more modest and not statistically significant in the control arm). It seems likely that learning effects were continuing into the third battery and then subdued into the final batteries as mental fatigue began to play a role. In this regard, it is well known that monotonous and repetitive tasks can facilitate mental fatigue (Tanaka et al. 2012), which is related to a loss in performance (Barwick, Arnett, and Slobounov 2012; Zhao et al. 2012) and accuracy (Barwick, Arnett, and Slobounov 2012; Tanaka et al. 2012). Regardless, both arms of the study appeared to be affected by this phenomenon and thus it is unlikely to have biased the results.

Concentration time improved from battery I to II and then apparently continued to improve into the third or even fourth batteries (although this further improvement is only modestly significant for the control side of the intervention arm). Concentration was assessed using the d2R-test and studies have shown that multiple d2R repetitions can lead to high learning effects (Budde et al. 2008; Lufi, Tzischinsky, and Hadar 2011) and better pattern recognitions (Xue et al. 2010), which could result in performance increases, regardless of accruing mental fatigue. Again, both arms were affected by this phenomenon and thus this trend was unlikely to have biased results.

Workload perception

Workload represents the effort people expend to accomplish a task (Hart 2006) and is related to personal feelings (Warr 1990), mental fatigue (Hockey and Earle 2006; Rydstedt, Johansson, and Evans 1998), need for recovery (Sonnentag and Zijlstra 2006) and musculoskeletal disorder symptoms (Byström, Hanse, and Kjellberg 2004). In occupational environments, workload can be altered by self-determined working (Hockey and Earle 2006), office design (De Croon et al. 2005) and physical activities such as walking (Ghesmaty Sangachin, Gustafson, and Cavuoto 2016; John et al. 2009).

This study found no workload differences for people working in alternating postures. These findings are consistent with prior studies suggesting that neither relatively lower physical activity (Ohlinger et al. 2011; Russell et al. 2015) nor working in standing postures (Drury et al. 2008; Ghesmaty Sangachin, Gustafson, and Cavuoto 2016) have an effect on cognitive performance. One study by Hasegawa et al. (2001) suggested lower workloads occur when alternating body postures; however, that study relied on less rigorous measurement methods. One plausible explanation for the statistically equivalent between-posture workloads observed in this study is that the marginal increase of physical activity for standing or alternating postures (Ainsworth et al. 1993; Júdice et al. 2016) is not strong enough to induce the workload-related changes seen in prior studies that included walking (Ghesmaty Sangachin, Gustafson, and Cavuoto 2016; John et al. 2009).

Interestingly, while there were no apparent differences between sit and stand, there were significant differences between the intervention arm's control period and the control arm (Figure 4). We believe that there were variations in workload estimation between intervention and control arm participants due to the missing weighting procedure for the NASA-TLX questionnaire and time-dependent changes within the subgroups of the intervention arm. Although the cross-over design within the intervention arm negated the bias caused by these unweighted items, this bias still existed for the control arm and likely resulted in structurally different baseline values between the two control populations.

Furthermore, a significant decrease between the first and the second day of measurement for the control arm and the intervention arm's intervention period participants occurred. Conversely, the workload slightly increased for the intervention arm's control period. In our study, participants were recruited from several Austrian universities and were not compensated for their time. It is possible that volunteer bias led to participants being more familiar with and/or interested in working in alternative ways. In turn this may have resulted in a nocebo-effect – transferring negative expectations onto personal perception (Olshansky 2007; Vase, Skyt, and Hall 2016) – driven by the intervention group participants' expectations that returning to the non-novel sitting procedure would be more burdensome.

Lastly, the statistical power of the analysis limited the validity of the study results and may explain the lack of statistical difference in workload. The effect size for perceived workload (d: 0.40) was in line with our hypothesis; however, the realised sample size resulted in statistical power of about 0.56.

Limitations

Stringent inclusion criteria paired with strong procedure restrictions (i.e. 2 days with exactly 7 days in between, measurements only in the afternoon) made recruitment of experienced office workers infeasible. Rather, participants in this study were 45 students from several Austrian universities (Table 1) creating a potentially relevant selection bias. In addition, participants received no financial compensation for their participation and thus it is reasonable to assume that participants were very highly motivated and interested. The fact that participants of this study performed much better than their comparative age cohorts in prior studies [based on d2r-test normative values (Brickenkamp, Schmidt-Atzert, and Liepmann 2010)] suggests that a volunteer bias may be present. Because of these biases, estimations about the effects of alternating postures on cognitive performance and workload for the general office worker population should be assessed with care. Furthermore, the small sample size paired with small effect sizes limited the power of our analysis and should be considered when interpreting results.

Conclusion

Several studies have shown positive effects of sit-to-stand workstations on sedentary behaviour (Neuhaus et al. 2014; Shrestha et al. 2015). Nevertheless, reservations concerning their effect on cognitive performance persist. This study used a randomised control cross-over trial design, and strong statistical methods – as suggested in previous research (Russell et al. 2015) – but found no significant difference in cognitive performance between alternating, sitting and standing postures. Alterations in workload were noticeably larger than those for cognitive performance, but not sufficiently large to reach statistical significance given the sample size of the study.

The findings of this study suggest that reservations concerning performance reduction due to alternating working postures might be unfounded. However, the findings also suggest that further research with sufficient statistical power and additional intervention time is warranted and needed to determine whether there is a long-lasting effect of alternating working postures on cognitive performance and workload.

Acknowledgements

The authors thank all participants involved in this research. They further thank Joseph Gloeckl (*Aeris Impulsmöbel GmbH*) for providing all height-adjustable desks used in this study.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research was supported by the Austrian Research Promotion Agency (FFG) under [grant number 834185, BRIDGE program, "Active Office"]. MH, AS and KP are supported by the

University of Applied Sciences Upper Austria (FH OOE). AB and BS are supported by the University of Vienna. JK is supported by the University of Wisconsin – Milwaukee. The desks used in the study were supplied via an in-kind donation from "*Aeris Impulsmöbel GmbH* ". This company as well as the funders had no role in the design, analysis or writing of this article.

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Appendix 1. Text editing task example

Text structure at the beginning of the task (German text, Arial 12, 1.15 line spacing, 150% zoom)

WennesheutzutageumdieGestaltungvonArbeitsplätzengeht,kommtimmerauchderBegriff
„Ergonomie“insSpiel.HändlerundHerstellerbewerbenihreProduktealsergonomisch,Vorsc
hriftenundGesetzewurdenundwerdenerlassen,umneueErkenntnissederErgonomieinalle
WinkelderArbeitsweltzutragen.WasalsoverbirgtsichhinterdiesemBegriffausderArbeitswi
ssenschaft?DerAusdrucksetztsichzusammenausdenbeidengriechischenWörtern„ergon“
fürArbeit,Werkund„nomos“fürRegel,Gesetz.ZunächstistErgonomieganzschlichteineFors
chungs-
Disziplin,diesichmitdenLeistungsmöglichkeitenundoptimalenArbeitsbedingungendesM
enschenbefasst.DazugehörtzumBeispieldieUntersuchungundEntwicklungmöglichsteffizi
enterArrangementsderArbeitsmittelineinerdazupassendenArbeitsumgebung.DasZielist
dabei,kurzeWegeundoptimierteBewegungsabläufezuerreichen.SolcheklassischenAnsä
tzesindnatürlichnachwievorsinnvoll,werdenjedochlängstumandereAspekteergänzt.Denn
Leistungkannnurdannoptimalentfaltetunderhaltenwerden,wennnebendendinglichenauch
diemenschlichenRahmenbedingungenstimmen.DabeiistesdasoberstePrinzipallerergon
omischenMaßnahmen,immerdieArbeitunddieArbeitsumgebungmitallIhrenFaktorendem
Menschenanzupassen–
undnichtumgekehrt.Nursokanneindauerhaftgesunder,sichererArbeitsplatzentstehen,and
emderBeschäftigtesichwohlfühltundvollerEngagementseinBestesgibt.Dazupasstauchda
sStatementderWeltgesundheitsorganisation(WHO)zumThemamenschengerechterArbei
tsplatz:„DieArtundWeise,wieeineGesellschaftdieArbeitunddieArbeitsbedingungenorga
nisiert,sollteeineQuellederGesundheitundnichtderKrankheitsein“.Amergonomischgest
altetenArbeitsplatzgiltes,psychischeundkörperlicheBelastungenzuvermeiden,dieGeräts
chaften,MöbelundsonstigeArbeitsutensilienbenutzerfreundlichundkörpergerechtzugestal
ten.AußerdemsinddieArbeitsabläufeundUmwelteinflüssesozusteuern,dassdieTätigkeitm
öglichstreibungslosausgeführtwerdenkann.AberderMenschsollsichanseinemArbeitsplat
zebenauchwohlfühlen,SpaßhabenanseinerArbeit–
inseinemeigenenInteresseundimInteressederökonomischenUnternehmensziele.Sovielz
urTheorie–
wiedieseAnsprücheinderPraxisumgesetztwerdenkönnenundwelcheMaßnahmenimDeta
ildenergonomischenBildschirmarbeitsplatzausmachen,lesenSieindennächstenKapiteln.
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Text structure after 10 minutes of text editing (German text, Arial 12, 1.15 line spacing, 150% zoom)

Wenn es heutzutage um die Gestaltung von Arbeitsplätzen geht, kommt immer auch der Begriff „Ergonomie“ ins Spiel. Händler und Hersteller bewerben ihre Produkte als ergonomisch, Vorschriften und Gesetze wurden und werden erlassen, um neue Erkenntnisse der Ergonomie in alle Winkel der Arbeitswelt zu tragen. Was al so verbirgt sich hinter diesem Begriff aus der Arbeitswissenschaft? Der Ausdruck setzt sich zusammen aus den beiden griechischen Wörtern „ergon“ für Arbeit, Werk und „nomos“ für Regel, Gesetz. Zunächst ist Ergonomie ganz schlicht eine Forschungs-Disziplin, die sich mit den Leistungsmöglichkeiten und optimalen Arbeitsbedingungen des Menschen befasst. Dazu gehört zum Beispiel die Untersuchung und Entwicklung möglichst effizienter Arrangements derArbeitsmittel in einer dazupassenden Arbeitsumgebung. Das Ziel ist dabei, kurze Wege und optimierte Bewegungsabläufe zu erreichen. Solche klassischen Ansätze sind natürlich nach wie vor sinnvoll, werden jedoch längst um andere Aspekte ergänzt. Denn Leistung kann nur dann optimal entfaltet und erhalten werden, wenn neben den dinglichen auch die menschlichen Rahmenbedingungen stimmen. Dabei ist es das oberste Prinzip aller ergonomischen Maßnahmen, immer die Arbeit und die Arbeitsumgebung mit all Ihren Faktoren dem Menschen anzupassen – und nicht umgekehrt. Nur so kann ein dauerhaft gesunder, sicherer Arbeitsplatz entstehen, an dem der Beschäftigte sich wohl fühlt und voller Engagement sein Bestes gibt. Dazu passt auch das Statement der Weltgesundheitsorganisation (WHO) zum Thema menschengerechter Arbeitsplatz: „Die Art und Weise, wie eine Gesellschaft die Arbeit und die Arbeitsbedingungen organisiert, sollte eine Quelle der Gesundheit und nicht der Krankheit sein“. Am ergonomisch gestalteten Arbeitsplatz gilt es, psychische und körperliche Belastungen zu vermeiden, die Gerätschaften, Möbel und sonstige Arbeitsutensilien benutzerfreundlich und körpergerecht zu gestalten. Außerdem ind die Arbeitsabläufe und Umwelteinflüsse so zu steuern, dass die Tätigkeit möglichst reibungslos ausgeführt werden kann. Aber der Mensch soll sich an seinem Arbeitsplatz eben auch wohl fühlen, Spaß haben an seiner Arbeit – in seinem eigenen Interesse und im Interesse der ökonomischen Unternehmensziele. So viel zur Theorie – wie diese Ansprüche in der Praxis umgesetzt werden können undwelcheMaßnahmenimDetaildenergonomischenBildschirmarbeitsplatzausmachen,lesenSieindennächstenKapiteln.„Schön–aberdaskostet!“werdenSiejetztsagen.DenKostenhabenwireineigenesKapitelgewidmet, dennnatürlichhabengeradeExistenzgründerdiefinanziellenAspekteimmerimAuge.Nunistesziemlicheinfach,mitunbegrenztemBudgetdenoptimalenArbeitsplatzzugestalten,derkeineWünscheoffenlässtundinjederBeziehunguptodateist.DieRealitätsiehtjedochandersaus,indenKassenjungerUnternehmenherrschteherEbbealsFlut.AberauchmitschmalemGeldbeutellassensichzufriedenstellendeLösungenfinden!Praxisnahe,kostenoptimierteBeispielezurergonomischenEinrichtungeinesBürosmitBildschirmarbeitsplatzfindenSieimKapitel„Finanzierung“.

Working speed analysis

Word count before text editing:	5 (determined via MS Word© word counting function)
Word count after text editing:	318 (determined via MS Word© word counting function)
working speed:	word count before text editing – word count after text editing
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Error type 1 (missing space):	2 (marked in green)
Error type 2 (space on false position):	2 (marked in pink)
Error rate:	4/ 313 * 100 = 1.28 %

Influence of a two-desk sit-to-stand workstation on sitting time: A randomized controlled pilot trial under real world conditions

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Abstract

Background

Sit-to-stand workstations are implemented to prevent long-lasting sitting periods. Workstation design can influence sitting time on occupational days.

Objective

Assessing the effects of a two-desk sit-to-stand workstation on sitting time, physical activity, and body mass.

Design

A two-arm randomized controlled cross-over trial with healthy people in working age.

Participants

Eighteen healthy (no chronic or acute disease) office workers (mean age 36.3 [SD 10.3] years; body mass index 23.1 [SD 1.8] kg/m^2, working 40.1 [SD 5.8] hours per week) from five different companies located in Linz (Austria) and surrounding areas independently allocated by a governmental health insurance provider.

Intervention

Usage of a two-desk sit-to-stand workstation for 23 weeks in office environments.

Methods

Between January 2014 and March 2015 participants alternatingly used interventional and traditional workstations for 23 weeks. Sitting time, physical activity and body mass were assessed before (baseline) and after (23-weeks follow up) the intervention period via the International Physical Activity Questionnaire (IPAQ) and self-reports, respectively.

Main outcome measure

Sitting time on occupational days.

Results

Mixed-design ANOVA results demonstrated differences in sitting time – especially for occupational days ($p=0.002$, partial $\eta^2=0.309$) – between sit-to-stand and traditional workstation users. In comparison to the traditional workstation, post intervention sitting time for the sit-to-stand workstation was reduced by 2.75 hours for workdays (95%CI:-5.15,-0.35;p=0.027). The novel work environment induced no differences on body mass (p=0.709, partial η^2=0.021) or physical activity (p=0.357, partial η^2=0.060) between groups.

Conclusion

Two-desk sit-to-stand workstations demonstrate a large potential for voluntary reduction of sitting time, without any compensational effect on physical activity.

Trial Status

ClinicalTrials.gov NCT02825303.

Funding

Austrian Research Promotion Agency (FFG), 834185

Keywords: sit/stand workstation; sit-to-stand workstation; postural changes; prolonged sitting; physical activity; office; workplace; body mass; standing; randomized controlled trial; IPAQ; behavior change techniques; pilot study

Introduction

Studies have shown associations between prolonged sitting and: cardiovascular and musculoskeletal diseases, diabetes, several types of cancer, and all-cause mortality [1–6]. The overall amount, duration and pattern of prolonged sitting bouts appear to influence these associations [4,7,8]. Regular breaks in sitting time have shown potential benefits with regard to waist circumference, body mass index (BMI), triglycerides, plasma insulin and glycaemia [8–12], and increased daily energy consumption [13]. As risks of prolonged sitting cannot be fully compensated by regular physical activity [8,14,15], several experts have recommended increasing postural changes and avoiding long sitting periods [16–18].

Increased time spent in prolonged, seated postures in modern societies have been attributed to: social change, transferring manufacturing occupations towards service jobs, alternations in domestic activities, and changes in transportation over the past decades [19,20]. The current European statistical report showed that, in 2014, an average of eleven percent and as many as 25% of European citizens sit more than 8.5 hours per day [21].

Occupation appears to play a strong role in how many hours per day a person sits. For example, it is estimated that 21% of white-collar workers spend more than 8.5 hours per day seated, a four times greater proportion than workers in manual occupations [21]. Regardless, it has been estimated that working adults sit for up to two-thirds of their working time, on average, with some office-based occupations (e.g., call center employees) requiring workers to sit for more than 80% of their working day [22,23]. Further, it is estimated that, worldwide, working adults spend nearly one third of their adult life at work [24] with more than two-thirds of those in developed countries spending the majority of their waking hours at work [25].

Thus, it is evident that worksite-based interventions – such as sit-to-stand workstations – are core elements to reduce sitting time. Sit-to-stand workstations are workstations enabling users to work in either a sitting or a standing position. Postural changes are typically realized by means of electrically or manually adjustable tables (enabling adjustments of the table top working height [26]) or by means of height-adjustable devices mounted on the table top (enabling adjustments of the screen and keyboard/mouse position [27]). These single-desk sit-to-stand solutions make it possible to fulfill ergonomic recommendations stated by ergonomic institutions (e.g. Austrian Workers' Compensation Board - "*AUVA"*). However, as mentioned by the leading board of the Austrian Workers' Compensation Board, these sit-to-stand working environments cannot always completely fulfill users' requirements. As a result, the usage of sit-to-stand workstations in Austria is very low. These findings are in line with prior studies exhibiting low utilization rates [28] as well as relationships between workstation design and utilization [29].

As previously shown [28] and from a compensation board leading staff practical perspective and especially in open-plan offices, long lasting (> 60 s) and noisy (> 60 dB) table top adjustment can irritate users and their surrounding colleagues, which can lead to an insufficient usage of sit-to-stand workstations. Furthermore, users' insufficient ergonomic knowledge and maladjustments might also negatively influence their will to change postures [29,30]. From a scientific perspective, as environmental conditions (i.e. working desk size), intervention type (desk only vs. multicomponent) as well as user friendliness (i.e. type of height adjustments) can noticeably influence the feasibility and performance of height-adjustable desks [22,26–29], these parameters should also be considered when developing novel sit-to-stand workstation designs.

One promising approach to solve the disadvantage of current one-desk sit-to-stand workstations might be two-desk sit-stand workstation solutions. Due to an additional, equally furnished desk, hardware adjustments (i.e. table tops, screen heights) are not further necessary; disadvantages due to the adjustment procedure (e.g. time effort, noise development, maladjustments) are obsolete and as a result, usability, acceptance rates and performance of these workstation concepts should increase.

To test this approach, the aim of this study was to determine the influence of a two-desk sit-to-stand workstation on sitting time (primary outcome) under real world conditions (office-based employees, 6-months). As sitting time reduction for sit-to-stand workstations is mainly driven by an increase of standing time [24,27] and there are concerns about a possible compensational loss of physical activity [31], we further investigate the effect of two-desk sit-stand workstations on physical activity and bodyweight (secondary outcome). Due to the simplicity of the workstation concepts, we hypothesized substantial reductions in daily sitting time for two-desk sit-stand users. Based on the small difference in energy consumption between sitting and standing [32,33], we further did not expect any change in physical activity or body mass for two-desk sit-stand users.

Materials and Methods

Study design

Data for this two-arm, randomized controlled crossover trial were collected between Jan 2014 and March 2015. The study was evaluated and approved by the Ethics Committee of the University of

Vienna (Reference number: 00052) and was registered at ClinicalTrials.gov (Identifier: NCT02825303). Participants and assessors were not blinded to group allocation. Study flow diagram, randomization process and the full study protocol was published elsewhere [34].

Recruitment

Eighteen office workers, aged between 20 and 60 years, were recruited from five companies in Linz (Austria) and surrounding areas. Managers, clerical, service, and sales professionals who could be expected to spend most of the work day (>80%) at their designated workstation were eligible to participate. Allocation was carried out randomly by a governmental health insurer (Upper Austrian Regional Public Health Insurance "*OOE GKK"*) between August and September 2013. All participating companies were provided with study details during information seminars at their respective company sites. Further, private interviews with people interested in participation were conducted after the seminars (i.e. study leader and 1 interested party per interview). Exclusion criteria were: pregnancy at baseline, plan to become pregnant within 12 months, chronic or acute diseases, heavy overweight and obesity (BMI: > 27.5 kg/m^2), short office stay duration (<6h/day or <20h/week), acute or chronic diseases, inability to stand, prior experience using sit-to-stand workstations, regular smokers (>1 cigarette/day)plans to change physical activity behavior, or relocation to another worksite during the planned study period, no consent to participate. After exclusion criteria were applied, selected participants were randomly allocated either to the intervention (study arm A) or the control arm (study arm B) in a 2:1 ratio (see Fig 1). In a second step, intervention arm participants were randomly allocated to two subgroups (1:1), one starting with a sit-to-stand workstation and the other starting with a traditional seated workstation. These randomizations were executed by means of a covariate adaptive randomization procedure by the study leader [35]. Group assignment within the intervention arm was changed at the study's midpoint and a wash out phase was implemented in between these phases. All participants provided written informant consent.

Fig 1: CONSORT diagram

Study arm A - intervention period

One day prior to the intervention period (study arm A) the traditional sitting workstation was replaced by an experimental two-desk workstation. Participants were introduced to the use of the standing and sitting desks of their experimental workstation. They could decide themselves how often they would use each kind of desk within the intervention period. In addition, brief verbal information (approx. 1-3 minutes**)** about the benefits of using a sit-stand workstation and performing regular postural changes were given by the study leader (e.g. higher energy expenditure while standing [32,33], positive effects on waist circumstance [9]). Hence, it was mentioned that reducing sitting time on a regular basis might induce health benefits.

Study arm A - control period (non-intervention period)

Within this period, study arm A participants used their traditional seated workstations. They were advised to maintain their usual working habits.

Study arm B - period I & II (non-intervention period)

The control arm consisted of two equal periods (period I & II). Within these periods, participants used their traditional seated workstations. Similar to the control period of study arm A, participants in study arm B were advised to maintain their usual working habits. As study arm B participants did not experience any sit-stand workstation period, they enable comparisons with an "unbiased" control group, albeit one consisting of different and unmatched participants.

Wash out phase

A 6-week wash out phase was embedded between the intervention and control period (see Fig 1). The washout period was mainly implemented for psychological performance tests (not directly relevant to the objective of these analyses) but also encouraged similar starting conditions (i.e. usage of a traditional workplace before intervention) for both groups [34].

Workstation design and experimental set-up

The principle of the two-desk sit-stand workstation was to ensure that participants spend the least possible time for changing their body posture while working. Hence, beside the postural change itself (i.e. sitting down, standing up), no further activity (e.g. adjustments of table and screen heights, moving laptops, shifting computer screen information) was necessary when workstation users wanted to change their body posture.

As a result, the experimental workstation consisted of two, equal height-adjustable desks standing next to each other (Fig 2). The participants were free to choose their preferred table arrangements (e.g. 0°- Fig 2 C & D, 90° - Fig 2 B and 180° - Fig 2 A) and every desk was furnished with the same amount and style of screens, keyboards and mice in order to ensure equal conditions. Depending on the participants´ pre-intervention working conditions, either one or two screens per desk were used (1 per desk - Fig 2 A/B/D or 2 per desk Fig 2 C). With the help of the study leader, desk heights were adjusted to the participants’ desired sitting and standing heights. In addition, office-chair and hardware properties (e.g. screen heights, screen angles) were adjusted by the study leader according to ergonomic recommendations (e.g. elbow height for the desks, screen heights for standing (15° to 45°) or sitting (20° - 50°) postures) and information being showed on the computer screens was set to be cloned (i.e. left screen information on the sitting desk equals left screen information on the standing desk). Thus, aside from being at sitting, or at standing height, the two workstations were identical. To ensure that the minimum space required for the two-desk setup did not exceed the minimum space requirements stated in local laws [36] each desk was equipped with a small tabletop (76 x 130 cm). Furthermore, although the overall tabletop area was approximately 50% above the minimum recommended tabletop area of 1.28 m² [37], the two-desk workstation (e.g. for the arrangement illustrated in Fig 2 A) did not exceed space requirements for traditional one-desk solutions after considering mandatory free floor areas. In addition, the implemented two-desk workstations, independent of the table arrangements (Fig 2 A/B/C/D), did not exceed the minimum space requirements (5.0 m^2) for office workstations [36].

Fig 2: Two-desk sit-to-stand workstations in real world conditions implemented in the current study for 4 different conditions. A: 180° - 1 screen per desk, B: 90° - 1 screen per desk, C: 0° - 2 screens per desk, D: 0° - 1 screen per desk

Measures

For each participant, data was collected on four assessment days during the period from Jan 2014 – March 2015. Due to the study's cross-over design half of the assessments were conducted pre (baseline) and the other half post (23 weeks follow-up) intervention. Sitting time and physical activity were investigated by means of the International Physical Activity Questionnaire (IPAQ) [38]. This questionnaire as well as others like the OSPAQ [39] is a valid and regularly used measuring method for worksite based interventions [23,40,41]. The participants' body masses were enquired by implementing an additional question. To avoid missing values the IPAQ was interview-administered (face to face) [42].

In addition, to fulfill current recommendations [43], a quantitative measurement method (logging-software), recognizing hardware inputs (mouse, keyboard) was installed on participants' computer to determine participants' time spent at each workstation and by proxy their presumed body postures for each single day during the whole intervention period (23 weeks). Due to several partly unforeseeable events: usage of unsupported operating system (2/12), software problems (2/12), IT-staff changed computer settings (3/12) and unintentional mis-calibration (2/12) the data of this quantitative method was neither analyzed nor illustrated in this manuscript. Graphical logging data results from the remaining participants (3/12) can be found in the supporting information (S 1 Fig 1).

Lastly, unstructured interviews were executed after the last assessment day (1 year after baseline). During these interviews, participants were asked to freely talk about their experiences with the two-desk sit-to-stand workstation. All data was assessed in a laboratory room at the campus site Linz of the University of Applied Sciences Upper Austria.

Data processing

IPAQ data processing was executed according to the IPAQ guideline [44]. Baseline and follow-up values for intervention and control period were pooled together and analyzed statistically (Fig 3). Data analysis performed in 2016 contained all participants (n=18).

Fig 3: Data analysis scheme

Statistical analysis

Prior to intervention, a non RCT with university staff members showed a sitting time reduction of 105 minutes for an 8h-workday within a 4 week interval [45]. As lower mid-term effects on sitting time were expected for non-university staff members, as well as prior studies showed decreasing effects on sitting time for longer interval periods [28], a sample size calculation for a 90-minute decrease was executed. Assuming an alpha risk of 0.05 (two-sided) and a beta risk of 0.20, twelve participants were needed for adequate statistical power, assuming a 20% loss to follow-up. This current study was not powered for health-related secondary outcomes (physical activity and body mass) and their effect was assessed to enable sample size estimations for subsequent trials.

Statistical analyses were conducted using SPSS version 23 for Windows (SPSS Inc., Chicago, IL, USA). Standard statistical methods were used for the calculation of means and standard deviations. A mixed-design ANOVA (3x2, group x time) was executed to determine differences and effect sizes (partial eta squared) between groups (study arm A – intervention period, study arm A – control period, study arm B), time (baseline, 23 weeks follow-up) and the interaction of both (group x time). One-way ANOVAs with subsequent Bonferroni post hoc tests were used to localize group differences. When the normality condition was satisfied, paired and unpaired t-tests were used to show differences between baseline and follow-up conditions as well as intervention and control conditions, respectively. Effect sizes (Cohen´s d) were calculated for comparison between the mean differences (baseline vs. 23 weeks follow up) between sit/stand and traditional workstation periods. Shapiro-Wilk-tests and Levene-tests were applied, respectively, in order to test for normality and homogeneity of variance. Chi-squared tests were used for estimating differences in participants' characteristics. A repeated measures ANOVA (1x4, group x time) was executed to estimate the effect size of seasonal fluctuations on physical activity. In general, two-sided tests with an alpha risk of 0.05 and a beta risk of 0.2 were accepted.

Results

Participants' characteristics

Table 1 shows participants' characteristics at baseline. All of them: were Caucasians (18/18), were mainly full-time employed (16/18), had been with the company for more than five years (13/18), and did not work at management level (14/18). Gender was distributed equally in the intervention arm (men, 6/12), and a minor amount of the participants possessed tertiary education (4/18). There were no statistical differences between the intervention and control arm participants.

Table 1: Socio-demographic, work and health characteristics of office-based employees at baseline (n=18)

	All (n=18)	Study arm A (n=12)	Study arm B (n=6)	p
Age (years)	36.3 (10.3)	35.7 (9.6)	37.5 (12.5)	0.924
Women	44.4% (8)	50.0% (6)	33.3% (2)	0.499
Caucasian	100.0% (18)	100.0% (12)	100% (6)	1.000
Tertiary education	27.8% (5)	16.7% (2)	50.0% (3)	0.144
Tenue at current workplace				
< 1 year	5.6% (1)	8.3% (1)	0.0% (0)	0.359
1 to <3 years	22.2% (4)	25.0% (3)	16.7% (1)	0.683
3 to <5 years	0.0% (0)	0.0% (0)	0.0% (0)	1.000
5 to <10 years	61.1% (11)	58.3% (7)	66.7% (4)	0.731
≥ 10 years	11.1% (2)	8.3% (1)	16.7% (1)	0.605
1.0 Full-time-equivalent	88.9% (16)	83.3 (10)	100% (6)	0.187
Working hours (h/wk)	40.1 (5.8)	39.5 (6.7)	41.4 (3.1)	0.298
Job category				
Managers/professionals	22.2% (4)	16.7% (2)	33.3% (2)	0.432
Clerical/service/sales	77.8% (14)	83.3% (10)	66.7% (4)	0.432
Body mass index (kg/m²)	23.1 (1.8)	23.3 (1.7)	22.6 (2.0)	0.135
Smoking habits				
Current smoker	0.0% (0)	0.0% (0)	0.0% (0)	1.000
Chipper	5.6% (1)	0.0% (0)	16.7% (1)	0.359
Stopped < 10 years ago	16.7% (3)	25.0% (3)	0.0% (0)	0.099
Stopped > 10 years ago	22.2% (4)	25.0% (3)	16.7% (1)	0.683
Never smoker	55.6% (10)	50.0% (6)	66.7% (4)	0.499

Table represents means (SD) or % (n)

Note: Participants (recruited Aug - Sep 2013) were employees of five different companies located in Upper Austria (Austria, Europe)

Physical behavior (baseline characteristics)

IPAQ results showed that the amount of sitting time spent on occupational days across all study groups ranged from 10.4 - 11.5 h/day at baseline and from 7.8 - 12.0 h/day at follow-up (see **Table 2**). All groups generally spent less time sitting on weekend days (i.e. Saturday, Sunday) both at baseline (6.5 – 8.1 h/day) and at follow-up (7.4 – 9.2 h/day). For the overall week (sum of 5 workdays and 2 weekend days) sitting time ranged from 64.9 – 73.7 h/week at baseline to 55.6 to 78.3 h/week at follow-up.

Table 2: Sitting time, physical activity and body mass for study arm A (sit-stand workstation & traditional workstation) and study arm B (traditional workstation) participants

	Study arm A				Study arm B	
	Sit/stand (n=12), mean (SD)		Traditional (n=12), mean (SD)		Traditional (n=12), mean (SD)	
	baseline	23 weeks	baseline	23 weeks	baseline	23 weeks
Sitting time (h)						
Occupational day	10.8 (2.2)	7.8 (2.2)	11.5 (3.2)	11.1 (2.5)	10.4 (2.7)	12.0 (1.9)
Weekend day	7.8 (2.3)	8.4 (2.4)	8.1 (2.7)	7.4 (2.9)	6.5 (1.8)	9.2 (2.6)
Week (7 days)	69.9 (3.7)	55.6 (3.4)	73.7 (19.7)	70.5 (15.3)	64.9 (13.4)	78.3 (3.6)
Physical acitivity (METmin wk^{-1})	2822 (1255)	3282 (2905)	3419 (2204)	3192 (2277)	3355 (1606)	2275 (1693)
Body mass (kg)	74.7 (11.6)	74.9 (12.7)	74.5 (12.7)	75.3 (12.6)	70.0 (3.1)	70.7 (3.1)

Behavioral changes (multivariate analysis)

Mixed-design ANOVA results (see ***Table 3***) demonstrated no significant within-group differences for sitting time or physical activity (p>0.05) across groups. A significant within-group difference for body mass (p=0.044, η^2=0.117) and a statistical between-group difference for sitting time on occupational days (p=0.030, η^2=0.191) was found. Bonferroni post hoc tests demonstrated that the between-group differences can only be located between the sit/stand workstation period and the traditional workstation periods of study arm A (p=0.002) and study arm B (p<0.001) at 23 weeks follow-up. There was no statistical between-group difference for sitting time on weekend days or the overall week (p>0.05). Mixed-design ANOVA results indicated different time dependencies (baseline vs. 23 week follow up) between study groups for sitting time on occupational days (p=0.002, η^2=0.309), weekend days (p=0.017, η^2=0.219) and during the overall week (p=0.002, η^2=0.321). No interactional effect (time x group) was found for physical activity and body mass (p>0.05).

Table 3: Mixed-design ANOVA results for sitting time, physical activity and body mass

	Time$^{\Delta}$		Group		Time$^{\Delta}$ x group	
	p	η^2	*p*	η^2	*p*	η^2
Sitting time (h)						
Occupational day	0.237	0.042	0.030	0.191	0.002	0.309
Weekend day	0.087	0.086	0.900	0.006	0.017	0.219
Week (7 days)	0.652	0.006	0.103	0.129	0.002	0.321
Physical acitivity (METmin wk^{-1})	0.519	0.013	0.757	0.017	0.357	0.060
Body mass (kg)	0.044	0.117	0.570	0.033	0.709	0.021

Δ Within-subject difference (baseline vs. 23 weeks)

Sitting time

At the conclusion of the intervention period (sit/stand workstation), participants altered their average sitting time on occupational days by -3.07 hours (95% CI: -4.92, -1.21; p<0.004), on weekend days (i.e. Saturday and Sunday) by +0.56 hours (95% CI: -1.06, 2.16; p=0.465) and their average weekly sitting time (7 days) by -14.22 hours (95% CI: -25.15, -3.30; p=0.015), as compared to baseline (see **Table 4**).

Table 4: Differences between baseline and 23 weeks follow-up for sitting time, physical activity and body mass for study arm A (sit-to-stand workstation & traditional workstation) and study arm B (traditional workstation) participants

	Study arm A				Study arm B	
	Sit/stand (n=12)		Traditional (n=12)		Traditional (n=12)	
	mean (95% CI)	p	mean (95% CI)	p	mean (95% CI)	p
Sitting time (h)						
Occupational day	-3.07 (-4.92, -1.21)	0.004	-0.32 (-2.06, 1.42)	0.694	1.59 (-0.49, 3.67)	0.120
Weekend day	0.56 (-1.06, 2.18)	0.465	-0.78 (-2.74, 1.19)	0.401	2.76 (0.88, 4.63)	0.008
Week (7 days)	-14.22 (-25.15, -3.30)	0.015	-3.16(-13.60, 7.28)	0.519	13.45 (1.94, 24.97)	0.026
Physical acitivity (METmin wk^{-1})	461 (-1315, 2236)	0.579	-227 (-1862,1408)	0.766	-1081 (-2609, 447)	0.148
Body mass (kg)	0.25 (-1.02, 1.52)	0.674	0.75 (0.20, 1.30)	0.012	0.71 (-0.43, 1.85)	0.198

In addition, baseline/follow-up comparisons between the sit/stand and the traditional workstation period (see **Table 5**) exhibited alterations of -2.75 hours (95% CI: -5.15, -0.35; p=0.027) and led to large effects (Cohen's d: -0.97) on sitting time for occupational days. On the contrary, alterations of +1.34 hours (95% CI: -1.06, 3.74; p=0.261) in sitting time for each of the weekend days (i.e. Saturday and Sunday) exhibited small (d: 0.47) effect sizes. For the overall week, medium effects (d: -0.66) have been found when comparing baseline/follow-up differences between the sit/stand and the traditional workstation period.

Table 5: Comparison between the mean differences (baseline vs. 23 weeks follow up) in sitting time, physical activity and body mass between sit-to-stand workstation and traditional workstation users (study arm A only).

	Study arm A			
	Sit/stand - traditional			
	mean (95% CI)	p	d	Effect
Sitting time (h)				
Occupational day	-2.75 (-5.15, -0.35)	0.027	-0.97	L
Weekend day	1.34 (-1.06, 3.74)	0.261	0.47	S
Week (7 days)	-11.06 (-25.30, 3.18)	0.121	-0.66	M
Physical acitivity (METmin wk^{-1})	688 (-1587, 2962)	0.537	0.26	S
Body mass (kg)	-0.50 (-1.81, 0.81)	0.436	-0.32	S

Notes: effect size conventions correspond to none (<0.20), small (S, 0.20 to <0.50), medium (M, 0.50 to <0.80), and large (L, ≥0.80)

Physical activity

As shown in Table 2, the study participants' average amount of weekly physical activity ranged between 2275 to 3419 METmin per week. In line with multivariate analysis results physical activity did not significantly differ ($p>0.05$) between baseline and 23-weeks follow-up for any study group (see, Table 4). Baseline/follow-up comparisons between the sit/stand and the traditional workstation period (see **Table 5**) exhibited a small non-significant increase in physical activity for sit-to-stand workstation users compared to traditional workstation users (688 $METminwk^{-1}$, 95% CI: -1857, 2962; $p=0.537$; d: 0.26).

In addition, before merging physical activity data, medium seasonal fluctuations in physical activity which did not reach significance level ($F(3,51)=2.416, p=0.08, \eta^2=0.124$) were observed (see Fig 4).

Fig 4: Study subjects' overall physical activity (n=18) – one-year trend (4 time points from left to right: baseline first period, 23 weeks follow up first period, baseline second period, 23 weeks follow up second period)

Body mass

The participants' mean body mass ranged from 70.0 to 75.3 kg and did not differ between study groups (see Table 2) at baseline and follow-up. In line with multivariate analysis, body mass for all groups increased between baseline and follow-up (see *Table 4*), but was found to be significant only for the traditional workstation period of study arm A ($p=0.012$). Baseline/follow-up comparisons between the sit-to-stand workstation and the traditional workstation period (see **Table 5**) exhibited a small effect size (d:-0.32).

Missing Values

There were no missing values for the parameters measured on assessment days.

Discussion

The primary objective of this study was to determine the effect of a two-desk sit-stand workstation on voluntary sitting-time reduction among office workers. In line with our hypothesis, study results showed that the two-desk sit-stand workstation encouraged substantial sitting time reduction on occupational days and for the overall week. Consistent with the findings of prior studies [24,31], comparisons between the sit-stand and the traditional workstation period of study arm A showed small sitting time changes on weekend days, suggesting a compensational effect – where increased standing at work leads to muscle fatigue that results in increased sitting outside of work – may have occurred. However, when comparing the sit-stand workstation period with the traditional workstation period of study arm B (different participants), the opposite effect on weekend day sitting time was observed.

Different boundary conditions between study arms A and B might explain the between-group differences in weekend sitting time. Whereas study arm A participants experienced both sit-stand and traditional workstations, study arm B participants were not exposed to sit-stand workstations. During the sit-stand workstation period, study arm A participants might have gotten used to regular standing periods and therefore, during the traditional workstation period, they might have reduced their sitting time on weekends to compensate for the missing sit-stand workstation during the occupational days. On the other hand a small increase in sitting time on weekend days for the sit-stand workstation period partly contradicts this hypothesis insofar as, if the usage of sit-to-stand workstations induced behavioral changes, those changes should also reduce sitting time on weekend days during the sit-stand workstation period (under the condition there is no maximum weekly value of standing). As a result, there may be another explanation for the opposing effects on sitting time. For example, it is likely that random or circumstantial weekend activities induced the aforementioned difference in weekend sitting time. Alternatively, the changes observed, while statistically significant, may simply be spurious findings.

Sitting time and workstation design

The efficiency of a workplace depends on several factors. Multicomponent interventions (e.g. interventions with additional support) [16,30] and interventions during paid working time [46] can influence the performance of this intervention. Complex, impracticable or noisy systems may further decrease usability as well as the willingness to break old habits. Especially when people are disrupted in their working process (e.g. automatic height adjustments every 20 minutes, darkening of the screen after 50 minutes of working), it is likely that they will find ways to escape the system or replace the intervention (e.g. deactivating reminders or adjustments) [47].

The two-desk sit-stand workstation enabled people to change postures without any additional adjustments or adaptations. Due to supported table height adjustments at the beginning of the study, participants, contrary to those in prior inventions [24,27,48], did not have to carry out any further height adjustments when changing postures within the working process. Hence, parameters reducing performance such as noise emissions (e.g. by manually or electrically induced desk movements) [28], adjustment times, technical problems (e.g. trapped cables) as well as adjustment errors (e.g. table or screen heights) [29,49] possibly leading to awkward postures and increased musculoskeletal problems [4,30,50,51] were minimized. The convenience of this two-desk sit-stand arrangement might explain why the sitting time reduction observed in this study was similar to multicomponent interventions using behavior change elements in form of social support, reminders or knowledge transfer [16,28,52].

Sitting time and behavior change techniques

Based on post-study interviews with participants, it appears that the two-desk sit-stand workstation setup used in this study indirectly implemented behavior change techniques (BCTs). BCTs can help to change personal behaviors [53–55] and may also be responsible for the large sitting time reduction observed in this study. Specifically, during the intervention period both standing desks were omnipresent, adjusted to the right height and enabled participants to continue working after postural changes within seconds (BCT - prompt practice). In most of the attending companies, the study participants were the first employees to receive height-adjustable desks (BCT – role model), which led to an enhanced interest and support from colleagues (BCT – feedback & social comparison). Private meetings at the workstation mainly executed in the standing posture due to environmental reasons (e.g. conversation on same eye level, no additional chair required) further increased the willingness to stand (BCT – social support). Prior findings exhibiting enhanced effectiveness for sedentary behavior interventions implementing feedback [56,57], social support [58] or reminders [30,59] substantiate this approach.

Sitting time and its measuring method

Besides workstation design and BCTs, differences in sitting time reductions between prior findings and this study's results might be due to differences in measurement methods. Although prior interventional studies commonly used reliable quantitative measuring methods like accelerometers to estimate sitting time [16,22,24,31], the IPAQ as well as other questionnaires (OSPAQ - Occupational Sitting and Physical Activity Questionnaire, WSQ - Workforce Sitting Questionnaire) are common instruments to estimate sitting time in a reliable, cheap, simple and quantitative way [26,60]. However, qualitative measuring methods, such as the IPAQ, present some challenges. For example, while the IPAQ can distinguish between workdays and weekend days, it cannot practicably differentiate between occupational and leisure sitting time and this can lead to an unknown bias [43] that can affect its comparability with quantitative measurements. Especially in behavioral related areas, the pervasive and habitual characteristics for sitting time lead to difficulties in estimating sitting time accurately.

Finally, the missing blinding process within the study could have led to wrong estimations regarding sitting time. Although all study participants were free of any disease, nearly all of them critically questioned the high prevalence of sitting in modern societies. This circumstance could have influenced their rating according sitting time and would explain more pronounced effects on sitting time in this study.

Physical activity

A secondary aim of this study was to investigate the effect of a two-desk sit-stand workstation on physical activity. As for this type of workstation intervention sitting is mainly compensated by standing rather than by additional physical activity, we hypothesized that the usage of a two-desk sit-stand workstation would not affect the level of physical activity. Although non-significant differences found in this study would confirm our expectations, small (univariate analysis) to medium (multivariate analysis) effects contradict them and are in contrast with prior findings reporting unaffected overall physical activity after implementing sit-stand workstations [31]. As prior investigations revealed compensatory effects on physical activity for sit-to-stand workstation users [31], our findings are in clear contrast to them.

Seasonal fluctuations and different measuring methods might explain physical activity differences found in earlier studies [31]. Seasonal fluctuations - an effect which also occurred within our study (see S 1 Fig 1) - can evidently affect overall and leisure time physical activity [61,62], especially for mid-term or long-term studies. Opposed to prior studies, this study comprised a cross-over design. Hence - although the variance of PA might have been increased - seasonal fluctuations were eliminated and changes in PA habits due to alternated environmental conditions (i.e. enhanced indoor activity during bad weather) might not have biased mid-term study results. Furthermore, the IPAQ – chosen due to its simple and cheap usage, its good reliabilities [38,42,63] and the fact that it does not disturb daily life – is less reliable in estimating physical activity than quantitative measurements (e.g. double-labeled water or accelerometers) [23,60]. Although the IPAQ enables the breakdown of physical activity into common parts of daily life (i.e. occupational, domestic, travel and leisure time) [42], it might not be sensitive enough to adequately detect shifts in light-intensity physical activity during a day. Lower validities for light-intensity physical activity determined by means of the IPAQ [38,64] would further confirm this approach and explain the non-comparability between prior findings and this study.

Contrary to these approaches, the reduction in sitting time might have induced changes in cognitive parameters like well-being [65] leading to increments in physical activity. Compared to working in a sitting posture only, working in alternating (sit and stand) body postures can alternate cognitive perception [66]. Less mental fatigue [67], less musculoskeletal problems [68] as well as alternated physiological states (e.g. alternated cortisol levels) after finishing occupational work in alternating postures might have increased participants' motivation for leisure time activities [69,70]. In addition, novel working conditions might have increased participants' attention to health promotion and prevention and triggered previous plans to change personal behaviors regarding physical activity. Nevertheless, Hawthorne effects characterized by an over-reporting of physical activity of sit-stand workstation users might have also biased study findings.

Body Mass

In line with prior investigations [11,71] multivariate analysis showed no difference in body mass for sit/stand workstation users. The insufficient additional metabolic effort induced by the sit/stand workstation might be the reason for this circumstance. Standing [32], sit-to-stand transitions [32,33] as well as working in alternating postures (sit/stand) [33] exhibit higher energy expenditures than sitting. Assuming that the sitting time reduction found in this study was completely replaced by standing activities, the additional effort – based on energy expenditure studies [32,33,72] – would have induced approximately 14 additional kcal per day. As 15-50 kcal per day are necessary to prevent weight gain [72] as well as 100 kcal per day are sufficient to induce body mass changes, the estimated increase in energy expenditure induced by the interventional setup was not sufficient to either lead to protective effects or induce a weight loss. In addition, as self reports of body mass are often characterized by underestimations [73] as well as due to the participants´ positive attitude towards sit/stand workstations, small effect sizes found for body mass might also be induced by a Hawthorne effect often observed for similar scientific investigations [29,74,75].

Limitations and strengths

Limitations of this study are the small sample size, strong inclusion criteria, and the lack of subject matching between the intervention (arm A) and control (arm B) arms of the study. The advantages are the cross-over design, an equal distribution of gender and the participation of people from several companies. The large reduction in sitting time encourages further research on novel two-desk sit-stand workstation principles. The implementation of further BCTs combined with modern technologies like wearables and fitness apps [57] may help to promote postural changes and their health-related benefits [8,9], beyond the effects of convenient sit-stand workstations alone.

Due to software problems, sitting time data for the whole group of participants was based on the IPAQ only. Although this questionnaire is a valid measurement tool for physical activity [38,63], self-reported values are subject to bias. Especially for parameters related to social norms (i.e. body mass, height) these reporting errors can lead to unintentional misclassifications [76,77]. Especially for these cases, objective data acquisition (e.g., by using ActiGraphs [43] or ActivPALs [78]) could help to minimize these problems in future studies. Furthermore, as it was not possible to blind participants within this study, they may have underreported their sitting time and body weight to strengthen results and consequently promote changes in their company. Due to the limitations of the study, general statements regarding the effect of two-desk sit-to-stand workstations on sitting time, physical activity and body mass for the overall population (e.g. for adolescents, children, elderly, overweight or underweight individuals) are not possible.

Conclusions

The two-desk setup used in this study revealed a great potential for self-selected occupational sitting time reduction. In addition to its flexibility to fulfill mandatory space requirements, it illustrates the potential of two-desk sit-stand workstations on sedentary behavior. The small sample size and strong inclusion criteria limit the generalisability of these results. Hence, further research on two-desk sit-stand workstations is needed to quantify the long-term benefits of the intervention.

Acknowledgments:

The authors thank all participants involved in this study and the Upper Austrian health insurance ("*Oberoesterreichische Gebietskrankenkasse"*) for allocating them. Moreover, the authors thank the leading experts of the Austrian Workers' Compensation Board (*"Allgemeine Unfallversicherungsanstalt – AUVA"*) for discussing and pointing out usability problems of currently already realized sit-to-stand workstation concepts in Austria. They further thank Dr. Michael Haller for initiating the project "Active Office". Lastly, the authors thank Dr. Kathrin Probst (University of Applied Sciences Upper Austria) for developing the logging software. Open access funding provided by University of Vienna.

Conflict of interest statement

This study was supported in part by the Austrian Research Promotion Agency (FFG) under [grant number 834185, BRIDGE program, "Active Office"]. BS is supported by the University of Applied Sciences for Health Professions Upper Austria and the University of Vienna. AB is supported by the University of Vienna. JK is supported by the University of Wisconsin – Milwaukee. The desks used in the study were supplied via an in-kind donation by "*Aeris Impulsmöbel GmbH & Co. KG*". The authors declare no conflict of interest. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Disclosure statement

No financial disclosures were reported by the authors of this paper.

Authors' contributions

Corresponding and first author BS led the development of this manuscript. He contributed to the research design and collected and analysed data. Authors AB and JK participated in the writing of the manuscript. All authors read and approved the final manuscript.

Supporting information

S 1 Fig 1: Graphical logging data results of 3 study participants using the two-desk sit-to-stand workstation; Left: Relative standing time while working at the workstation; Right: Amount of sit to stand transitions per hour while using the workstation

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Figure 1

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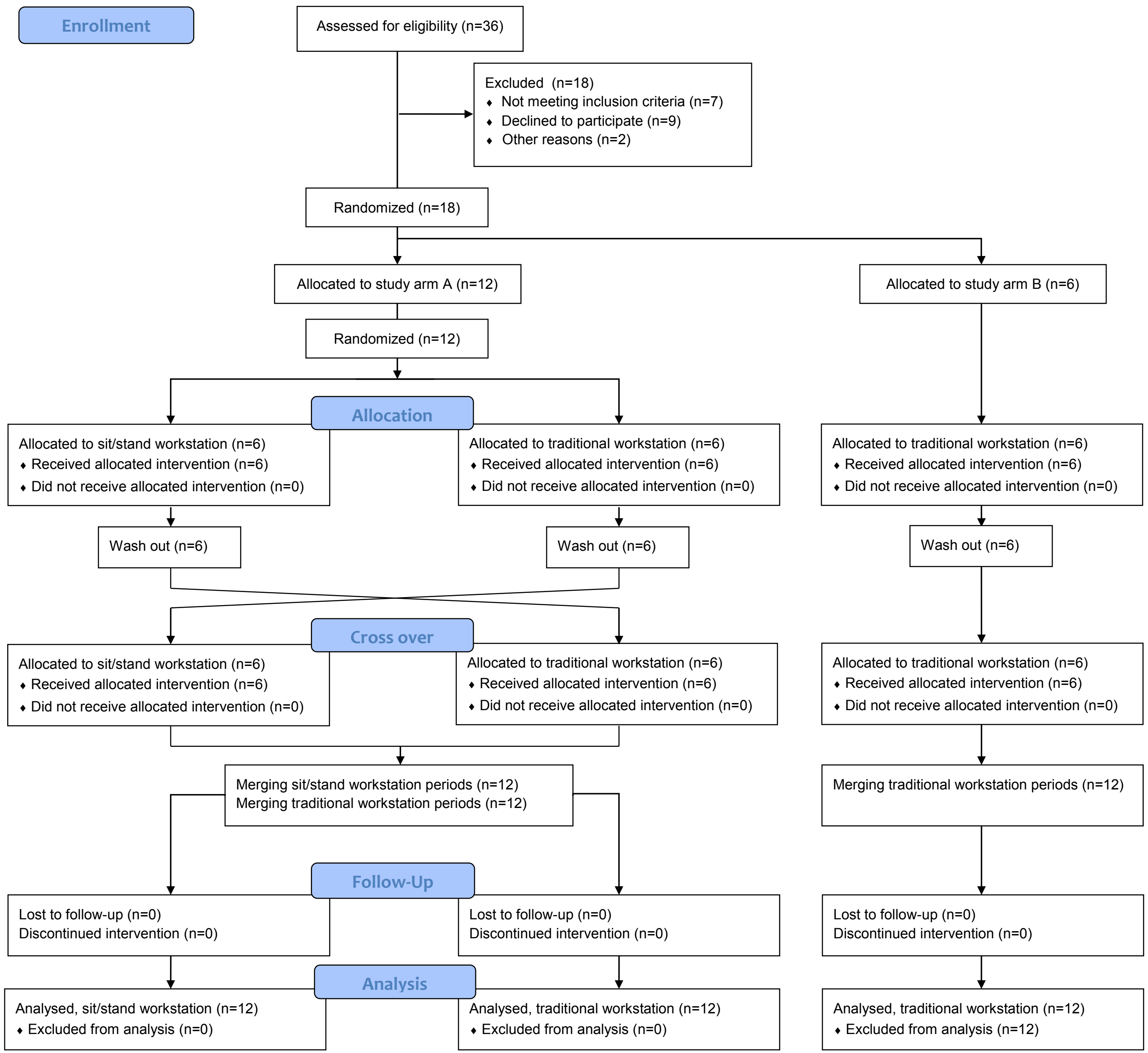

Figure 2

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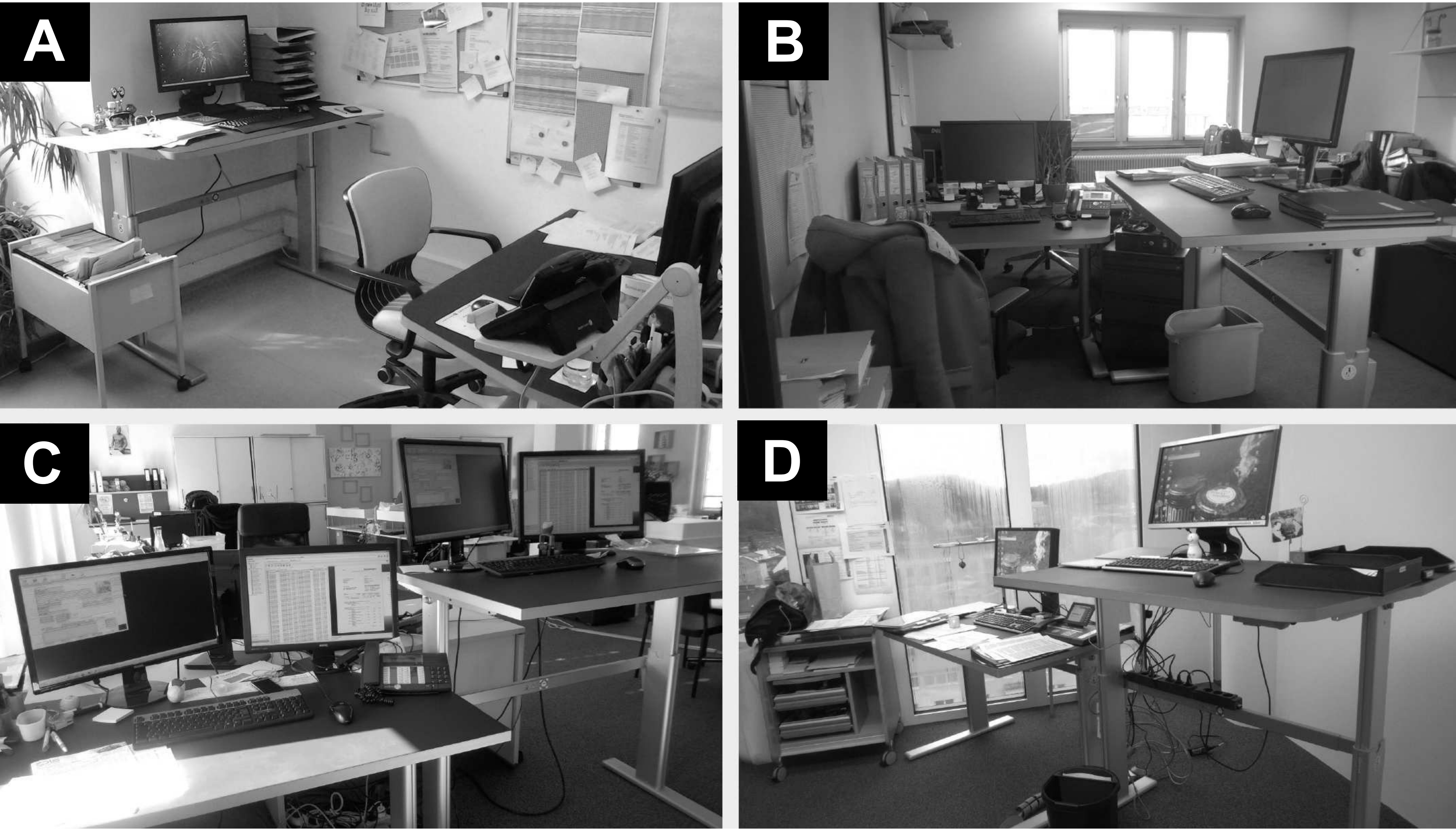

Figure 3

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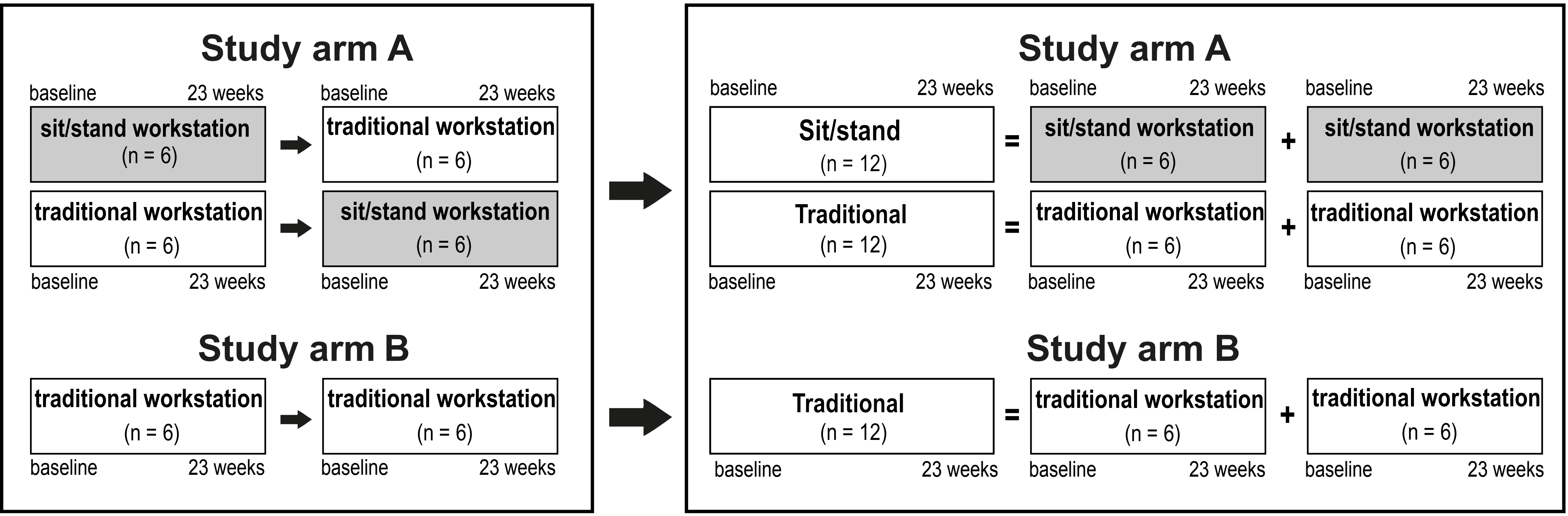

Figure 4

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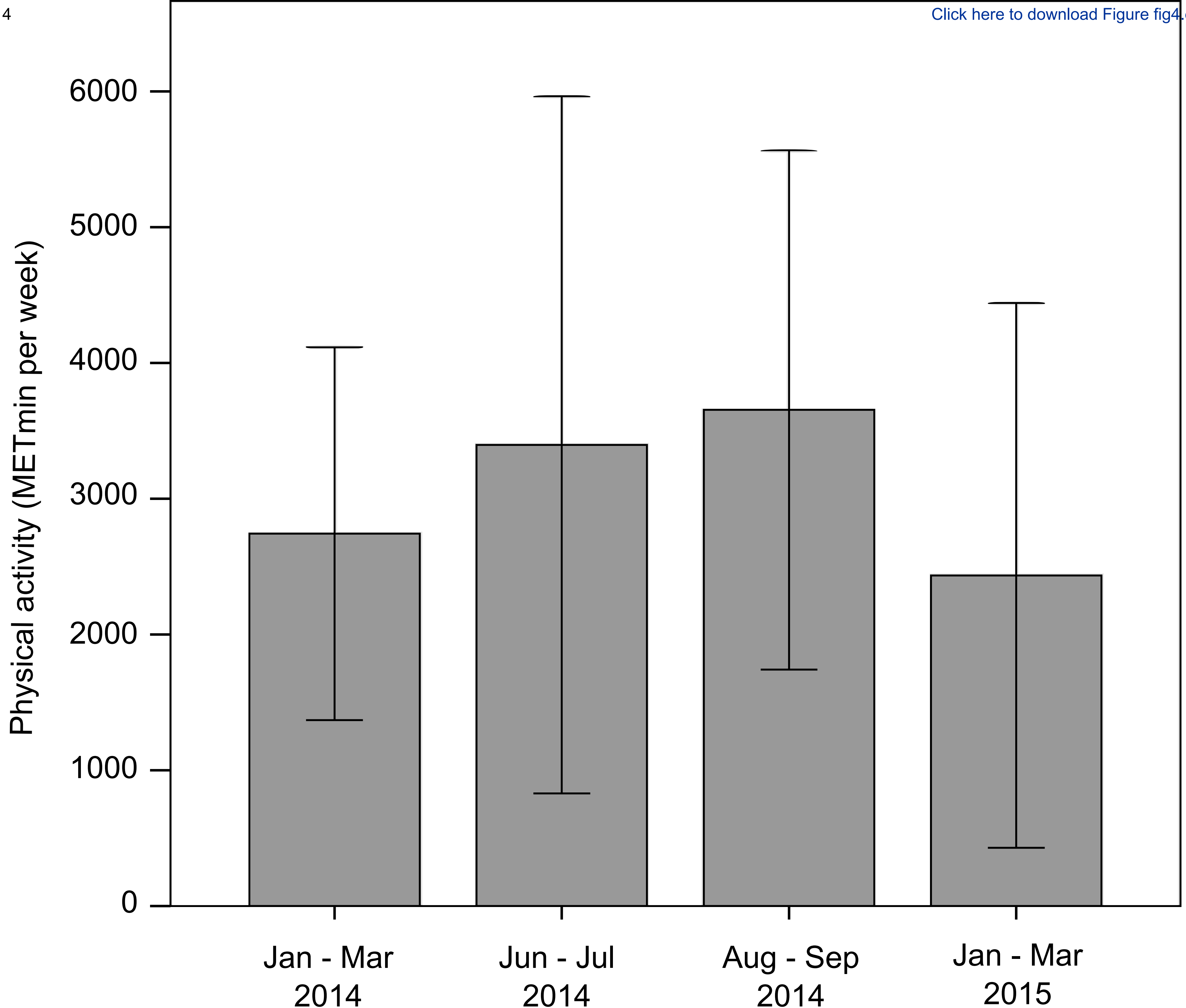
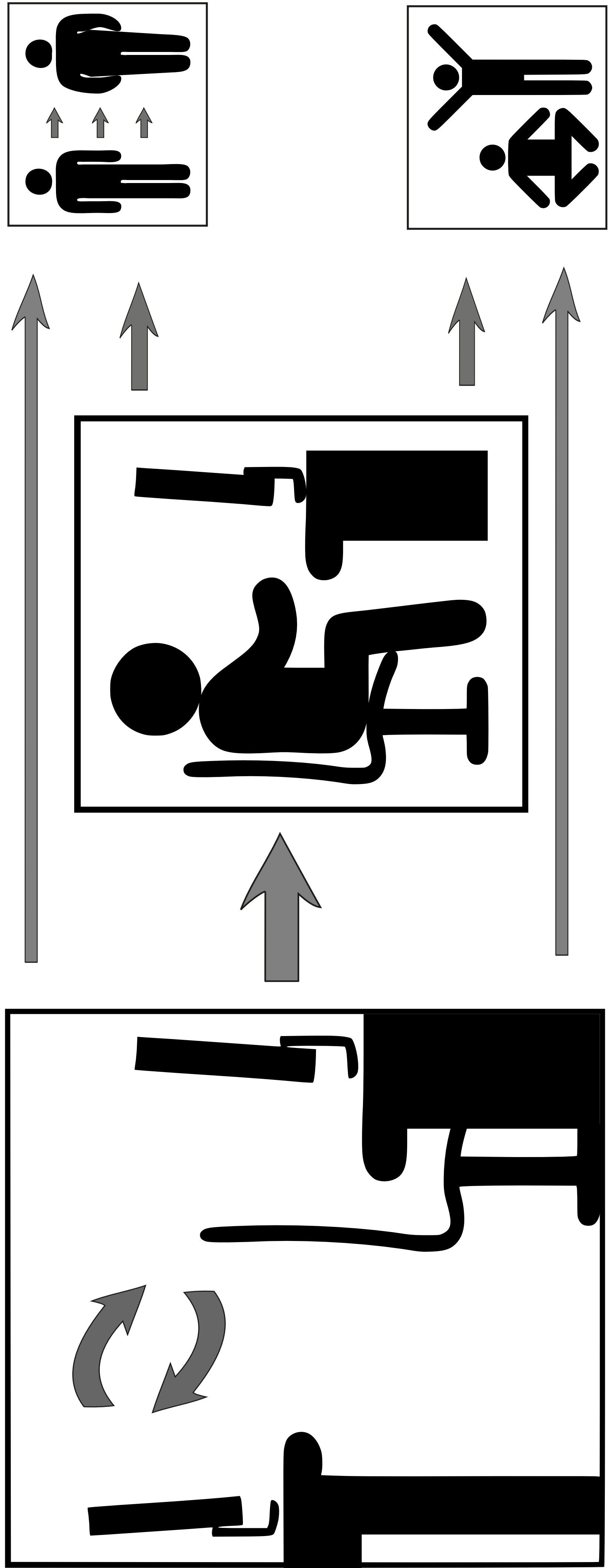


Striking Image



Mid-term effects of a two-desk sit/stand workstation on cognitive performance and workload for healthy people performing sedentary work: A secondary analysis of a pilot randomised controlled trial

Journal:	*Ergonomics*
Manuscript ID	Draft
Manuscript Type:	Original Article
Date Submitted by the Author:	n/a
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Keywords:	sit/stand workstation, cognitive performance, physiological stress, randomised controlled trial, workload

Bernhard Schwartz
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June 20th, 2018

Dear Editor,

Enclosed to this letter you will find the manuscript entitled " Mid-term effects of a two-desk sit/stand workstation on cognitive performance and workload for healthy people performing sedentary work: A secondary analysis of a pilot randomised controlled trial" we would like to submit as an article to "Ergonomics".

In this manuscript we describe a randomized controlled cross-over trial evaluating the effect on cognitive performance (reaction time, concentration performance, working speed), perceived workload and mental stress caused by the mid-term usage of a novel sit-to-stand workstation.

Within this one-year study 18 office workers from several company sites have been alternatingly equipped with a traditional or a novel sit-to-stand workstation. To determine workstation related changes on cognitive parameters they underwent four one-day assessments under laboratory conditions pre and post (23 weeks) intervention.

Stringent inclusion criteria's, similar environmental conditions, appropriate statistical analysis (MANOVA, RANOVA) as well as study's cross-over design led to enhanced comparability within this study. We believe that study's results can help to understand the potential of sit-to-stand workstations and help to soothe away fears concerning a performance loss based on novel workstation concepts. Furthermore, this study is based on another study previously published at your journal evaluating the short-term effect of alternating postures on cognitive performance (title: "Effect of alternating postures on cognitive performance for healthy people performing sedentary work", Ergonomics. 2018 Jun;61(6):778-795).

We confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere. The research reported in this manuscript has been funded in part by the Austrian Research Promotion Agency (FFG, Project number 834185). The study protocol and all pertinent documents have been evaluated and approved by the Ethics Committee of the University of Vienna (RefNr.: 00052). Is has further been registered at ClinicalTrials.gov (Identifier: NCT02825303, July 2016).

We have no conflicts of interest to disclose.

Thank you for your consideration of our manuscript. We look forward to hearing from you.

Yours sincerely,

Bernhard Schwartz

Title: Mid-term effects of a two-desk sit/stand workstation on cognitive performance and workload for healthy people performing sedentary work: A secondary analysis of a pilot randomised controlled trial

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Acknowledgements

The authors thank all participants involved in this research as well as the Upper Austrian health insurance (*Oberoesterreichische Gebietskrankenkasse*) for allocating them. They further thank Joseph Gloeckl (*Aeris Impulsmoebel GmbH & Co. KG*) and Christian Ecker (*Schiller Medizintechnik GmbH*) for providing all height-adjustable desks and ECG-recorders used in this study, respectively and Michael Haller and Andreas Schrempf (*University of Applied Sciences Upper Austria*) for initiating the research project "Active Office".

Conflict of interest statement

This study was supported in part by the Austrian Research Promotion Agency (FFG) under [grant number 834185, BRIDGE program, "Active Office"]. BS is supported by the University of Applied Sciences for Health Professions Upper Austria and the University of Vienna. BW and AB are supported by the University of Vienna. JK is supported by the University of Wisconsin – Milwaukee. The desks and ECG-recorder used in the study were supplied via an in-kind donation by "*Aeris Impulsmöbel GmbH & Co. KG*" and "*Schiller Medizintechnik GmbH*", respectively. These companies as well as the funders had no role in the design, analysis or writing of this article.

Disclosure statement

No financial disclosures were reported by the authors of this paper.

Authors' contributions

Corresponding and first author BS led the development of this manuscript. He contributed to the research design and collected and analysed data. BW analysed the cortisol data. AB contributed to the research design. Authors BW, AB and JK participated in the writing of the manuscript. All authors read and approved the final manuscript.

Word count:	Abstract	134 (max. 150)
	Introduction	706
	Methods	1588
	Results	703
	Discussion	1861
	Conclusion	93
	Overall	**4951**

Number of pages:	35
Number of tables:	4 + 2 (Appendix)
Number of figures:	4 + graphical abstract
Appendix:	2 additional table

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Mid-term effects of a two-desk sit/stand workstation on cognitive performance and workload for healthy people performing sedentary work: A secondary analysis of a pilot randomised controlled trial

Implementing sit/stand workstations in sedentary work environments is a common way to reduce sedentary time, but their mid-term effect on cognitive performance is unclear. To address this circumstance, eighteen office workers participated in a two-arm, randomised controlled cross-over pilot trial (ClinicalTrials.gov Identifier: NCT02825303), either working at a traditional (sit) or an interventional (sit/stand) workplace for 23 weeks. Cognitive performance (working speed, reaction time, concentration performance, accuracy), workload and relevant covariates (salivary cortisol level, heart rate, physical activity, sitting time) were measured pre- and post-intervention under laboratory conditions. MANOVA and RMANOVA results did not show differences in performance parameters and workload, respectively, between sit/stand and traditional workplace users. Differences in text editing accuracy and cortisol levels for sit/stand workstation users indicate potential connectivity to cognitive parameters which should be further examined with large-scale studies.

Keywords: sit/stand workstation, cognitive performance, physiological stress, randomised controlled trial, workload

Practitioner Summary

Mid-term effects of working at sit/stand workstations on cognitive performance and workload are unexplored. This randomised controlled pilot trial suggests that cognitive performance and workload are unaffected for sit/stand workstation users after 23 weeks of use. However, accuracy appeared to improve and physiological stress appeared to be altered.

1. Introduction

Prolonged sitting is a risk factor for several diseases (Brown, Miller, and Miller 2003; Gierach et al. 2009; Patel et al. 2006; Lis et al. 2007; Peeters, Burton, and Brown 2013; Van Der Ploeg et al. 2012) and is a risk regardless of an individual's level of physical activity (Peddie et al. 2013; Healy et al. 2008; Van Uffelen et al. 2010; Kerr et al. 2016). In addition, long bouts of uninterrupted sitting can increase these risks (Lis et al. 2007) and can negatively affect cognitive performance and comfort (Karakolis, Barrett, and Callaghan 2016). Hence, especially as occupations have become less physically active and more sedentary over the past few decades (Brownson, Boehmer, and Luke 2005; Church et al. 2011), workplace interventions such as sit/stand workstations and active workstations (e.g. treadmill or cycling workstations), which have the potential to alternate physical activity pattern (Carr et al. 2013; Mansoubi et al. 2016) and increase energy expenditure (Rovniak et al. 2014; Elmer and Martin 2014; Levine and Miller 2007), have received increased scientific attention (Kerr et al. 2016; Graves et al. 2015; Tew et al. 2015; Shrestha et al. 2015).

The effects of sit/stand and active workstations on cognitive performance have mainly been studied in laboratory settings and the findings are somewhat inconsistent and controversial (Neuhaus et al. 2014; Russell et al. 2015). Working in motion (e.g. cycling or walking) leads to performance decreases in motor tasks such as mouse moving or finger tapping (Koren, Pišot, and Šimunič 2016; Ohlinger et al. 2011; Straker, Levine, and Campbell 2009), and performance appears to be modulated by the level of physical activity (Funk et al. 2012; Straker, Levine, and Campbell 2009). Similarly, decrements in arithmetic performance have been found (John et al. 2009). Non-motor cognitive skills such as reading (John et al. 2009; Commissaris et al. 2014), attention (John et al. 2009; Ohlinger et al. 2011), and working memory (Bantoft et al. 2015) appear to be unaffected. Accuracy seems to be affected by these workstations; however, the current findings show contradictory effects, making the nature of the association difficult to ascertain (Commissaris et al. 2014; Ghesmaty Sangachin, Gustafson, and Cavuoto 2016). When comparing findings of standing to sitting workstations, standing does not appear to alter reading skills (Commissaris et al. 2014), working memory (Bantoft et al. 2015; Russell et al. 2015) or arithmetic problem solving (Karakolis, Barrett, and Callaghan 2016), while contradictory effects on motor tasks (Ghesmaty Sangachin, Gustafson, and Cavuoto 2016; Karakolis, Barrett, and Callaghan 2016; Straker, Levine, and Campbell 2009) and attention (Schraefel, Jay, and Andersen 2012) have been found. Despite numerous studies of standing and sit/stand workstations, the effect of sit-to-stand transitions and sitting time reduction on cognitive performance has rarely been investigated. Currently, there are only a few studies that quantify the effects of sit-to-stand transitions and those studies are limited to short-term effects (Karakolis, Barrett, and Callaghan 2016; Schwartz et al. 2017). Further, to our knowledge, besides a small number of studies investigating productivity (Garrett et al. 2016), no randomised controlled trial determining the mid-term effect of a sit/stand workstation on cognitive parameters exists. However, there are several physiological and cognitive pathways potentially leading to alternations in cognitive performance when using sit/stand workstations for prolonged periods.

Sit/stand workstations can influence physical activity (Mansoubi et al. 2016), sitting time (Shrestha et al. 2016) and the intensity level of back pain (Agarwal, Steinmaus, and Harris-Adamson 2017). Due to higher activities and volumes in the prefrontal cortex (Loprinzi et al. 2013), physical activity can positively influence cognitive performance parameters like attention, memory or executive functions (Loprinzi et al. 2013; Colcombe and Kramer 2003; Ratey and Loehr 2011). In addition, physical activity as well as regular sitting breaks can induce positive effects on waist circumference, triglycerides, postprandial plasma insulin (Peddie et al. 2013; Healy et al. 2008), cardio-respiratory fitness and daily energy consumption (MacEwen, MacDonald, and Burr 2015; Swartz, Squires, and Strath 2011). These physiological parameters are related to higher-cerebral blood flow (Ratey and Loehr 2011), being overweight or obese (Hu et al. 2003; J. O. Hill et al. 2003; Must and Tybor 2005), and subsequently are connected to human well-being and working productivity (Puig-Ribera et al. 2015; Pronk and Kottke 2009). Due to the relationship between well-being and physiological stress (Llewellyn et al. 2008; Allerhand, Gale, and Deary 2014) and physiological stress and cognitive performance (Marin et al. 2011; Shields, Bonner, and

Moons 2015; Lupien et al. 2009) direct improvements in well-being found for reduced sedentary time (Karakolis and Callaghan 2014; Karakolis, Barrett, and Callaghan 2016) might improve cognitive performance, too.

Pain – another influencing factor for physical activity (Boutevillain et al. 2017; Schaller et al. 2017) – can also affect attention, memory and accuracy (D. J. Moore, Keogh, and Eccleston 2012; Dick, Eccleston, and Crombez 2002; Attridge et al. 2015) due to its ability to bias cognitive demands (D. J. Moore, Keogh, and Eccleston 2012). Especially as pain (chronic & acute) can influence cognitive performance (D. J. Moore, Keogh, and Eccleston 2012; Dick, Eccleston, and Crombez 2002; Attridge et al. 2015) and as working in alternating body postures and on sit/stand workstations can positively influence the development of musculoskeletal pain (Gallagher, Campbell, and Callaghan 2014; Fewster, Gallagher, and Callaghan 2017), it is possible that reduced pain intensities for sit/stand workstation users (Agarwal, Steinmaus, and Harris-Adamson 2017) might result in improved cognitive performance.

Lastly, studies have shown that interrupting continuous sitting by implementing sitting breaks (e.g. light intensity walking or standing period) can positively influence mental fatigue (Wennberg et al. 2016; Thorp et al. 2014) which is related to several cognitive performance parameters (Kaplan et al. 2016) and can be influenced by task duration and motivation (Ishii, Tanaka, and Watanabe 2014; R. D. Moore et al. 2012). In particular there is an interaction between mental fatigue and accuracy, characterized by increasing error rates as fatigue levels rise (Faber, Maurits, and Lorist 2012). Thus, sit/stand workstations might positively influence cognitive performance by reducing mental fatigue caused by continuous sitting.

In summary, although physiological alterations caused by sit/stand workstation usage have been investigated (Gallagher, Campbell, and Callaghan 2014; Peddie et al. 2013; Healy et al. 2011), their effect on cognitive performance – especially for the mid- and long-term use – is unclear. Hence, based on previously reported short-term findings (Schwartz et al. 2017), the primary aim of this study was to report the mid-term effect of a two-desk sit/stand workstation on cognitive performance (working speed, reaction time, concentration performance, accuracy) and workload under controlled laboratory conditions. As a sedentary lifestyle is related to declines in cognitive performance (Colcombe and Kramer 2003; Yaffe et al. 2001) and well-being (Hamer and Stamatakis 2014) and based on the physiological and psychological pathways induced by sit/stand workstations (less sitting time, less pain development, higher physical activity), we hypothesized that working at a sit/stand workstation for several consecutive weeks would positively influence cognitive performance and workload.

2. Methods

2.1 Participants

Participants were recruited via e-mail by a regional health insurance provider (*"Oberoesterreichische Gebietskrankenkasse"*) between August and September 2013. Seminars providing study details to interested parties (e.g. study goals & methodology) were held by the study leader (BS) at respective company sites. Subsequent personal interviews were executed by BS to ascertain subjects' eligibility for the study. After the consideration of the inclusion and exclusion criteria, a total of 18 out of 36 office workers between 21 and 53 years (10 male / 8 female) participated in this study (Figure 1) between January 2014 and March 2015. According to the exclusion criteria, these participants - employed at five different companies - did not report any acute or chronic diseases (a) and had at least high school education (b). They were used to working at a computer predominantly in a sitting posture (c) and had no prior experience with sit/stand workstations (d). They were not: heavily overweight or obese (BMI > 27.5 kg/m², (e)), colour blind (f), pregnant (g), unable to stand (i), regular smokers (> 1 cigarette/day, (j)), did not have any visual impairments that had not been corrected (k) and did not plan to go on holiday during the intervention period (g).

Demographic information including age, sex, weekly sitting hours and physical activity was collected from each participant by a questionnaire (Table **1**). All study participants gave their written consent to participate prior to involvement in the study. The study was approved by the Ethics Committee of the University of Vienna (Reference number: 00052) and was registered at ClinicalTrials.gov (Identifier: NCT02825303, July 2016). A detailed description of the study protocol (exclusion and inclusion criteria, sample size calculations and screening) was published elsewhere (Schwartz et al. 2016).

2.2 Study design

In this two-arm, randomised controlled cross-over trial, 18 office workers randomly recruited via e-mail by a regional health insurance were randomly allocated to either an intervention arm (study arm I) or a control arm (study arm II) by means of a covariate adaptive randomization (Kang, Ragan, and Park 2008). According to the cross over design of this study, arm I participants were randomly allocated to two different subgroups (Figure 1). Due to the nature of the intervention, participants were not blind to their allocation.

2.3 Intervention & control period

Depending on group allocation, study arm I participants' traditional workplaces were replaced by a two-desk sit/stand workstation either in the first or second half of the study (Figure 1). These novel workstations were installed by BS one day prior to the intervention period and consisted of two identical height-adjustable desks (Aluforce Pro 110 HC, Actiforce, Amersfoort, Netherlands) placed in close proximity to each other (Figure 2). Each desk was equally furnished (screen, mouse, keyboard) and configured to either standing or sitting height to enable sit-to-stand transitions without any desk adjustments. Adjustments were executed according to ergonomic recommendations (European commitee for standardization 1998) and the participants' preferences. Preferred table arrangements (e.g. 0°- Figure 2 C/D, 90° - Figure 2 B and 180° - Figure 2 A) were chosen by the participants and, depending on their pre-intervention working conditions, either one or two screens per desk were used (1 per desk - Figure 2 A/B/D or 2 per desk - Figure 2 C). Detailed workstation descriptions were previously published (Schwartz et al. 2016).

During the control periods (study arm I & II) participants worked at traditional, seated workstations. Study arm II (control arm) was implemented to obtain information about the within-group changes in cognitive performance for an unbiased (no intervention) study group.

2.4 Wash out phase

Six-week wash out phases were embedded between intervention and control periods (Figure 1) to diminish practice effects on cognitive parameters and to enable similar starting conditions for each participant (i.e. using a traditional workstation prior to pre-intervention measurements). During the wash out phase all participants worked at traditional workstations.

2.5 Environmental conditions

Participants underwent four one-day, laboratory assessments. These measurements were done during their paid working time one day prior (baseline) or after (23 weeks) each 23-week interval (Figure 1). Participants were asked to refrain from exercise, caffeine, alcohol and undue stress for 24 hours prior to laboratory testing. To avoid fluctuations of performance due to time of day, measurements always started between 1:30 pm and 2:45 pm. All measurements were executed in a laboratory exhibiting controlled temperature, air flow, humidity, lighting conditions (artificial light only) and noise level.

2.6 Study protocol

The study protocol, described in detail by Schwartz et al., (2016), consisted of completion of two questionnaires (International Physical Activity Questionnaire - IPAQ and NASA Task Load Index - NASA TLX), resting periods, and a test-battery. The study protocol took approximately 4 - 4.5h to complete and was designed to assess reaction time, cognitive performance, working speed, accuracy, workload, physical activity and sedentary behaviour (

Figure 3). Three cognitive tests (text editing task, digital Stroop-Word-Colour-Conflict test, d2R-test of attention) characterized by high test-retest reliability (r = 0.77–0.95) were realized within the test-battery (Brickenkamp, Schmidt-Atzert, and Liepmann 2010; Franzen et al. 1987; Van der Elst et al. 2006; MacLeod 2005; Mead et al. 2002).

To simulate alternating working postures, the test-battery was repeated five times in alternating postures (sit-stand-sit-stand-sit). To increase data quality, pilot runs (first battery) were excluded from data analysis, while the remaining batteries (battery 2 to 5) were merged together for day-wise baseline/23weeks comparisons.

As physiological stress can bias cognitive performance (McCormick et al. 2007), heart rate and salivary cortisol measurements were implemented to determine participants' stress states via mobile ECGs (medilog AR12 plus, Schiller AG, Baar, Switzerland) and cortisol ELISAs (ACCESS Cortisol - Ref: 33600, Beckman Coulter, Brea, USA), respectively. Cortisol measurements - collected via Salivette (Sarstedt, Sevelen, Switzerland) - were conducted during each break implemented in the study protocol (Figure 3). Saliva samples were centrifuged at 1000 rpm for 2 min (room temperature) and stored at -80°C for later analysis. To avoid intra-assay variability, all cortisol analyses were conducted in a single batch after the study.

Heart rate was continuously measured during the day assessments until the next morning. Cortisol level and heart rate were clustered in 'pre-testing' (rest period before executing the cognitive batteries), 'testing' (while executing cognitive batteries) and 'post-testing' (rest period after executing the cognitive batteries) conditions. Contrary to the cortisol level which was calculated by the mean value of 5 battery-based cortisol measurements (see Figure 3), the heart rate for the time point 'testing' represented the mean value for the whole battery-based time interval (approx. 2.5 h). In addition to the primary aim (i.e. control participants' physiological stress), this 'stress control procedure' made it possible to analyse possible differences in stress responses between traditional and sit/stand workstation users during the test procedure.

2.7 Data processing

Due to the study's cross over design, study arm I interventional (sit/stand workstation) and control (traditional workstation) periods, as well as both periods of study arm II (traditional workstation), were merged to enable appropriate data analysis (Figure 4). Reaction time and working speed were automatically measured and recorded using MATLAB (MathWorks®, Natick, MA), while d2r-test results were manually analysed and digitized by BS. To reduce practice effects biases for cognitive tests, the first tests within the first battery of each measuring day were excluded from statistical analysis. Identically to our initial, short-term study (Schwartz et al. 2017), data preparation and Stroop-test outlier elimination (values that differed by more than 3 standard deviations from a subject's mean) were performed using MATLAB to reduce errors due to occasional violations of the protocol (e.g. asking the investigator a question mid-test and thereby missing their cue). In total 1.39% of all reaction time trials (2.63 ± 1.33 items per trial per person – equally distributed between participants and ranging from 0 to 7 items per trial) were excluded during the automated outlier elimination procedure. No group-related outlier (values that differed by more than 3 standard deviations from a study collective mean) was found for reaction time, text editing speed or concentration performance.

In addition, one participant from study arm I and one from study arm II were excluded from data analysis due to elevated cortisol levels (values were outside of the limit of 3 standard deviations).

2.8 Statistical analysis

Statistical analyses were conducted using SPSS version 23 for Windows (SPSS Inc., Chicago, IL, USA). Standard statistical methods were used for the calculation of means and standard deviations. To test for normality and homogeneity of variance, Shapiro-Wilk-tests and Levene-tests were used, respectively. A two-way multivariate analysis of variance (2x2 MANOVA) was performed to compare cognitive performance test scores by group (sit/stand vs. traditional workstation), time (baseline vs. 23 weeks) and the interaction of both. Two-way repeated measures ANOVAs (3x2) were used to estimate time effects (pre-testing vs. testing vs. post-testing) on physiological (cortisol level and heart rate) and cognitive parameters, when the normality condition was satisfied. Additional two-way repeated measures ANOVAs (3x4) were executed to determine the battery-based practice effect (battery 2 vs. 3 vs. 4 vs. 5) for each cognitive test. Furthermore, one-way ANOVAs performing group comparison were executed. When the assumption of sphericity was not met, the significance of F-ratios was adjusted according to the Greenhouse-Geisser procedure. Friedman- and Kruskal-Wallis-tests were used when normality conditions were not satisfied.

For normally distributed data, paired and unpaired t-tests were used to show raw data differences between baseline and 23 weeks follow-up as well as 'sit/stand workstation' and 'traditional workstation' conditions, respectively. For violations of normality non-parametric equivalents were applied (Mann-Whitney-U & Wilcoxon signed-rank tests). Chi-squared tests were used for ordinal scales values. In general, two-sided tests with an alpha risk of 0.05 and a beta risk of 0.2 were accepted and effect sizes for multivariate analysis (partial eta squared) were calculated

3. Results

3.1 Participants' characteristics

Independent t-tests and chi-squared tests confirmed that there weren't any between-group differences for participants' characteristics at baseline (Table **1**).

3.2 Missing values

Based on insufficient sampling, 3 out of 576 cortisol measurements were lost. Missing values were replaced by means of the Expectation-Maximization-model (EM). No further data loss occurred during the study.

3.3 Performance (study arm I: sit/stand vs. traditional workstation)

A two-way MANOVA was executed for the intervention group to determine the effect of time (between day differences: baseline vs. 23 weeks), group (between-group differences: sit/stand workstation vs. traditional workstation (I)) and the interaction 'time x intervention' (temporal changes: sit/stand workstation vs. traditional workstation (I)) on cognitive performance. MANOVA showed no significant difference in working speed, concentration performance and reaction time between groups (Wilk'sΛ= 0.918, $F_{(3,38)}=1.131$, $p=0.349$, partial $\eta^2=0.082$), time (Wilk'sΛ=0.951, $F_{(3,38)} = 0.658$, $p=0.583$, partial $\eta^2=0.049$) and the interaction 'group x time' (Wilk'sΛ=0.991, $F_{(3,38)} = 0.113$, $p=0.952$, partial $\eta^2=0.009$).

3.4 Cognitive Parameters

Repeated measures ANOVAs were executed to determine the effects of time (between day differences: baseline vs. 23 weeks), group (between-group differences**:** sit/stand workstation vs. traditional workstation (I) vs. traditional workstation (II)) and the interaction 'time x group' (time alteration between groups) on working speed, reaction time, concentration performance and workload (Table 2).

Repeated measures ANOVAs showed significant differences in time for working speed ($F_{(1,29)}=14.890$, $p<0.001$, partial $\eta^2=0.339$), reaction time ($F_{(1,29)}=8.715$, $p=0.006$, partial $\eta^2=0.231$) and concentration performance ($F_{(1,29)}=35.826$, $p<0.001$, partial $\eta^2=0.553$), which likely represent practice effects. There was no evidence of practice effect for perceived workload ($F_{(1,29)}=0.041$, $p=0.841$, partial $\eta^2=0.001$). Further, based on baseline differences for study arm II participants, between-group differences were found for reaction time

($F_{(2,29)}$=4.358, p=0.022, partial η^2=0.231) and workload ($F_{(2,29)}$=4.407, p=0.021, partial η^2=0.233).

Based on significantly smaller baseline values for the traditional workstation (I) period (**Table 3**) time-related changes for concentration performance differed between groups ($F_{(2,29)}$=3.878, p=0.032, partial η^2=0.211). Contrary to this, no 'group x time' effect was found for the remaining cognitive parameters (p>0.05).

Accuracy rates did not differ between groups for Stroop- and d2R-test tasks. Contrary, text editing accuracy significantly improved (p=0.033) post-intervention for the intervention period (Table **3** , detailed information see Appendix).

3.5 Stress response

Repeated measures ANOVAs were executed to determine the effect of time (pre-testing vs. testing vs. post-testing), group (sit/stand workstation vs. traditional workstation (I) vs. traditional workstation (II)) and the interaction 'time x group' (time alteration between groups) on salivary cortisol level and heart rate.

At baseline, repeated measures ANOVAs for salivary cortisol levels showed a significant difference in time ($F_{(1.337, 38.768)}$=24.339, p<0.001, partial η^2=0.456), but not for group ($F_{(2,29)}$=0.477, p=0.625, partial η^2=0.032) and the interaction 'group x time' ($F_{(2.674, 38.768)}$=0.627, p=0.584, partial η^2=0.041). Contrary, repeated measures ANOVA for salivary cortisol levels at 23 weeks follow-up showed significant differences for interaction 'group x time' ($F_{(4,58)}$=4.033, p=0.006, partial η^2=0.218), while 'time' ($F_{(2, 58)}$=19.880, p<0.001, partial η^2=0.407) remained significant. Group effects remained non-significant for post-intervention analysis ($F_{(2,29)}$=0.811, p=0.454, partial η^2=0.053).

At baseline, repeated measures ANOVAs for heart rates showed significant differences in time ($F_{(2,58)}$=130.351, p<0.001, partial η^2=0.818) and the interaction 'group x time' ($F_{(4,58)}$=0.382, p=0.821, partial η^2=0.026), but not for group alone ($F_{(2,29)}$=0.016, p=0.985, partial η^2=0.001). Similar conditions have been shown for time ($F_{(2,58)}$=97.185, p<0.001, partial η^2=0.770), group ($F_{(2,29)}$=0.427, p=0.657, partial η^2= 0.029) and the interaction 'group x time ' ($F_{(4,58)}$ = 0.471, p=0.757, partial η^2= 0.031) for heart rates at 23 weeks follow-up. Paired t-tests (Bonferroni corrected, p=0.025) showed time dependent changes for salivary cortisol level and heart rate primarily between pre-testing, testing and post-testing conditions (Table 4). Furthermore, a baseline/23 weeks effect on the post-testing cortisol level (p=0.027) was found for the sit/stand workstation group (Table 4 , detailed information see Appendix).

3.6 Sedentary behaviour

Sitting time on occupational days for the sit/stand workstation period significantly decreased by 2.85 hours per day (p=0.010), but remained stable for the traditional workstation periods (p>0.05). Furthermore, a weekly (5 occupational days & 2 weekend days) sitting time reduction of 12.65 hours per week (p=0.034) for the sit/stand workstation period occurred (Table 4). For the traditional workstation periods sitting time for weekend days and the whole week increased in study arm II (p<0.05), but not in study arm I (p>0.05). Physical activity remained stable for both study arms.

4. Discussion

This study - based on a previous short-term (1day) study with 45 students (Schwartz et al. 2017) - represents the first randomised controlled trial examining the mid-term effect (23-weeks) of a sit/stand workstation (traditional vs. sit/stand) on cognitive performance and workload in healthy office workers of working age.

4.1 Comparisons to prior studies

Contrary to our hypothesis, we found no evidence indicating mid-term changes in cognitive performance when considering reaction time, working speed and concentration. These findings are consistent with short-term findings reporting no differences in cognitive performance for alternating postures (Karakolis, Barrett, and Callaghan 2016; Schwartz et al.

2017) or sit-to-stand comparisons (Russell et al. 2015; Knight and Baer 2014; Straker, Levine, and Campbell 2009; Ohlinger et al. 2011) as well statements by Grunseit et al. (2013) indicating no altered performance for mid-term usage of sit/stand workstations.

Our current findings contradict those of Garrett et al. (2016) that productivity for people working in a standing position during 6 months of sit/stand workstation use, as well as those of Schraefel, Jay, and Andersen (2012) that showed a performance decrement when standing. However, significant baseline differences exhibited in the study by Garrett et al. (2016) are likely to have been caused by a missed gender and seniority balancing. Hence the effect of sit/stand workstations on performance in that study may have been overestimated. Similarly, the subjects in the Schraefel, Jay, and Andersen (2012) study were working with screen and keyboard heights that were inconsistent with current ergonomic recommendations (European commitee for standardization 1998) and it is well established that insufficient ergonomic design can alter performance (Dellerman, Haslegrave, and Chaffin 2004) and can lead to musculoskeletal problems (Ariëns et al. 2000). Therefore, it is likely that the exhibited performance decrement in that study was caused by inappropriate standing conditions rather than body posture per se.

4.2 Effects on reaction time, working speed and concentration performance

Postural changes can have a positive influence on several physiological parameters (Healy et al. 2008; Peddie et al. 2013) and increased sedentariness is related to poor cognitive performance (Colcombe and Kramer 2003; Yaffe et al. 2001), thus we hypothesized that facilitating sitting breaks, postural changes as well as increased standing time would influence cognitive performance in a positive way. Several factors might be responsible for the missing proof of our hypothesis. Nevertheless, the results from this mid-term analysis - in-line with the previously reported short-term findings (Schwartz et al. 2017) - failed to provide evidence of changes in cognitive performance.

It is conceivable that the relatively small increase in physical activity for sit/stand workstation users (Júdice et al. 2016; Levine and Miller 2007) - paired with unaffected physical activity in this study - was simply not strong enough to induce the hypothesized changes in performance. This supposition is supported by prior investigations of office ergonomics that have shown altered performance for relatively more physically intensive activities, such as walking (Commissaris et al. 2014; John et al. 2009) or cycling (Koren, Pišot, and Šimunič 2016; Straker, Levine, and Campbell 2009), and have further shown that intensity levels (Koren, Pišot, and Šimunič 2016; Straker, Levine, and Campbell 2009) as well as self-determination (Funk et al. 2012) can further influence this relationship.

While the two-desk sit/stand workstation used in this study reduced the average sitting time of the sit/stand workstation users by approximately 171 minutes per occupational day, these workstations - similar to other sit/stand workstations (Straker et al. 2013; Kerr et al. 2016) - might not have sufficiently improved frequency of postural changes (i.e. > 2 sit/stand transitions per hour) and this lack of regularity of postural changes during intervention periods might have negatively affected study findings. Specifically, the frequency of body posture alternations might have been insufficient to induce changes in physiological parameters related to cognition or to compensate possible novelty effects of the study protocol (i.e. decreased performance due to executing cognitive tests in unusual working postures).

Interestingly, baseline/follow-up differences between study groups exhibited mixed results according to single cognitive performance parameters. For concentration performance strong effects occurred between study arm I subgroups (sit/stand vs. traditional workstation), but not between study arm comparisons (i.e., arm I vs. arm II). It is likely that baseline differences - possibly caused by an insufficient wash out phase - paired with ceiling effects for concentration performance are the reason for this circumstance. Strong group-independent practice effects, consistent with the short-term study results (Schwartz et al. 2017) and common for multiple usage (Nuechterlein et al. 2008; Russell et al. 2015; Wennberg et al. 2016), could have led to ceiling effects within the d2R-test (Brickenkamp, Schmidt-Atzert, and Liepmann 2010). These ceiling effects can attenuate performance increases and therefore lead to underestimated time dependencies (Brickenkamp, Schmidt-Atzert, and Liepmann 2010). Normative values for the d2r-test (i.e. participants´ performance better than 90% of their age cohort (Brickenkamp, Schmidt-Atzert, and Liepmann 2010)) support this claim.

In general, an insufficient statistical power found in our study and strong practice effects - common for repetitive measurements (MacEwen, MacDonald, and Burr 2015; Lemay et al. 2004) - may have influenced our findings. This study was the first RCT evaluating the mid-term effect of working at a sit/stand workstation on cognitive performance. It was powered for sedentary behaviour changes and similar to short-term study findings (Schwartz et al. 2017) the very small effect sizes found in this study limited our statistical power.

4.3 Effects on accuracy

In this study, text editing accuracy (not part of the MANOVA due to violation of normality) significantly increased between intervention and control periods, while accuracy for Stroop- and d2R-tests was not altered. These findings are inconsistent with earlier sit/stand comparisons, indicating unchanged short-term reading (Commissaris et al. 2014; Russell et al. 2015), typing (Straker, Levine, and Campbell 2009; Commissaris et al. 2014) and reaction time task accuracies (Bantoft et al. 2015). Participants in this study were regular office workers who were familiar with writing or editing documents during working hours. Executing these tasks in alternating postures over a longer period may have led to habituation effects, resulting in higher accuracies. Furthermore, sit/stand familiarization may have diminished additional physical efforts reported due to standing (Grunseit et al. 2013) and subsequently might have led to less mental fatigue (Wennberg et al. 2016). As simple tasks (e.g. reaction time tasks, automatic tasks) are less affected by sleepiness (Cerasuolo et al. 2016; Kaplan et al. 2016) than highly demanding cognitive tasks, this would further explain differences between the implemented tests. Due to the test structure and contrary to the text editing task, the Stroop- and d2R-test strongly depend on reaction times and automation.

4.4 Effects on workload

Perceived workload determined by the NASA TLX questionnaire is highly related to mental and physical efforts as well as job satisfaction (Hart, California, and Staveland 1988). Changes in working posture can alter physiological wellbeing, which leads to alternations in work satisfaction and productivity (Garrett et al. 2016). Working in a standing posture negatively influences discomfort located in lower extremities (Neuhaus et al. 2014), while sit-to-stand transitions decrease physiological discomfort (Karakolis, Barrett, and Callaghan 2016), fatigue (Wennberg et al. 2016) and improve mood states (Pronk et al. 2012).

However, contrary to our expectations, workload alternations (pre vs. post) in this study did not differ between groups. The small difference in physical activity between working in alternating postures and sitting positions (Júdice et al. 2016; Barone Gibbs et al. 2017) might be one reason for this situation. As previously shown, workload perception is related to the intensity level of physical activity (Ghesmaty Sangachin, Gustafson, and Cavuoto 2016) as well as the need for recovery (Sonnentag and Zijlstra 2006). It seems possible that the additional physical effort caused by standing periods and postural changes might be too small to induce changes in workload. Previous investigations (Schwartz et al. 2017) exhibiting similar results would underpin this approach.

Nevertheless, as workload is also related to musculoskeletal symptoms (Byström, Hanse, and Kjellberg 2004) as well as mental fatigue (Hockey and Earle 2006; Rydstedt, Johansson, and Evans 1998), sit-to-stand transitions with the potential to induce alterations in physiological and mental parameters (Karakolis, Barrett, and Callaghan 2016; Pronk et al. 2012) should have led to improvements in workload. This discrepancy might be explained by the structure of the study protocol. To ensure appropriate statistical analysis, sitting as well as standing periods lasted for the same duration of time. This unpreferred 1:1 sit-to-stand ratio (Sheahan, Diesbourg, and Fischer 2016) led to unfamiliar test conditions for both traditional as well as sit/stand workstation users. Hence, habituation effects which may have resulted in altered workloads are marginally small. Furthermore, as predetermined physiological efforts (i.e. walking speed during work or postural change pattern) can influence cognitive parameters (Funk et al. 2012) or personal well-being (Sheahan, Diesbourg, and Fischer 2016), predefined sit-to-stand ratios might have biased the study results. A recent meta-analysis (Agarwal, Steinmaus, and Harris-Adamson 2017) exhibiting stronger reductions in discomfort for people following their personal body posture preferences while working underpins this thesis.

Lastly, baseline between-group differences, also described in previous research (Schwartz et al. 2017) were found in this study. A missing weighting procedure for the NASA TLX items can explain this between-group differences.

4.5 Effects on stress response

Salivary cortisol level and heart rate were measured within this study to detect possible bias on cognitive performance caused by physiological stress. For two participants (2/18) the dramatically elevated cortisol levels (above the maximum allowed threshold) led to data exclusion. For the remaining participants (approx. 90 %) statistical analysis showed no difference in cortisol levels between groups. Hence, a feasible bias due to different stress levels can be excluded.

Nevertheless, unexpected differences in cortisol levels for the sit/stand workstation users occurred at the 23 weeks follow-up. In contrast to heart rate, which did not differ between groups, cortisol slopes were altered. Compared to traditional workstation users, sit/stand workstation users' cortisol level did not follow the cortisol drop during 2.5 hours of cognitive testing, which further led to higher post-testing cortisol levels.

As previous investigations of sit/stand workstations have not included cortisol measurements and as the relationship between cortisol levels and cognitive performance under non-stress situations has not been investigated yet (contrary to chronic stress which was shown to be related to cognitive declines (Marin et al. 2011)), the interpretation of the post-testing cortisol differences is particularly challenging and should be handled with care.

In general, cortisol, the prevailing hormone in the glucocorticoid group (Stachowicz and Lebiedzińska 2016), can be influenced by several environmental conditions like age (Aardal and Holm 1995), gender (Nater et al. 2007; Marin et al. 2011) as well as mental fatigue (Leproult, Buxton, and Cauter 1997). It is commonly used to estimate stress (Almela et al. 2011; Bakke et al. 2004; Goldfarb et al. 2017) and characterized by a steadily drop in the afternoon hours (Nater et al. 2007; Leproult, Buxton, and Cauter 1997; Oosterholt et al. 2015). Although these daytime-related decrements in cortisol occurred in our study too, less pronounced drops for the intervention period follow-up might be induced by an additional effect.

States of fatigue (Pronk et al. 2012; Ellegast, Weber, and Mahlberg 2012) as well as perceived stress (Pronk et al. 2012), mainly determined by questionnaires, can be positively affected by sit/stand workstations. To our knowledge this dampened cortisol slope might be caused by lower states of boredom and mental fatigue induced by sit-to-stand transitions. Boredom is inversely correlated with cortisol levels (Merrifield and Danckert 2014), while repetitive tasks can lead to increased mental fatigue (Hasegawa et al. 2001). Contrary to this, sit-to-stand transitions can reduce monotonous feelings of fatigue while executing repetitive tasks

(Hasegawa et al. 2001). Additional physical effort, caused by standing periods, might lead to higher fatigue for traditional workplace users, while sit/stand users might not be affected due to habituation effects. Lastly, as meal consumption (Stachowicz and Lebiedzińska 2016), coffee intake (Stachowicz and Lebiedzińska 2016) and physical activity (E. E. Hill et al. 2008) can affect cortisol levels, too, it is also possible - even if the likelihood due to unaltered heart rates and physical activities is quite small - that a violation of the study protocol was the reason for the cortisol drop difference. Further research is necessary to investigate the causal chains behind this effect.

4.6 Strengths and limitations

To our knowledge, this study is the first randomised controlled trial examining the mid-term effect of two-desk sit/stand workstations on cognitive performance under laboratory conditions. Strengths of this study were stringent inclusion criteria, minimally biased measuring environments and appropriate statistical methods. A cross-over design diminishing inter-personal differences, balanced gender distribution and an independent recruiting process (a smaller recruiting bias as participants were recruited by an independent regional health insurance) add to the strength of the study results. Contemporary ergonomics recommendations were used when setting up the workstations and the dual-workstation approach ensured that optimal conditions could be met for both sitting and standing conditions. In addition, in comparison to previous studies (Alkhajah et al. 2012) none of the participants worked in the ergonomic or health-related sector.

Nevertheless, due to the small sample size the power of this study was limited. Further, although there are gender differences in performance (Bates and Lemay 2004; Tun and Lachman 2008) gender stratification was not possible. An equal gender distribution as well as the cross-over design within the intervention group minimized this potential bias.

As described by Schwartz et al., (2016) this study was intended to quantify the short- and mid-term effects of using a sit-stand intervention device strategy. With this design it is not possible to draw any conclusions about the long-term sustainability of the measured differences in performance. Multi-year, prospective studies are needed to test the efficacy of sit-stand technologies, devices and administrative strategies in regard to cognitive performance.

5. Conclusion

This study was the first randomised controlled trial investigating the mid-term effect of a two-desk sit/stand workstation on working performance. It demonstrated no differences in reaction time, concentration performance or working speed. However, text editing accuracy as well as salivary cortisol levels significantly increased for sit/stand users, suggesting that the intervention induced lower mental fatigue states. Due to the small sample size of this study, results should be interpreted with care despite the randomised controlled trial design. Multi-year, prospective studies are needed to test the long-term efficacy of sit-stand workstations in regard to cognitive performance.

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Table 1: Participants' socio-demographic, work and health characteristics

	All (n=18)	Study arm I (n=12)	Study arm II (n=6)	p
Age (years)	36.3 (10.3)	35.7 (9.6)	37.5 (12.5)	0.924
Women	44.4% (8)	50.0% (6)	33.3% (2)	0.499
Caucasian	100.0% (18)	100.0% (12)	100% (6)	1.000
Bachelor degree completed	27.8% (5)	16.7% (2)	50.0% (3)	0.144
Tenue at current workplace				
< 1 year	5.6% (1)	8.3% (1)	0.0% (0)	0.359
1 to <3 years	22.2% (4)	25.0% (3)	16.7% (1)	0.683
3 to <5 years	0.0% (0)	0.0% (0)	0.0% (0)	1.000
5 to <10 years	61.1% (11)	58.3% (7)	66.7% (4)	0.731
≥ 10 years	11.1% (2)	8.3% (1)	16.7% (1)	0.605
1.0 full-time-equivalent	88.9% (16)	83.3% (10)	100% (6)	0.187
Working hours (h/wk)	40.1 (5.8)	39.5 (6.7)	41.4 (3.1)	0.298
Job category				
Managers/professionals	22.2% (4)	16.7% (2)	33.3% (2)	0.432
Clerical/service/sales	77.8% (14)	83.3% (10)	66.7% (4)	0.432
Body mass index (kg/m²)	23.1 (1.8)	23.3 (1.7)	22.6 (2.0)	0.135
Smoking habits				
Current smoker	0.0% (0)	0.0% (0)	0.0% (0)	1.000
Chipper (< 1 cigarette/day)	5.6% (1)	0.0% (0)	16.7% (1)	0.359
Stopped < 10 years ago	16.7% (3)	25.0% (3)	0.0% (0)	0.099
Stopped > 10 years ago	22.2% (4)	25.0% (3)	16.7% (1)	0.683
Never smoker	55.6% (10)	50.0% (6)	66.7% (4)	0.499
Occupational sitting (h/d)	11.0 (1.9)	11.2 (1.8)	10.8 (2.1)	0.669
Physical activity (METmin/wk)	2743 (1373)	2699 (1190)	2830 (1812)	0.855

Table represents means (SD) or % (n), p-values representing differences between study arm participants (χ^2-test, t-test)

Note: Participants (recruited Aug - Sep 2013) were employees of five different companies located in Upper Austria (Austria, Europe)

Table 2: Repeated measures ANOVA results for cognitive parameters

Measure	Time$^{\Delta}$ p	Time$^{\Delta}$ η^2	Group p	Group η^2	Time$^{\Delta}$ x group p	Time$^{\Delta}$ x group η^2
Working speed (words)	<0.001	0.339	0.705	0.024	0.705	0.024
Reaction time (ms)	0.006	0.231	0.022	0.231	0.985	0.001
Concentration performance (a.u.)	<0.001	0.553	0.696	0.025	0.032	0.211
Workload (a.u.)	0.841	0.001	0.021	0.233	0.934	0.005

Δ Within-subject difference (baseline vs. 23 weeks)

Table 3: Working speed, reaction time, concentration performance, workload and accuracy rates for study arm I (sit/stand workstation & traditional workstation) and study arm II (traditional workstation) participants

	Study arm I (n=11)				Study arm II (n=10)	
	Sit/stand workstation		Traditional workstation (I)		Traditional workstation (II)	
	Mean (SD) Median [min, max]		Mean (SD) Median [min, max]		mean (SD) Median [min, max]	
Measure	baseline	23 weeks	baseline	23 weeks	baseline	23 weeks
Text editing task						
Working speed (words)	368.3 (40.5)	376.0 (44.2)	360.7 (34.1)	373.8 (35.8)$^{\Delta}$	346.6 (56.7)	359.0 (63.6)
Errors (%)	0.97 [0.20, 3.96]	0.53 [0.19, 4.20]$^{\Delta}$	0.63 [0.25, 3.56]	1.19 [0.14, 7.49]	0.41 (0.12, 17.02)	0.66 (0.17, 17.01)
Stroop-test						
Reaction time (ms)	846.5 (136.9)	807.0 (106.0)$^{\Delta}$	818.8 (110.8)	782.2 (117.6)	719.0 (80.6)	684.9 (73.2)
Errors (%)	0.40 [0.00, 5.50]	0.66 [0.00, 3.77]	0.93 [0.00, 5.22]	1.33 [0.00, 4.56]	0.73 (0.00, 2.80)	1.00 (0.27, 3.87)
d2R-test						
Concentration performance (a.u.)	213.2 (46.6)	223.8 (45.9)$^{\Delta}$	193.2 (35.9)	216.1 (34.3)$^{\Delta}$	211.3 (37.6)	219.5 (37.5)
Errors (%)	2.97 [0.21, 11.66]	1.45 [0.29, 8.82]	2.41 [0.00, 28.82]	1.47 [0.23, 20.70]	3.46 (0.46, 7.44)	1.89 (0.50, 7.68)
NASA TLX						
Workload (a.u.)	37.0 (13.6)	37.8 (14.4)	35.1 (17.6)	33.6 (17.1)	50.0 (10.8)	49.2 (10.8)

$\Delta p < 0.05$ for within-group difference (baseline vs. 23 weeks)

Table 4: Salivary cortisol level, heart rate, sitting time and heart rate for study arm I (sit/stand workstation & traditional workstation) and study arm II (traditional workstation) participants

	Study arm I (n=11)				Study arm II (n=10)	
	Sit/Stand workstation		Traditional workstation (I)		Traditional workstation (II)	
	Mean (SD)		Mean (SD)		Mean (SD)	
Measure	baseline	23 weeks	baseline	23 weeks	baseline	23 weeks
Cortisol (ug/dl)						
Pre-working	0.55 (0.22)	0.53 (0.20)	0.46 (0.14)	0.56 (0.14)	0.46 (0.22)	0.46 (0.14)
Working condition	0.44 (0.14)	0.48 (0.17)	0.41 (0.12)	0.41 (0.09)**	0.40 (0.11)	0.43 (0.11)
Post-working	0.34 (0.18)*	0.45 (0.19)$^{\Delta}$	0.30 (0.13)**	0.30 (0.11)**	0.33 (0.13)	0.39 (0.17)
Heart rate (bpm)						
Pre-working	68.5 (4.5)	68.6 (10.2)	68.2 (8.5)	67.2 (3.9)	68.8 (3.8)	70.4 (5.1)
Working condition	70.2 (7.0)	71.6 (12.1)	70.3 (8.1)	68.5 (6.9)	69.7 (6.3)	71.9 (6.6)
Post-working	61.6 (5.8)***	60.5 (9.9)	60.6 (7.6)***	59.7 (5.7)***	60.4 (4.6)***	62.1 (5.8)***
Sitting time (h)						
Occupational day	10.88 (2.29)	8.03 (2.07)$^{\Delta}$	11.17 (3.15)	11.06 (2.26)	9.98 (2.80)	11.83 (2.01)
Weekend day	7.56 (2.15)	8.35 (2.50)	8.08 (2.84)	7.10 (2.84)	6.43 (1.76)	9.03 (2.19)$^{\Delta\Delta}$
Week (7 days)	69.50 (13.44)	56.85 (11.58)$^{\Delta}$	71.98 (19.78)	69.48 (15.68)	62.78 (13.66)	77.18 (11.70)$^{\Delta}$
Physical activity (METmin wk^{-1})						
Week (7 days)	3010 (1125)	3500 (2942)	3644 (2162)	3422 (2237)	3032 (1562)	2133 (1355)

*p < 0.05 for within-group difference from pre-working (paired test, Bonferroni corrected)
**p < 0.01 for within-group difference from pre-working (paired test, Bonferroni corrected)
***p < 0.001 for within-group difference from pre-working (paired test, Bonferroni corrected)
Δp < 0.05 for within-group difference (baseline vs. 23 weeks)
ΔΔp < 0.01 for within-group difference (baseline vs. 23 weeks)

Figure 1: CONSORT flow chart

Figure 2: Two-desk sit/stand workstations in real world conditions implemented in the current study for 4 different conditions. A: 180° - 1 screen per desk, B: 90° - 1 screen per desk, C: 0° - 2 screens per desk, D: 0° - 1 screen per desk

Figure 3: Study protocol according to Schwartz et al., (2016) **- adapted from Schwartz et al.,** (2017)

Figure 4: Data analysis scheme

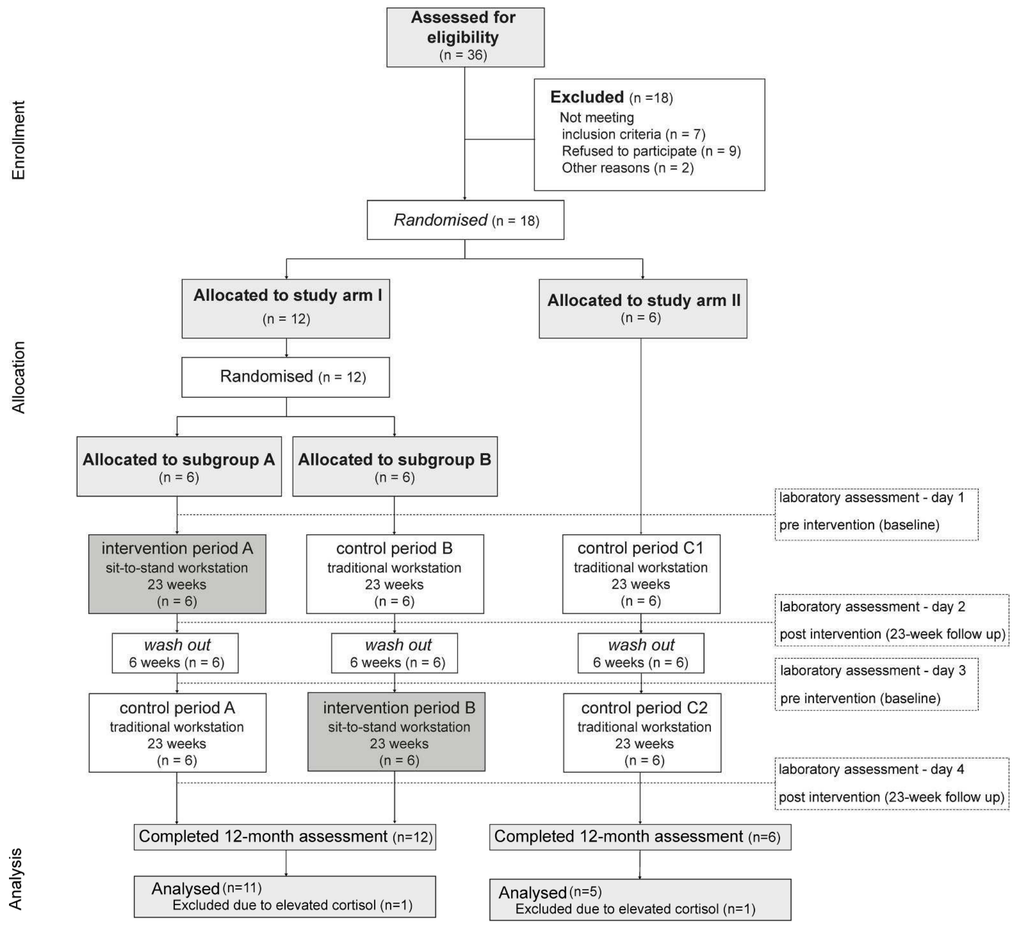

Figure 1: CONSORT flow chart

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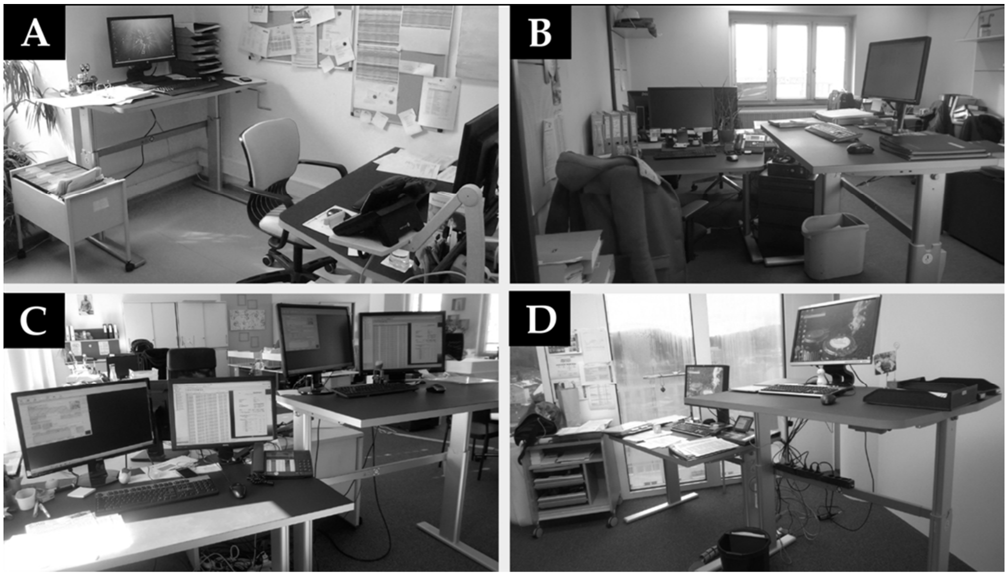

Figure 2: Two-desk sit/stand workstations in real world conditions implemented in the current study for 4 different conditions. A: 180° - 1 screen per desk, B: 90° - 1 screen per desk, C: 0° - 2 screens per desk, D: 0° - 1 screen per desk

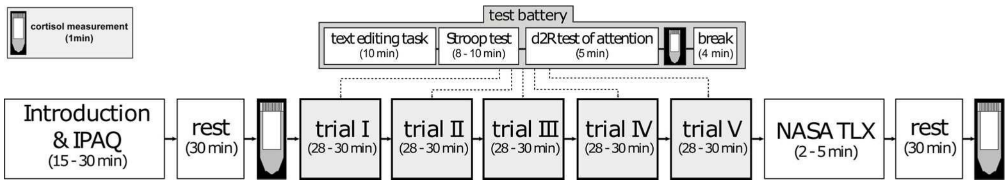

Figure 3: Study protocol according to Schwartz et al., (2016) - adapted from Schwartz et al., (2017)

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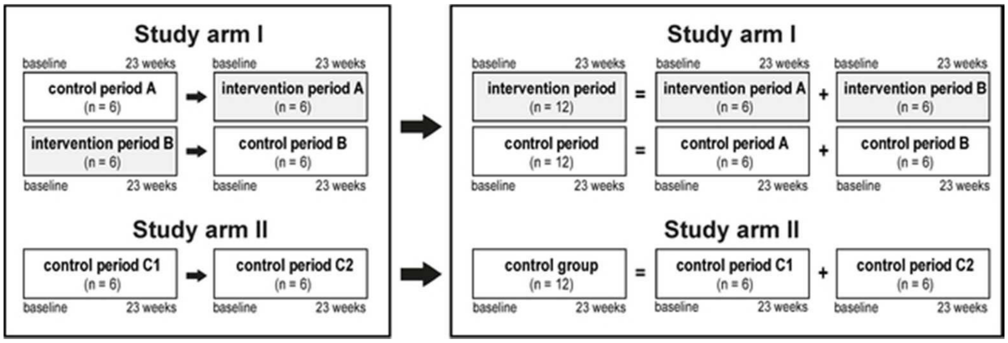
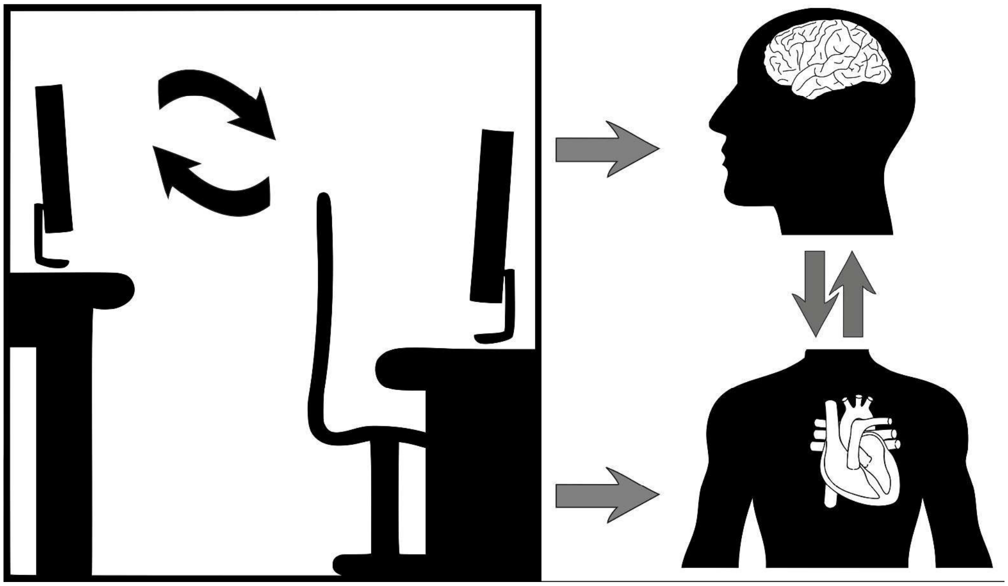


Figure 4: Data analysis scheme

54x18mm (300 x 300 DPI)



GraphicalAbstract1

	All (n=18)	Study arm I (n=12)	Study arm II (n=6)	p
Age (years)	36.3 (10.3)	35.7 (9.6)	37.5 (12.5)	0.924
Women	44.4% (8)	50.0% (6)	33.3% (2)	0.499
Caucasian	100.0% (18)	100.0% (12)	100% (6)	1,000
Bachelor degree completed	27.8% (5)	16.7% (2)	50.0% (3)	0.144
Tenue at current workplace				
< 1 year	5.6% (1)	8.3% (1)	0.0% (0)	0.359
1 to <3 years	22.2% (4)	25.0% (3)	16.7% (1)	0.683
3 to <5 years	0.0% (0)	0.0% (0)	0.0% (0)	1,000
5 to <10 years	61.1% (11)	58.3% (7)	66.7% (4)	0.731
≥ 10 years	11.1% (2)	8.3% (1)	16.7% (1)	0.605
1.0 full-time-equivalent	88.9% (16)	83.3% (10)	100% (6)	0.187
Working hours (h/wk)	40.1 (5.8)	39.5 (6.7)	41.4 (3.1)	0.298
Job category				
Managers/professionals	22.2% (4)	16.7% (2)	33.3% (2)	0.432
Clerical/service/sales	77.8% (14)	83.3% (10)	66.7% (4)	0.432
Body mass index (kg/m²)	23.1 (1.8)	23.3 (1.7)	22.6 (2.0)	0.135
Smoking habits				
Current smoker	0.0% (0)	0.0% (0)	0.0% (0)	1,000
Chipper (< 1 cigarette/day)	5.6% (1)	0.0% (0)	16.7% (1)	0.359
Stopped < 10 years ago	16.7% (3)	25.0% (3)	0.0% (0)	0.099
Stopped > 10 years ago	22.2% (4)	25.0% (3)	16.7% (1)	0.683
Never smoker	55.6% (10)	50.0% (6)	66.7% (4)	0.499
Occupational sitting (h/d)	11.0 (1.9)	11.2 (1.8)	10.8 (2.1)	0.669
Physical activity (METmin/wk)	2743 (1373)	2699 (1190)	2830 (1812)	0.855

Table represents means (SD) or % (n), p-values representing differences between study arm participants (χ^2-test, t-test)

Note: Participants (recruited Aug - Sep 2013) were employees of five different companies located in Upper Austria (Austria, Europe)

Measure	Time$^{\Delta}$		Group		Time$^{\Delta}$ x group	
	p	η^2	p	η^2	p	η^2
Working speed (words)	<0.001	0.339	0.705	0.024	0.705	0.024
Reaction time (ms)	0.006	0.231	0.022	0.231	0.985	0.001
Concentration performance (a.u.)	<0.001	0.553	0.696	0.025	0.032	0.211
Workload (a.u.)	0.841	0.001	0.021	0.233	0.934	0.005

Δ Within-subject difference (baseline vs. 23 weeks)

	Study arm I (n=11)				Study arm II (n=10)	
	Sit/stand workstation		Traditional workstation (I)		Traditional workstation (II)	
	Mean (SD) Median [min, max]		Mean (SD) Median [min, max]		mean (SD) Median [min, max]	
Measure	baseline	23 weeks	baseline	23 weeks	baseline	23 weeks
Text editing task						
Working speed (words)	368.3 (40.5)	376.0 (44.2)	360.7 (34.1)	373.8 (35.8)$^{\Delta}$	346.6 (56.7)	359.0 (63.6)
Errors (%)	0.97 [0.20, 3.96]	0.53 [0.19, 4.20]$^{\Delta}$	0.63 [0.25, 3.56]	1.19 [0.14, 7.49]	0.41 (0.12, 17.02)	0.66 (0.17, 17.01)
Stroop-test						
Reaction time (ms)	846.5 (136.9)	807.0 (106.0)$^{\Delta}$	818.8 (110.8)	782.2 (117.6)	719.0 (80.6)	684.9 (73.2)
Errors (%)	0.40 [0.00, 5.50]	0.66 [0.00, 3.77]	0.93 [0.00, 5.22]	1.33 [0.00, 4.56]	0.73 (0.00, 2.80)	1.00 (0.27, 3.87)
d2R-test						
Concentration performance (a.u.)	213.2 (46.6)	223.8 (45.9)$^{\Delta}$	193.2 (35.9)	216.1 (34.3)$^{\Delta}$	211.3 (37.6)	219.5 (37.5)
Errors (%)	2.97 [0.21, 11.66]	1.45 [0.29, 8.82]	2.41 [0.00, 28.82]	1.47 [0.23, 20.70]	3.46 (0.46, 7.44)	1.89 (0.50, 7.68)
NASA TLX						
Workload (a.u.)	37.0 (13.6)	37.8 (14.4)	35.1 (17.6)	33.6 (17.1)	50.0 (10.8)	49.2 (10.8)

$\Delta p < 0.05$ for within-group difference (baseline vs. 23 weeks)

Measure	Study arm I (n=11) Sit/Stand workstation Mean (SD) baseline	23 weeks	Traditional workstation (I) Mean (SD) baseline	23 weeks	Study arm II (n=10) Traditional workstation (II) Mean (SD) baseline	23 weeks
Cortisol (ug/dl)						
Pre-working	0.55 (0.22)	0.53 (0.20)	0.46 (0.14)	0.56 (0.14)	0.46 (0.22)	0.46 (0.14)
Working condition	0.44 (0.14)	0.48 (0.17)	0.41 (0.12)	0.41 (0.09)**	0.40 (0.11)	0.43 (0.11)
Post-working	0.34 (0.18)*	0.45 (0.19)$^{\Delta}$	0.30 (0.13)**	0.30 (0.11)**	0.33 (0.13)	0.39 (0.17)
Heart rate (bpm)						
Pre-working	68.5 (4.5)	68.6 (10.2)	68.2 (8.5)	67.2 (3.9)	68.8 (3.8)	70.4 (5.1)
Working condition	70.2 (7.0)	71.6 (12.1)	70.3 (8.1)	68.5 (6.9)	69.7 (6.3)	71.9 (6.6)
Post-working	61.6 (5.8)***	60.5 (9.9)	60.6 (7.6)***	59.7 (5.7)***	60.4 (4.6)***	62.1 (5.8)***
Sitting time (h)						
Occupational day	10.88 (2.29)	8.03 (2.07)$^{\Delta}$	11.17 (3.15)	11.06 (2.26)	9.98 (2.80)	11.83 (2.01)
Weekend day	7.56 (2.15)	8.35 (2.50)	8.08 (2.84)	7.10 (2.84)	6.43 (1.76)	9.03 (2.19)$^{\Delta\Delta}$
Week (7 days)	69.50 (13.44)	56.85 (11.58)$^{\Delta}$	71.98 (19.78)	69.48 (15.68)	62.78 (13.66)	77.18 (11.70)$^{\Delta}$
Physical activity (METmin wk^{-1})						
Week (7 days)	3010 (1125)	3500 (2942)	3644 (2162)	3422 (2237)	3032 (1562)	2133 (1355)

*$p < 0.05$ for within-group difference from pre-working (paired test, Bonferroni corrected)
**$p < 0.01$ for within-group difference from pre-working (paired test, Bonferroni corrected)
***$p < 0.001$ for within-group difference from pre-working (paired test, Bonferroni corrected)
$\Delta p < 0.05$ for within-group difference (baseline vs. 23 weeks)
$\Delta\Delta p < 0.01$ for within-group difference (baseline vs. 23 weeks)

Appendix 1: Mean baseline and follow-up (23 weeks) differences for performance parameters and workload for sit/stand workstation and traditional workstation users

	Study arm I (n=11)				Study arm II (n=10)	
	Sit/stand workstation		Traditional workstation (I)		Traditional workstation (II)	
Measure	Mean (95% CI)	p	Mean (95% CI)	p	Mean (95% CI)	p
Text editing task						
Working speed (words)	7.73 (-0.16, 15.62)	0.054	13.14 (0.67, 25.61)	0.041	12.33 (-0.26, 24.91)	0.054
Errors (%)	n.a.	0.033	n.a.	0.374	n.a.	0.139
Stroop-test						
Reaction time (ms)	-39.5 (-78.1, -0.8)	0.046	-36.6 (-97.3, 24.1)	0.209	-34.1 (-74.4, 6.2)	0.088
Errors (%)	n.a.	0.386	n.a.	1.000	n.a.	0.878
d2R-test						
Concentration performance (a.u.)	10.57 (2.50, 18.64)	0.015	22.91 (13.68, 32.14)	<0.001	8.23 (-1.50, 17.95)	0.088
Errors (%)	n.a	0.050	n.a.	0.091	n.a.	0.445
NASA TLX						
Workload (a.u.)	0.76 (-7.76, 9.27)	0.847	-1.52 (-13.88, 10.85)	0.790	-0.83 (-9.58, 7.91)	0.834

Appendix 2: Mean baseline and follow-up (23 weeks) differences for salivary cortisol level, heart rate, sitting time and physical activity for sit/stand workstation and traditional workstation users

	Study arm I (n=11)				Study arm II (n=10)	
	Sit/stand workstation		Traditional workstation (I)		Traditional workstation (II)	
Measure	Mean (95% CI)	p	Mean (95% CI)	p	Mean (95% CI)	p
Cortisol (ug/dl)						
Pre-working (baseline)	-0.02 (-0.16, 0.12)	0.763	0.11 (-0.03, 0.24)	0.112	0.00 (-0.13, 0.13)	1.000
Working condition	0.05 (-0.05, 0.14)	0.305	0.00 (-0.09, 0.10)	0.926	0.03 (-0.08, 0.15)	0.525
Post-working	0.11 (0.02, 0.21)	0.027	0.00 (-0.12, 0.12)	1.000	0.06 (-0.10, 0.22)	0.434
Heart rate (bpm)						
Pre-working (baseline)	0.13 (-4.94, 5.20)	0.955	-0.93 (-5.41, 3.55)	0.653	1.62 (-2.46, 5.70)	0.362
Working condition	1.38 (-3.88, 6.64)	0.572	-1.83 (-6.07, 2.40)	0.357	2.14 (-2.76, 7.04)	0.350
Post-working	-1.04 (-5.65, 3.58)	0.672	-0.93 (-5.04, 3.18)	0.624	1.67 (-1.80, 5.15)	0.304
Sitting time (h)						
Occupational day	-2.85 (-4.83, -0.86)	0.010	-0.11 (-1.98, 1.75)	0.897	1.84 (-0.65, 4.34)	0.129
Weekend day	0.79 (-0.92, 2.50)	0.327	-0.98 (-3.10, 1.15)	0.331	2.59 (1.32, 3.87)	0.001
Week (7 days)	-12.65 (-24.15, -1.16)	0.034	-2.51 (-13.97, 8.96)	0.637	14.39 (1.64, 27.14)	0.031
Physical activity (METmin wk $^{-1}$)						
Week (7 days)	491 (-1477, 2459)	0.590	-223 (-2036, 1591)	0.790	-900 (-2596, 797)	0.261

Beschluss der Ethikkommission Decision of the Ethics Committee	universität wien Ethikkommission

Antragsteller/Applicant: **Bernhard Schwartz, MSc BSc**
Bearbeitungsnummer/Reference Number: **00052**
Projekttitel/Title of Project: **Einfluss von Haltungsänderungen während Bürotätigkeiten auf kognitive und biomechanische Parameter (Orginaltitel: "Cognitive and biomechanical effects of postural changes in office environments")**

Die Stellungnahme der Ethikkommission erfolgt aufgrund folgender eingereichter Unterlagen/
The decision of the Ethics Committee is based on the following documents:
• Anhang - Expose-Schwartz_V1.03_Ethikkommission • Anhang - Firmeninformation - Haltungswechsel V1.3 • Anhang - Patienteninformation - KS V1.0 • Anhang - Patienteninformation - LS V1.0 • Anhang - Patienteninformation - VS V1.0 • Anhang - Projektantrag-FFG-Bridge-Active_Office • Anhang - Studenteninformation - Kurzfassung_V1.0 • Anhang - Studenteninformation - V1.0 • Antrag-Ethikkommission-letzte-Seite-erweitert • Ethikkommmission-Antrag-Schwartz_Bernhard • Unterschriebener Antrag Scan
• Mail_Klaerung Projektstart_07.10.13 • Ethikkommmission-Antrag-AO-V1.2
• Patienteninformation_Active_Office_KS_V1.2 • Patienteninformation_Active_Office_LS_V1.2
• Patienteninformation_Active_Office_VS_V1.2 • Studenteninformation_Active_Office_V1.1

Die Kommission fasst folgenden Beschluss (mit X markiert)/The Ethics Committee has made the following decision (marked with an X):

☒ Zustimmung: Es besteht kein ethischer Einwand gegen die Durchführung der Studien/
Consent: there is no ethical objection to any accomplishments of the project

☐ Negative Beurteilung: Der Antrag wird von der Ethikkommission abgelehnt /negative evaluation: the proposal is refused by the Ethics Committee

Unterschrift/Signature

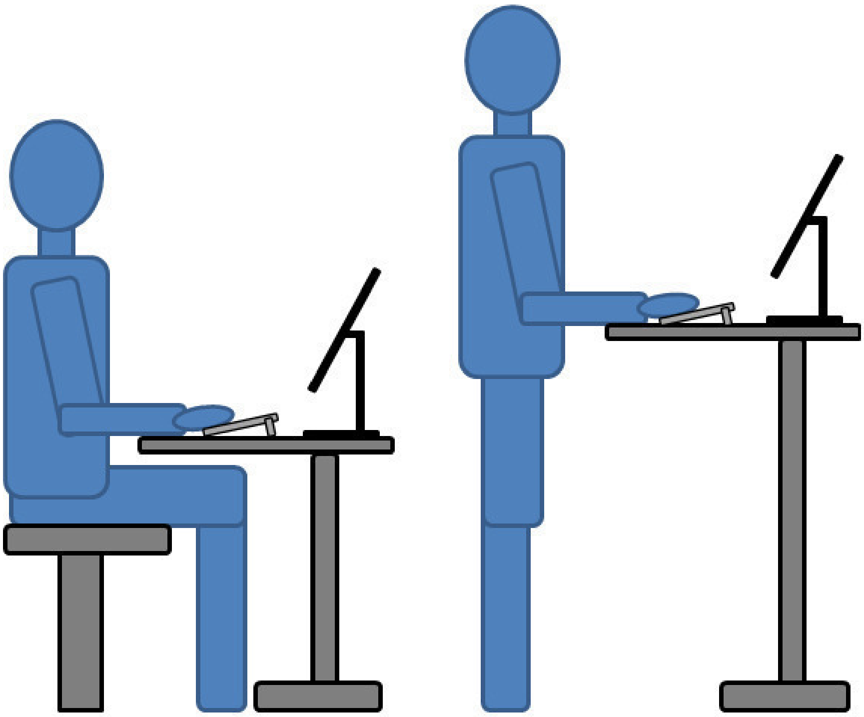
Datum/Date

07.11.2013

Stellvertretende Vorsitzende der Ethikkommission/Deputy Chairwoman of the Ethics Committee
ao. Univ.-Prof. MMag. Dr. Sylvia Kirchengast

Themenschwerpunkt: Gesunder Büroarbeitsplatz

Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz



Informationsblatt der FH Oberösterreich

für interessierte und teilnehmende Firmen

26. Juni 2013

Version 1.03

Die Idee

Regelmäßige Bewegung ist das Fundament eines vitalen Körpers und gleichzeitig ein notwendiges Element physiologischer Prozesse. Da vor allem an Büroarbeitsplätzen die Bewegung häufig durch lang anhaltendes statisches Sitzen stark vermindert wird, kommt es oft zu körperlichen Beschwerden wie Bandscheibenvorfällen, unspezifischen Schmerzen im Bereich der Wirbelsäule, Bluthochdruck, Diabetes und Übergewicht [1]. Folgen davon spiegeln sich nicht selten in Form von Arbeitsausfällen, reduzierter Produktivität oder reduziertem Wohlbefinden der Mitarbeiter wieder. Neben einer Beeinträchtigung der Mitarbeitergesundheit ergeben sich auch negative ökonomische Folgen für die Unternehmen.

Eine Möglichkeit zur Förderung der Gesundheit der Mitarbeiter am Büroarbeitsplatz ist die Implementierung höhenverstellbarer Tische am Büroarbeitsplatz. Diese von zahlreichen Ergonomen gestützte Maßnahme ermöglicht es dem Mitarbeiter, Bürotätigkeiten sowohl im Sitzen als auch im Stehen durchführen zu können und fördert somit den Haltungswechsel am Arbeitsplatz.

Da besonders dem regelmäßigen Haltungswechsel sowohl körperliche als auch mentale Verbesserungen in Form von positiven Änderungen der Herzratenvariabilität und gesteigerter Konzentrationsfähigkeit zugeschrieben werden, diese jedoch noch nicht wissenschaftlich belegt wurden, ist es Ziel der FH OÖ, durch eine geeignete Langzeitstudie den Effekt wissenschaftlich aufzuzeigen.

Die Studie

Die geplante Studie erstreckt sich über einen Zeitraum von 8 bis 12 Monaten, wobei der Großteil der Teilnehmer zu unterschiedlichen Zeitpunkten mit 2 höhenverstellbaren Tischen (Sitz- und Steharbeitsplatz) versorgt wird. Während der gesamten Laufzeit sind die Teilnehmer angehalten, sich vier Mal für Testmessungen (à 4 – 6 h) zur Verfügung zu stellen. Bei diesen Messungen absolvieren die Teilnehmer eine vordefinierte Reihe von Konzentrationstests unter Beobachtung der Herzfrequenz. Dabei beschränken sich die Konzentrationstests auf einfache Textaufgaben, Reaktionszeittests und Durchstreichtests. Da physiologische Änderungen des Körpers nur über länger andauernde Zeiträume wissenschaftlich aussagekräftig sind, wird die Herzfrequenz über eine Zeitspanne von 24 Stunden, ab Beginn der Messung, mit einem tragbaren Messgerät aufgezeichnet. Dies ermöglicht somit auch Analysen des Schlafes, womit weitere mögliche Auswirkungen der neuen Arbeitsumgebung aufgezeigt werden sollen. Um eine möglichst repräsentative Studie durchführen zu können, ist es wünschenswert, Teilnehmer aus verschiedenen heimischen Unternehmen in die Studie aufzunehmen.

[1] Owen, N., Bauman, A., Brown, W., Feb. 2009. Too much sitting: a novel and important predictor of chronic disease risk? British journal of sports medicine 43 (2), 81 - 83.

Die Voraussetzungen

Voraussetzung für die Teilnahme an der Langzeitstudie sind Mitarbeiter die an der Thematik „Gesundheitsprävention am Arbeitsplatz“ interessiert sind und für die es vorstellbar ist, auch im Stehen zu arbeiten. Da die Studie den präventiven Effekt auf gesunde Arbeitnehmer aufzeigen soll, werden vorrangig gesunde Teilnehmer ohne physische (keine chronischen physischen Erkrankungen) und psychische (Depressionen, chronische Schlafstörungen, …) Erkrankungen gesucht. Idealerweise stehen diese in einem Vollzeit-Beschäftigungsverhältnis mit einem hohen Anteil an computerisierten Bürotätigkeiten. Weiters rundet ein normalgewichtiger, nichtrauchender Mitarbeiter das Profil des perfekten Teilnehmers ab.

Pro Unternehmen werden 3 Arbeitnehmer gesucht, die bereit sind, an der Studie teilzunehmen. Von Seiten des Unternehmens sollte insgesamt ein zusätzlicher Bildschirm inklusive Tastatur und Maus zur Verfügung stehen. Die FH OÖ stattet die teilnehmenden Unternehmen mit zwei geeigneten Sitz- und Stehtischen aus, welche nebeneinander angeordnet werden und insgesamt nicht mehr Bürofläche als ein herkömmlicher Büroarbeitsplatz benötigen. Die höhenverstellbaren Tische stehen nach Beendigung der Studie den Teilnehmern weiterhin kostenlos zur Verfügung.

Der Datenschutz

Der Datenschutz ist sowohl für die Teilnehmer, als auch für die Fachhochschule OÖ von höchster Bedeutung. Die von den teilnehmenden Firmen erhobenen Daten der Mitarbeiter (Alter, Geschlecht, Gewicht, Größe, Tätigkeit) werden vertraulich behandelt und anonymisiert ausgewertet. Die während der Studie erhobenen persönlichen Daten und kognitiven Leistungswerte einzelner Teilnehmer werden weder den teilnehmenden Firmen noch fremden Institutionen zur Verfügung gestellt. Ausschließlich die anonymisierten, nicht einzelnen Personen zurechenbaren Studienergebnisse werden den teilnehmenden Mitarbeitern und Unternehmen zur Verfügung gestellt.

Die FH OÖ garantiert die Einhaltung wissenschaftsethischer Grundsätze und wird im Zuge dessen auch von der unabhängigen Ethikkommission der Universität Wien überprüft.

Das Ziel

Ziel der Studie ist es, den Einfluss auf körperliche und mentale Parameter bedingt durch regelmäßige Haltungswechsel während Bürotätigkeiten zu analysieren. Die daraus gewonnenen Erkenntnisse im Bereich der Arbeitsplatzergonomie ermöglichen es den Beteiligten, zukünftige Arbeitsplatzkonzepte gesundheitsorientiert gestalten zu können.

Für weitere Fragen bzw. für weitere Informationen zu diesem Thema stehen wir Ihnen gerne zur Verfügung.

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Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz - Zusammenfassung

Was ist das Ziel:	Die Auswirkungen von wechselnder Körperhaltung am persönlichen Büroarbeitsplatz untersuchen
Untersuchungszeitraum:	12 Monate (um alle Teilnehmer zu vermessen)
Zeitaufwand für den Teilnehmer:	4 Nachmittage im Abstand von 1 – 6 Monaten
Wie lang dauert eine Messung:	3 – 6 Stunden
Was wird gemessen:	Puls, Reaktionszeiten, Konzentrationsleistung (optional Stresshormone im Speichel)
Wie lange trage ich das EKG:	Während der Messung bis zum Aufwachen am nächsten Tag
Welche Voraussetzungen gibt es:	Teilnehmer sollten frei von physischen und psychischen Erkrankungen sein
Weitere Voraussetzungen (ideal):	Nichtraucher, Normalgewichtig, Sportlich
Weitere Einschränkungen:	Keine koffeinhaltigen Speisen und Getränke am Tag der Messung, kein Hochleistungssport am Tag vor der Messung, kein akuter Stress am Tag der Messung, Normaler Schlaf am Tag vor der Messung

Für weitere Fragen bzw. für weitere Informationen zu diesem Thema stehe ich Ihnen gerne zur Verfügung.

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EKG … Elektrokardiogramm (Pulsmessung)

TeilnehmerInneninformation und Einwilligungserklärung zur Teilnahme an der Studie – *V 1.2*

„Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz“- Langzeitstudie

Sehr geehrte Teilnehmerin, sehr geehrter Teilnehmer!

Wir laden Sie ein, an der oben genannten Studie, teilzunehmen. Die Aufklärung darüber erfolgt in einem ausführlichen Gespräch mit einem der Studiendurchführenden.

Ihre Teilnahme an dieser klinischen Prüfung erfolgt freiwillig. Sie können jederzeit ohne Angabe von Gründen aus der Studie ausscheiden. Die Ablehnung der Teilnahme oder ein vorzeitiges Ausscheiden aus dieser Studie hat keine nachteiligen Folgen für Ihre medizinische Betreuung.

Studien sind notwendig, um verlässliche neue Forschungsergebnisse zu gewinnen. Unverzichtbare Voraussetzung für die Durchführung einer Studie ist jedoch, dass Sie Ihr Einverständnis zur Teilnahme an dieser Studie schriftlich erklären. Bitte lesen Sie den folgenden Text als Ergänzung zum Informationsgespräch mit Ihrer Kontaktperson sorgfältig durch und zögern Sie nicht, Fragen zu stellen.

Bitte unterschreiben Sie die Einwilligungserklärung nur,

- wenn Sie Art und Ablauf der Studie vollständig verstanden haben,
- wenn Sie bereit sind, der Teilnahme zuzustimmen und
- wenn Sie sich über Ihre Rechte als TeilnehmerIn an dieser Studie im Klaren sind.

Zu dieser Studie wurde von der Ethikkommission der Universität Wien eine befürwortende Stellungnahme abgegeben.

1. Was ist der Zweck dieser Studie?

Der Zweck dieser Studie ist es, den langfristigen Effekt bedingt durch regelmäßige Haltungswechsel am Büroarbeitsplatz, auf kognitive und physische Parameter wissenschaftlich zu untersuchen.

2. Wie läuft die Studie ab?

Die Studie wird am Standort Linz der FH Oberösterreich mit ungefähr 18 Personen durchgeführt. Die Gesamtdauer der Studie erstreckt sich über einen Zeitraum von ca. einem Jahr, wobei jede Person vier Messtage im Abstand von 1 – 6 Monaten absolviert.
Während jedes Messtages werden vordefinierte kognitive Testungen, unter Beobachtung vitaler Parameter mit Hilfe von medizintechnischen Geräten durchgeführt. Je nach Situation beträgt die Gesamtdauer der Messungen je Messtag zwischen 4 und 6 Stunden.

<u>Was geschieht an den Messtagen?</u>

Nach einer Einführung in den Studienablauf und Klärung Ihrer eventuell noch offenen Fragen, wird die vorliegende Einwilligungserklärung von Ihnen und einer studiendurchführenden Person unterschrieben und für die Sie kopiert. Anschließend werden Ihre, für die Studie relevanten, persönlichen Daten erhoben (Körpergröße, Gewicht, Name, Alter,…).
Nach einer detaillierten Erklärung des nachfolgenden Messablaufs durch die studiendurchführende Person, werden Sie von dieser mit den für die Studien benötigten Messgeräten ausgestattet. Danach wird Ihnen die Möglichkeit geboten, die Durchführung der kognitiven Tests, mit Unterstützung der Studiendurchführenden, zu üben.
Nach einer Ruhepause starten Sie dann die eigentlichen Messungen. Diese besteht aus fünf halbstündigen Testblöcken, welch Sie entweder im Sitzen oder im Stehen absolvieren müssen. Während dieser Zeit herrscht Stille im Raum und Sie arbeiten völlig eigenständig.
Sollten Sie in dieser Zeit wichtige Fragen zu den kognitiven Tests haben, können Sie diese jederzeit der studiendurchführenden Person vor Ort stellen.
Nach Abschluss des fünften Testblocks, sowie einer weiteren Ruhephase sind die kognitiven Messungen für Sie beendet. Die studiendurchführende Person wird Ihnen weitere Informationen zur Studie geben und mit samt Pulsmessgerät (EKG) und Speichel-sammelgefäßen entlassen.

Um Ihren Schlaf analysieren zu können, ist es notwendig das Pulsmessgerät (EKG) bis zum nächsten Morgen zu tragen. Wir bitten Sie daher dieses erst in den Morgenstunden des nächsten Tages abzunehmen. Anschließend werden wir das Gerät inklusive der Speichelproben am nächsten Tag bei Ihnen abholen.

Was ist ein EKG und wie läuft die EKG-Messung ab?

Bei der EKG-Messung wird der Herzschlag einer Person gemessen. Diese Art der Messung wird auch bei geläufigen Pulsuhren oder Pulsfrequenzbrustgurten durchgeführt. Da der Herzschlag innerhalb dieser Studie möglichst exakt gemessen werden soll, wird in dieser Studie, anders als im Freizeitsport, ein tragbares, wissenschaftliches, medizinisches Gerät verwendet. Für dieses müssen jedoch Oberflächenelektroden auf den Köper geklebt werden. Diese sind dermatologisch getestet, unbedenklich und für eine mehrtägige Verwendung ausgelegt. Sollten Sie weitere Fragen zur EKG-Messung haben richten Sie diese bitte an die studiendurchführende Person.

Was ist Kortisol und wie läuft die Kortisolspiegel-Messung ab?

Kortisol ist ein körpereigenes Hormon welches im wissenschaftlichen Bereich oft für Untersuchungen des Stressniveaus von Personen verwendet wird. Es kann sowohl innerhalb des Bluts, als auch innerhalb des Speichels bestimmt werden. Aus Gründen der Sicherheit und der Anwenderfreundlichkeit wird der Kortisolspiegel innerhalb dieser Studie nur aus dem Speichel bestimmt.
Die Sammlung der Speichelproben erfolgt schmerz- und verletzungsfrei mit Hilfe von Sammelbehältnissen und sollte nicht bei Krankheiten, Entzündungen oder Verletzungen der Mundhöhle durchgeführt werden. Des Weitern sollten die TeilnehmerInnen 30 Minuten vor der Probensammlung nicht essen, trinken, Kaugummi kauen oder Zähne putzen, da dies die Messergebnisse verfälschen könnte.

3. Worin liegt der Nutzen einer Teilnahme an der Studie?

Es ist möglich, dass Sie durch die Teilnahme an dieser Studie keinen direkten Nutzen für Ihre Gesundheit ziehen können.
Die Ergebnisse dieser Studie sollen dazu beitragen, neue wissenschaftliche Erkenntnisse im Bereich der betrieblichen Gesundheitsvorsorge zu erlangen um zukünftig noch besser auf den Faktor Mensch am Arbeitsplatz, im speziellen am Büroarbeitsplatz, eingehen zu können.

4. Gibt es Risiken, Beschwerden und Begleiterscheinungen?

Im Rahmen der Studie ist mit keinen gesundheitsgefährdeten Risiken zu rechnen.
Das für die EKG-Messung verwendete Messgerät inklusiver der Oberflächenklebe-elektroden sind medizinproduktezertifiziert, auf deren Sicherheit überprüft und entsprechen dem medizinischen Standard.
Durch die lange Tragezeit der Klebelektroden kann es unter Umständen zu leichten Reizungen der Haut kommen. Da diese Reizung durch eine mechanische Reizung der Haut von statten geht, sollte diese nach Abnahme der Elektroden, mit anschließender Hautreinigung nicht weiter bestehen.
Weiters kann es durch die kognitive Anstrengung der Messung zu Symptomen mentaler und physischer Ermüdung kommen. Auch dieser Effekt ist als reversibel einzustufen.

5. **Was ist zu tun beim Auftreten von Symptomen, Begleiterscheinungen und/oder Verletzungen?**

Sollten im Verlauf der klinischen Prüfung irgendwelche Symptome, Begleiterscheinungen oder Verletzungen auftreten, müssen Sie diese den Studiendurchführenden mitteilen, bei schwerwiegenden Begleiterscheinungen umgehend.

6. **Hat die Teilnahme an der Studie sonstige Auswirkungen auf die Lebensführung und welche Verpflichtungen ergeben sich daraus?**

Am Tag vor der Messung sollte auf hohe sportliche Leistungen verzichtet werden. Des Weiteren sollte am Tag vor der Messung, wie auch am Tag der Messung auf koffeinhaltige Speisen und Getränke verzichtet und bewusst ein natürlicher Schlafrhythmus eingehalten werden.

Sofern möglich, sollte auch akuter Stress am Tag der Messung verhindert werden.

7. **Wann wird die Studie vorzeitig beendet?**

Sie können jederzeit, auch ohne Angabe von Gründen, Ihre Teilnahmebereitschaft widerrufen und aus der klinischen Prüfung ausscheiden, ohne dass Ihnen dadurch irgendwelche Nachteile entstehen.

Bei Eintritt von unvorhersehbaren Ereignissen (Unfall, Ausscheiden aus dem Unternehmen, Schwangerschaft, …) gilt es die Situation gesondert abzuschätzen.

Sollte eine Gefährdung für Teilnehmer oder Studie bestehen, wird die diese automatisch beendet. Auch hier entstehen für Sie keinerlei Nachteile.

8. **In welcher Weise werden die im Rahmen dieser klinischen Prüfung gesammelten Daten verwendet?**

Die Weitergabe der Daten im In- und Ausland erfolgt ausschließlich zu statistischen Zwecken in verschlüsselter (nur „indirekt personenbezogener“) oder anonymisierter Form, das heißt, Sie werden nicht namentlich genannt. Auch in etwaigen Veröffentlichungen der Daten dieser klinischen Prüfung werden Sie nicht namentlich genannt.

Die PrüferInnen und ihre MitarbeiterInnen unterliegen im Umgang mit den Daten den Bestimmungen des österreichischen Datenschutzgesetzes 2000 in der jeweils geltenden Fassung.

Wenn Sie Ihre Einwilligung zurückziehen und damit Ihre Teilnahme vorzeitig beenden, werden keine neuen Daten mehr über Sie erhoben.

9. Entstehen für die Teilnehmer Kosten? Gibt es einen Kostenersatz oder eine Vergütung?

Kosten

Durch die Teilnahme an der Studie entstehen der teilnehmenden Person keine Kosten und der durch die Teilnahme entstehende Arbeitszeitausfall der TeilnehmerInnen wird von den jeweiligen Arbeitgebern übernommen.

Vergütung

Es ist keine individuelle Vergütung für die Teilnahme an der Studie von Seiten der FH OÖ vorgesehen. Als gemeinschaftliche Vergütung gehen alle den Unternehmen während der Studienzeit zur Verfügung gestellten, höhenverstellbaren Tische, ins Eigentum des Unternehmens über und können somit über die Studie hinaus verwendet werden. Des Weiteren werden die anfallenden Reisekosten, durch die Fachhochschule, auf Basis eines amtlichen Kilometergeldes, rückerstattet.

10. Möglichkeit zur Diskussion weiterer Fragen

Für weitere Fragen im Zusammenhang mit dieser Studie steht Ihnen die Kontaktperson gerne zur Verfügung. Auch Fragen, die Ihre Rechte als Teilnehmer Studie betreffen, werden Ihnen gerne beantwortet.

Name der Kontaktperson: **Schwartz Bernhard**

Ständig erreichbar unter: 0680 / 311 69 22

bernhard.schwartz@fh-linz.at

11. Einwilligungserklärung

Name des Teilnehmers in Druckbuchstaben: ....

Geburtsdatum: ....

Ich erkläre mich bereit, an der Studie „Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz" – Langzeitstudie teilzunehmen.

Ich bin von der studiendurchführenden Person ausführlich und verständlich über mögliche Belastungen und Risiken, sowie über Wesen, Bedeutung und Tragweite der Studie, sowie die sich für mich daraus ergebenden Anforderungen aufgeklärt worden. Ich habe darüber hinaus den Text dieser Patientenaufklärung und Einwilligungserklärung, die insgesamt *6* Seiten umfasst, gelesen. Aufgetretene Fragen wurden mir von der studiendurchführenden Person verständlich und genügend beantwortet. Ich hatte ausreichend Zeit, mich zu entscheiden. Ich habe zurzeit keine weiteren Fragen mehr.

Ich werde den ärztlichen Anordnungen, die für die Durchführung der Studie erforderlich sind, Folge leisten, behalte mir jedoch das Recht vor, meine freiwillige Mitwirkung jederzeit zu beenden, ohne dass mir daraus Nachteile entstehen.

Ich bin zugleich damit einverstanden, dass meine im Rahmen dieser Studie ermittelten Daten gespeichert werden. Mir ist bekannt, dass zur Überprüfung der Richtigkeit der Datenaufzeichnung Beauftragte der zuständigen Behörden, der Ethikkommission und ggf. des Auftraggebers beim Studienleiter Einblick in meine personenbezogenen Daten nehmen dürfen.

Beim Umgang mit den Daten werden die Bestimmungen des derzeit gültigen Datenschutzgesetzes beachtet.

Eine Kopie dieser Patienteninformation und Einwilligungserklärung habe ich erhalten. Das Original verbleibt bei der studiendurchführenden Person.

....
(Datum und Unterschrift des Teilnehmers)

....
(Datum, Name und Unterschrift der studiendurchführenden Person)

Studienprotokoll - Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz - V1.0

Die folgenden persönlichen Daten der TeilnehmerInnen werden im Laufe des Erstgespräches durch die studiendurchführende Person erhoben und niedergeschrieben. Da dieses Dokument eine direkte Zuordenbarkeit der teilnehmenden Personen und deren Messdaten ermöglicht, ist dieses getrennt von den Messdaten aufzubewahren.

Dabei ist zu beachten, dass studienfremden Personen der Zugang zu den persönlichen Daten verwehrt bleibt.

Teilnehmerdaten:

Name: ____________________________

Probanden ID: ____________________________

Geburtsdatum: ____________________________

Köpergröße: ____________________________ cm

Körpergewicht: ____________________________ kg

BMI: ____________________________kg/m²

Geschlecht: ☐ männlich ☐ weiblich

Studiendurchführende Person:

Name: ____________________________

Datum: ____________________________

Unterschrift: ____________________________

In welcher Branche arbeiten Sie?

____

____

Welche Tätigkeiten zählen zu Ihren beruflichen Hauptaufgaben ?

____

____

____

(Maximal 5 Nennungen, Beispiele: Sachbearbeitung, Programmierung, CAD, Projektplanung,…)

Wie viel Zeit verbringen sie durchschnittlich in Ihrem Unternehmen?

______________________________ Stunden / Tag

______________________________ Stunden / Woche

Wie lange arbeiten Sie schon in Ihrem Unternehmen?

☐ weniger als 1 Jahr
☐ 1 Jahr bis unter 3 Jahre
☐ 3 Jahre bis unter 5 Jahre
☐ 5 Jahre bis unter 10 Jahre
☐ 10 Jahre bis unter 20 Jahre
☐ 20 Jahre und mehr

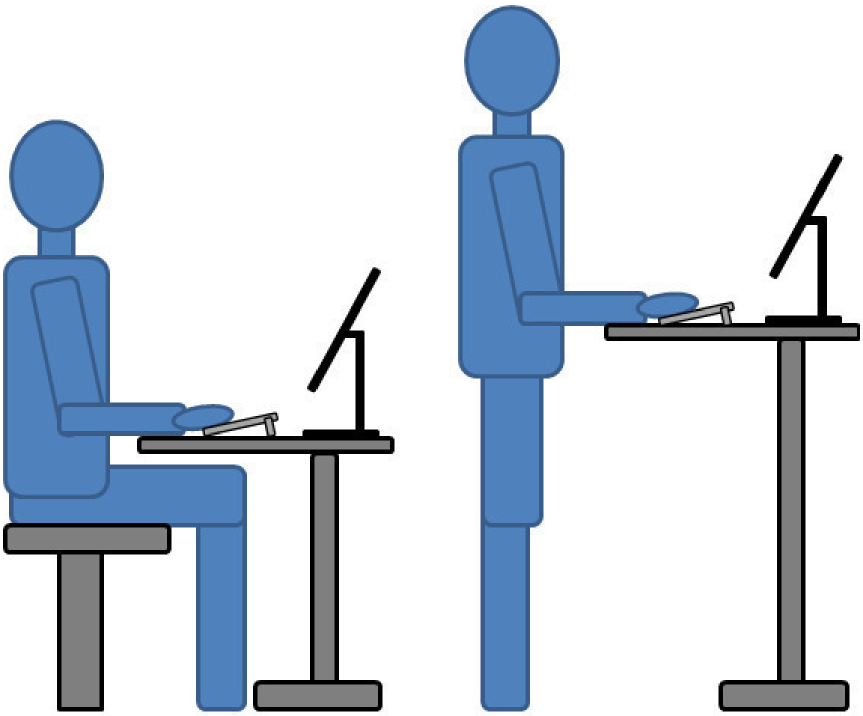
<u>Angaben der studiendurchführenden Person:</u>

Name: ________________________ Datum: __________________

Unterschrift: ________________________ Probanden ID: __________________

Themenschwerpunkt: Gesunder Büroarbeitsplatz

Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz



Informationsblatt der FH Oberösterreich

für interessierte Teilnehmer

04. November 2013 Version 1.1

Die Idee

Regelmäßige Bewegung ist das Fundament eines vitalen Körpers und gleichzeitig ein notwendiges Element physiologischer Prozesse. Da vor allem an Büroarbeitsplätzen die Bewegung häufig durch lang anhaltendes statisches Sitzen stark vermindert wird, kommt es oft zu körperlichen Beschwerden wie Bandscheibenvorfällen, unspezifischen Schmerzen im Bereich der Wirbelsäule, Bluthochdruck, Diabetes und Übergewicht [1]. Folgen davon spiegeln sich nicht selten in Form von Arbeitsausfällen, reduzierter Produktivität oder reduziertem Wohlbefinden der Mitarbeiter wieder. Neben einer Beeinträchtigung der Mitarbeitergesundheit ergeben sich auch negative ökonomische Folgen für die Unternehmen.

Eine Möglichkeit zur Förderung der Gesundheit der Mitarbeiter am Büroarbeitsplatz ist die Implementierung höhenverstellbarer Tische am Büroarbeitsplatz. Diese von zahlreichen Ergonomen gestützte Maßnahme ermöglicht es dem Mitarbeiter, Bürotätigkeiten sowohl im Sitzen als auch im Stehen durchführen zu können und fördert somit den Haltungswechsel am Arbeitsplatz.

Da besonders dem regelmäßigen Haltungswechsel sowohl körperliche als auch mentale Verbesserungen in Form von positiven Änderungen der Herzratenvariabilität und gesteigerter Konzentrationsfähigkeit zugeschrieben werden, diese jedoch noch nicht wissenschaftlich belegt wurden, ist es Ziel der FH OÖ, durch eine geeignete Kurzzeitstudie den Effekt wissenschaftlich aufzuzeigen.

Die Studie

Der geplante Zeitraum der Studie erstreckt sich über 12 Monate, wobei jeder Teilnehmer für insgesamt 2 Termine im Abstand von einer Woche für Testmessungen zur Verfügung stellen sollte (Messung stets am Nachmittag). Bei diesen Messungen absolvieren die Teilnehmer eine vordefinierte Reihe von Konzentrationstests unter Beobachtung der Herzfrequenz. Dabei beschränken sich die Konzentrationstests auf einfache Textaufgaben, Reaktionszeittests und Durchstreichtests. Da physiologische Änderungen des Körpers nur über länger andauernde Zeiträume wissenschaftlich aussagekräftig sind, wird die Herzfrequenz über eine Zeitspanne von 12 - 24 Stunden, ab Beginn der Messung, mit einem tragbaren Messgerät aufgezeichnet. Dies ermöglicht somit auch Analysen des Schlafes.

[1] Owen, N., Bauman, A., Brown, W., Feb. 2009. Too much sitting: a novel and important predictor of chronic disease risk? British journal of sports medicine 43 (2), 81 - 83.

Die Voraussetzungen

Da die Studie den präventiven Effekt auf gesunde Personen aufzeigen soll, werden vorrangig gesunde Teilnehmer ohne physische (keine chronischen physischen Erkrankungen) und psychische (Depressionen, chronische Schlafstörungen, …) Erkrankungen gesucht. Idealerweise sind diese zusätzlich vertraut mit computerisierten Tätigkeiten. Weiters rundet ein normalgewichtige, nichtrauchender Student das Profil des perfekten Teilnehmers ab.

Der Datenschutz

Der Datenschutz ist sowohl für die Teilnehmer, als auch für die Fachhochschule OÖ von höchster Bedeutung. Die von Teilnehmern erhobenen Daten (Alter, Geschlecht, Gewicht, Größe, Tätigkeit) werden vertraulich behandelt und anonymisiert ausgewertet. Die während der Studie erhobenen persönlichen Daten und kognitiven Leistungswerte einzelner Teilnehmer werden weder studienfremden Personen der FH OÖ, noch externen Institutionen zur Verfügung gestellt. Ausschließlich die anonymisierten, nicht einzelnen Personen zurechenbaren Studienergebnisse werden veröffentlicht.

Das Ziel

Ziel der Studie ist es, den Einfluss auf körperliche und mentale Parameter bedingt durch regelmäßige Haltungswechsel während Bürotätigkeiten zu analysieren. Die daraus gewonnenen Erkenntnisse im Bereich der Arbeitsplatzergonomie ermöglichen es den Beteiligten, zukünftige Arbeitsplatzkonzepte gesundheitsorientiert gestalten zu können.

Für weitere Fragen bzw. für weitere Informationen zu diesem Thema stehe ich Ihnen gerne zur Verfügung.

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Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz - Zusammenfassung

Was ist das Ziel:	Die Auswirkungen von wechselnder Körperhaltung am Büroarbeitsplatz zu untersuchen
Zeitaufwand für den Teilnehmer:	2 Nachmittage im Abstand von genau 7 Tagen
Wie lang dauert eine Messung:	3,5 – 4,5 Stunden
Was wird gemessen:	Puls, Reaktionszeiten, Konzentrationsleistung
Wie lange trage ich das EKG:	Während der Messung bis zum Aufwachen am nächsten Tag
Welche Voraussetzungen gibt es:	Teilnehmer sollten frei von physischen und psychischen Erkrankungen sein
Weitere Voraussetzungen (ideal):	Nichtraucher (max. 1 Zigarette pro Tag) Normalgewichtig (BMI zwischen 18,5 und 25)
Weitere Einschränkungen:	Keine koffeinhaltigen Speisen und Getränke am Tag der Messung, kein Hochleistungssport am Tag vor der Messung

Für weitere Fragen bzw. für weitere Informationen zu diesem Thema stehe ich Ihnen gerne zur Verfügung.

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EKG … Elektrokardiogramm (Pulsmessung)

TeilnehmerInneninformation und Einwilligungserklärung zur Teilnahme an der Studie – *V 1.2*

„Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz“ - Vorstudie

Sehr geehrte Teilnehmerin, sehr geehrter Teilnehmer!

Wir laden Sie ein, an der oben genannten Studie, teilzunehmen. Die Aufklärung darüber erfolgt in einem ausführlichen Gespräch mit einem der Studiendurchführenden.

Ihre Teilnahme an dieser klinischen Prüfung erfolgt freiwillig. Sie können jederzeit ohne Angabe von Gründen aus der Studie ausscheiden. Die Ablehnung der Teilnahme oder ein vorzeitiges Ausscheiden aus dieser Studie hat keine nachteiligen Folgen für Ihre medizinische Betreuung.

Studien sind notwendig, um verlässliche neue Forschungsergebnisse zu gewinnen. Unverzichtbare Voraussetzung für die Durchführung einer Studie ist jedoch, dass Sie Ihr Einverständnis zur Teilnahme an dieser Studie schriftlich erklären. Bitte lesen Sie den folgenden Text als Ergänzung zum Informationsgespräch mit Ihrer Kontaktperson sorgfältig durch und zögern Sie nicht, Fragen zu stellen.

Bitte unterschreiben Sie die Einwilligungserklärung nur,

- wenn Sie Art und Ablauf der Studie vollständig verstanden haben,
- wenn Sie bereit sind, der Teilnahme zuzustimmen und
- wenn Sie sich über Ihre Rechte als TeilnehmerIn an dieser Studie im Klaren sind.

Zu dieser Studie wurde von der Ethikkommission der Universität Wien eine befürwortende Stellungnahme abgegeben.

1. Was ist der Zweck dieser Studie?

Der Zweck dieser Studie ist es, den kurzfristigen Effekt von Körperhaltungsänderungen auf kognitive und physische Parameter, während Tätigkeiten am Computer wissenschaftlich analysieren zu können.

2. Wie läuft die Studie ab?

Die Studie wird am Standort Linz der FH Oberösterreich mit ungefähr 10 Personen durchgeführt. Die Gesamtdauer der Studie erstreckt sich über einen Zeitraum von ca. 1 – 2 Monaten, wobei jede Person zwei Messtage im Abstand von ca. einer Woche absolviert.
Während jedes Messtages werden vordefinierte kognitive Testungen, unter Beobachtung vitaler Parameter mit Hilfe von medizintechnischen Geräten durchgeführt. Je nach Situation beträgt die Gesamtdauer der Messungen je Messtag zwischen 4 und 6 Stunden.

Was geschieht an den Messtagen?

Nach einer Einführung in den Studienablauf und Klärung Ihrer eventuell noch offenen Fragen, wird die vorliegende Einwilligungserklärung von Ihnen und einer studiendurchführenden Person unterschrieben und für die Sie kopiert. Anschließend werden Ihre, für die Studie relevanten, persönlichen Daten erhoben (Körpergröße, Gewicht, Name, Alter,...).
Nach einer detaillierten Erklärung des nachfolgenden Messablaufs durch die studiendurchführende Person, werden Sie von dieser mit den für die Studien benötigten Messgeräten ausgestattet. Danach wird Ihnen die Möglichkeit geboten, die Durchführung der kognitiven Tests, mit Unterstützung der Studiendurchführenden, zu üben.
Nach einer Ruhepause starten Sie dann die eigentlichen Messungen. Diese besteht aus fünf halbstündigen Testblöcken, welche Sie entweder im Sitzen oder im Stehen absolvieren müssen. Während dieser Zeit herrscht Stille im Raum und Sie arbeiten völlig eigenständig.
Sollten Sie in dieser Zeit wichtige Fragen zu den kognitiven Tests haben, können Sie diese jederzeit der studiendurchführenden Person vor Ort stellen.
Nach Abschluss des fünften Testblocks, sowie einer weiteren Ruhephase sind die kognitiven Messungen für Sie beendet. Die studiendurchführende Person wird Ihnen weitere Informationen zur Studie geben und mit samt Pulsmessgerät (EKG) und Speichel-sammelgefäßen entlassen.

Um Ihren Schlaf analysieren zu können, ist es notwendig das Pulsmessgerät (EKG) bis zum nächsten Morgen zu tragen. Wir bitten Sie daher dieses erst in den Morgenstunden des nächsten Tages abzunehmen. Anschließend werden wir das Gerät inklusive der Speichelproben am nächsten Tag bei Ihnen abholen.

Was ist ein EKG und wie läuft die EKG-Messung ab?

Bei der EKG-Messung wird der Herzschlag einer Person gemessen. Diese Art der Messung wird auch bei geläufigen Pulsuhren oder Pulsfrequenzbrustgurten durchgeführt. Da der Herzschlag innerhalb dieser Studie möglichst exakt gemessen werden soll, wird in dieser Studie, anders als im Freizeitsport, ein tragbares, wissenschaftliches, medizinisches Gerät verwendet. Für dieses müssen jedoch Oberflächenelektroden auf den Köper geklebt werden. Diese sind dermatologisch getestet, unbedenklich und für eine mehrtägige Verwendung ausgelegt. Sollten Sie weitere Fragen zur EKG-Messung haben richten Sie diese bitte an die studiendurchführende Person.

Was ist Kortisol und wie läuft die Kortisolspiegel-Messung ab?

Kortisol ist ein körpereigenes Hormon welches im wissenschaftlichen Bereich oft für Untersuchungen des Stressniveaus von Personen verwendet wird. Es kann sowohl innerhalb des Bluts, als auch innerhalb des Speichels bestimmt werden. Aus Gründen der Sicherheit und der Anwenderfreundlichkeit wird der Kortisolspiegel innerhalb dieser Studie nur aus dem Speichel bestimmt.
Die Sammlung der Speichelproben erfolgt schmerz- und verletzungsfrei mit Hilfe von Sammelbehältnissen und sollte nicht bei Krankheiten, Entzündungen oder Verletzungen der Mundhöhle durchgeführt werden. Des Weitern sollten die TeilnehmerInnen 30 Minuten vor der Probensammlung nicht essen, trinken, Kaugummi kauen oder Zähne putzen, da dies die Messergebnisse verfälschen könnte.

3. Worin liegt der Nutzen einer Teilnahme an der Studie?

Es ist nicht zu erwarten, dass Sie durch die Teilnahme an dieser Studie keinen direkten Nutzen für Ihre Gesundheit ziehen können.
Die Ergebnisse dieser Studie sollen dazu beitragen neue wissenschaftliche Erkenntnisse im Bereich der betrieblichen Gesundheitsvorsorge zu erlangen um zukünftig noch besser auf den Faktor Mensch am Arbeitsplatz, im speziellen am Büroarbeitsplatz, eingehen zu können.

4. Gibt es Risiken, Beschwerden und Begleiterscheinungen?

Im Rahmen der Studie ist mit keinen gesundheitsgefährdeten Risiken zu rechnen.
Das für die EKG-Messung verwendete Messgerät inklusiver der Oberflächenklebe-elektroden sind medizinproduktezertifiziert, auf deren Sicherheit überprüft und entsprechen dem medizinischen Standard.
Durch die lange Tragezeit der Klebelektroden kann es unter Umständen zu leichten Reizungen der Haut kommen. Da diese Reizung durch eine mechanische Reizung der Haut von statten geht, sollte diese nach Abnahme der Elektroden, mit anschließender Hautreinigung nicht weiter bestehen.
Weiters kann es durch die kognitive Anstrengung der Messung zu Symptomen mentaler und physischer Ermüdung kommen. Auch dieser Effekt ist als reversibel einzustufen.

OBERÖSTERREICH

5. Was ist zu tun beim Auftreten von Symptomen, Begleiterscheinungen und/oder Verletzungen?

Sollten im Verlauf der klinischen Prüfung irgendwelche Symptome, Begleiterscheinungen oder Verletzungen auftreten, müssen Sie diese den Studiendurchführenden mitteilen, bei schwerwiegenden Begleiterscheinungen umgehend.

6. Hat die Teilnahme an der Studie sonstige Auswirkungen auf die Lebensführung und welche Verpflichtungen ergeben sich daraus?

Am Tag vor der Messung sollte auf hohe sportliche Leistungen verzichtet werden. Des Weiteren sollte am Tag vor der Messung, wie auch am Tag der Messung auf koffeinhaltige Speisen und Getränke verzichtet und bewusst ein natürlicher Schlafrhythmus eingehalten werden.

Sofern möglich, sollte auch akuter Stress am Tag der Messung verhindert werden.

7. Wann wird die Studie vorzeitig beendet?

Sie können jederzeit, auch ohne Angabe von Gründen, Ihre Teilnahmebereitschaft widerrufen und aus der klinischen Prüfung ausscheiden ohne dass Ihnen dadurch irgendwelche Nachteile entstehen.

Sollte eine Gefährdung für Teilnehmer oder Studie bestehen, wird die diese automatisch beendet. Auch hier entstehen für Sie keinerlei Nachteile.

8. In welcher Weise werden die im Rahmen dieser klinischen Prüfung gesammelten Daten verwendet?

Die Weitergabe der Daten im In- und Ausland erfolgt ausschließlich zu statistischen Zwecken in verschlüsselter (nur „indirekt personenbezogener“) oder anonymisierter Form, das heißt, Sie werden nicht namentlich genannt. Auch in etwaigen Veröffentlichungen der Daten dieser klinischen Prüfung werden Sie nicht namentlich genannt.

Die Prüfer/innen und ihre Mitarbeiter/innen unterliegen im Umgang mit den Daten den Bestimmungen des österreichischen Datenschutzgesetzes 2000 in der jeweils geltenden Fassung.

Wenn Sie Ihre Einwilligung zurückziehen und damit Ihre Teilnahme vorzeitig beenden, werden keine neuen Daten mehr über Sie erhoben.

9. Entstehen für die Teilnehmer Kosten? Gibt es einen Kostenersatz oder eine Vergütung?

Durch die Teilnahme an der Studie entstehen der teilnehmenden Person keine Kosten. Für die Teilnahme ist kein Kostenersatz oder Vergütung vorgesehen.

10. Möglichkeit zur Diskussion weiterer Fragen

Für weitere Fragen im Zusammenhang mit dieser Studie steht Ihnen die Kontaktperson gerne zur Verfügung. Auch Fragen, die Ihre Rechte als Teilnehmer Studie betreffen, werden Ihnen gerne beantwortet.

Name der Kontaktperson: **Schwartz Bernhard**

Ständig erreichbar unter: 0680 / 311 69 22

bernhard.schwartz@fh-linz.at

11. Einwilligungserklärung

Name des Teilnehmers in Druckbuchstaben: ....

Geburtsdatum: ....

Ich erkläre mich bereit, an der Studie „Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz“ – Vorstudie teilzunehmen.

Ich bin von der studiendurchführenden Person ausführlich und verständlich über mögliche Belastungen und Risiken, sowie über Wesen, Bedeutung und Tragweite der Studie, sowie die sich für mich daraus ergebenden Anforderungen aufgeklärt worden. Ich habe darüber hinaus den Text dieser Patientenaufklärung und Einwilligungserklärung, die insgesamt *6* Seiten umfasst gelesen. Aufgetretene Fragen wurden mir von der studiendurchführenden Person verständlich und genügend beantwortet. Ich hatte ausreichend Zeit, mich zu entscheiden. Ich habe zurzeit keine weiteren Fragen mehr.

Ich werde den ärztlichen Anordnungen, die für die Durchführung der Studie erforderlich sind, Folge leisten, behalte mir jedoch das Recht vor, meine freiwillige Mitwirkung jederzeit zu beenden, ohne dass mir daraus Nachteile entstehen.

Ich bin zugleich damit einverstanden, dass meine im Rahmen dieser Studie ermittelten Daten gespeichert werden. Mir ist bekannt, dass zur Überprüfung der Richtigkeit der Datenaufzeichnung Beauftragte der zuständigen Behörden, der Ethikkommission und ggf. des Auftraggebers beim Studienleiter Einblick in meine personenbezogenen Daten nehmen dürfen.

Beim Umgang mit den Daten werden die Bestimmungen des derzeit gültigen Datenschutzgesetzes beachtet.

Eine Kopie dieser Patienteninformation und Einwilligungserklärung habe ich erhalten. Das Original verbleibt bei der studiendurchführenden Person.

....

(Datum und Unterschrift des Teilnehmers)

....

(Datum, Name und Unterschrift der studiendurchführenden Person)

Studienprotokoll - Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz - V1.0

Die folgenden persönlichen Daten der TeilnehmerInnen werden im Laufe des Erstgespräches durch die studiendurchführende Person erhoben und niedergeschrieben. Da dieses Dokument eine direkte Zuordenbarkeit der teilnehmenden Personen und deren Messdaten ermöglicht, ist dieses getrennt von den Messdaten aufzubewahren.

Dabei ist zu beachten, dass studienfremden Personen der Zugang zu den persönlichen Daten verwehrt bleibt.

Teilnehmerdaten:

Name: ______________________________

Probanden ID: ______________________________

Geburtsdatum: ______________________________

Köpergröße: ______________________________ cm

Körpergewicht: ______________________________ kg

BMI: ______________________________ kg/m²

Geschlecht: ☐ männlich ☐ weiblich

Studiengang : ______________________________

Studiendurchführende Person:

Name: ______________________________

Datum: ______________________________

Unterschrift: ______________________________

Gewichtsprotokoll - Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz - V1.0

Die folgenden persönlichen Daten der TeilnehmerInnen werden im Laufe der Langzeitstudie durch die studiendurchführende Person erhoben und niedergeschrieben.

Teilnehmerdaten

Probanden ID: ____________________________

Köpergröße: ____________________________ cm

Körpergewicht zu den Zeitpunkten

ZP 1: ________________ kg Datum: ______________

ZP 2: ________________ kg Datum: ______________

ZP 3: ________________ kg Datum: ______________

ZP 4: ________________ kg Datum: ______________

Studiendurchführende Person:

Name: ____________________________

Datum: ____________________________

Unterschrift: ____________________________

Informationsblatt – Cortisolmessung - V1.0

Sehr geehrte Teilnehmerin, sehr geehrter Teilnehmer!

Sie haben vom Studienleiter, nach Abschluss Ihres Messtages, **ein Sammelgefäß** für Speichelproben erhalten. Da der morgendliche Speichel wissenschaftlich sehr von Bedeutung ist, möchten wir Sie bitten die folgenden Punkte bei der Probenentnahme zu berücksichtigen:

Vor der Messung **nicht Zähneputzen**, sowie **keine Getränke** und **Speisen** zu sich zu nehmen (ausgenommen Leitungswasser).

Das Ausspülen des Mundes mit **Leitungswasser**, sowie das Konsumieren von Leitungswasser **bis 5 Minuten** vor der Messung **sind erlaubt.**

Die Messung **20 Minuten nach dem Aufstehen** durchführen (**große zeitliche Unterschiede verfälschen das Ergebnis enorm**)

Bei der Messung die Baumwollrolle ca. 1 Minute lang kauen (um genügend Speichel aufzufangen) und anschließend in das Kunststoffgefäß spucken.

<u>Ergänzend zur Messung bitten wir Sie folgende Zeitpunkte schriftlich festzuhalten:</u>

Zeitpunkt des Schlafengehens: _______________ Uhr

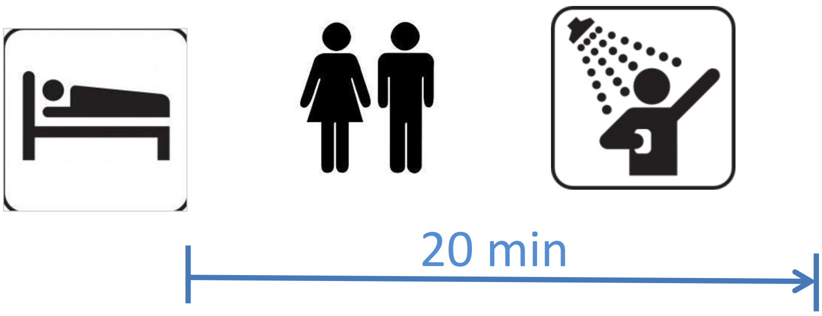
Zeitpunkt des Aufstehens: _______________ Uhr

Zeitpunkt der Messung: _______________ Uhr

Bitte geben Sie die **Speichelprobe**, den **Neoprengurt** und das **EKG-Gerät** Ihrer Kollegin bzw. Ihrem Kollegen mit nach **Linz**. Danke!

<u>Hinweis:</u>

Vor der Cortisolmessung dürfen Sie das EKG-Gerät abnehmen und **<u>ohne Gerät</u>** duschen oder baden.



MESSENDE ☺

Erstbefragung Gesundheitszustand - Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz - V1.1

Die folgenden persönlichen Daten der TeilnehmerInnen werden im Laufe des Erstgespräches durch die studiendurchführende Person erhoben und niedergeschrieben.

Die in diesem Dokument gestellten Fragen dienen der Abklärung des Gesundheitszustandes der an der Studie teilnehmenden Personen und werden nur aus Gründen der Dokumentation festgehalten.

Eine weiterführende Analyse, über die Studieneignung hinaus, soll nicht durchgeführt werden.

Studiendurchführende Person:

Name: ______________________

Datum: ______________________

Unterschrift: ______________________

Probanden ID: ______________________

Personendaten:

Probanden ID: ______________________________

Mögliche Messtage:

☐ Mo ☐ Di ☐ Mi ☐ Do ☐ Fr ☐ Sa ☐ So

Fühlen Sie sich körperlich/physisch gesund?

☐ Ja ☐ Nein ☐ keine Angabe

Fühlen Sie sich geistig/psychisch gesund?

☐ Ja ☐ Nein ☐ keine Angabe

Sind Sie derzeitig schwanger?

☐ Ja ☐ Nein ☐ keine Angabe

Konsumieren Sie derzeit Tabakwaren?

☐ Ja ☐ Nein ☐ keine Angabe

Wenn Ja, hoch ist zirka Ihr täglicher Konsum?

______________________________ Gramm / Stück / Packungen

Konsumierten Sie in der Vergangenheit Tabakwaren?

☐ Ja ☐ Nein ☐ keine Angabe

Wenn Ja, hoch war zirka Ihr täglicher Konsum?

______________________________ Gramm / Stück / Packungen

Wie lange konsumieren Sie schon Tabakwaren bzw. wie lange konsumieren Sie schon keine Tabakwaren mehr?

☐ Ich rauche seit __________________ Jahren

☐ Ich rauche seit __________________ Jahren nicht mehr

und hab davor __________________ Jahre geraucht

Leiden Sie derzeit unter chronischen körperlichen oder geistigen Beschwerden?

Zu diesen zählen z.B.: Bluthochdruck, chronische Rückenschmerzen, Depressionen, chronische Schlafstörungen,...

☐ Ja ☐ Nein ☐ keine Angabe

Leiden Sie derzeit unter akuten körperlichen oder geistigen Beschwerden?

Zu diesen zählen z.B.: Bluthochdruck, akute Rückenschmerzen, Depressionen, Schlafmangel,...

☐ Ja ☐ Nein ☐ keine Angabe

Wurden an Ihnen in der Vergangenheit größere Operationen oder medizinische Eingriffe durchgeführt bzw. haben Sie gesundheitliche Einschränkungen / Beschwerden die Sie uns nennen wollen?

☐ Ja ☐ Nein ☐ keine Angabe

Wenn Ja, welche:

____

____

____

Wenn keine Angabe, haben Sie weitere gesundheitliche Einschränkungen / Beschwerden die Sie uns nicht nennen wollen?

☐ Ja ☐ Nein ☐ keine Angabe

Konsumieren Sie derzeitig Medikamente?

☐ Ja ☐ Nein ☐ keine Angabe

Wenn Ja, wogegen:

____

____

Messprotokoll

Datum			**ID**	
Start der Messung				
Vorbereitungsphase				
Einlernphase	von		bis	
Ruhe	von		bis	
Müdigkeit	physisch		mental	
Messphase				
Kognitiver Block 1				
	von		bis	
Kognitiver Block 2				
	von		bis	
Kognitiver Block 3				
	von		bis	
Kognitiver Block 4				
	von		bis	
Kognitiver Block 5				
	von		bis	
Endphase				
Ruhe	von		bis	
Müdigkeit	physisch		mental	
Ende der Messung				
Schlaf	von		bis	

Sonstiges

Protokollführer:

Protokoll Nr. ____

Datum: ____________ Messtag: ________ Gruppe: __________ Teilnehmer ID: _________

„Haltungswechsel am persönlichen Büroarbeitsplatz" - Beanspruchungshöhe

Wie haben Sie den heutigen Messtag erlebt? Wie hoch war dabei die Beanspruchung in den einzelnen Dimensionen? Markieren Sie dazu auf den folgenden Skalen, in welchem Maße Sie sich in den sechs genannten Dimensionen beansprucht oder gefordert gesehen haben.

Geistige Anforderung: Wie viel geistige und wahrnehmende Aktivität war notwendig (z.B. denken, entscheiden, rechnen, erinnern, sehen, suchen,…)? Waren die Aufgaben leicht oder anstrengend, einfach oder komplex, erfordern sie hohe Genauigkeiten oder sind sie fehlertolerant?

gering hoch

Körperliche Anforderung: Wie viel körperliche Aktivität war notwendig (z.B. drücken, ziehen, drehen, steuern, aktivieren,…)? Waren die Aufgaben leicht oder anstrengend, langsam oder flott, entspannend oder anstrengend, erholsam oder hektisch?

gering hoch

Zeitliche Anforderung: Wie viel Zeitdruck verspürten Sie auf Grund der mit den Aufgaben und Aufgabenteilen aufgetretenen Geschwindigkeit? War das Tempo eher langsam und gemächlich oder schnell und hektisch?

gering hoch

Arbeitsleistung: Wie erfolgreich waren Sie Ihrer Meinung nach bei der Erreichung der vom Versuchsleiter oder Ihnen selber gesetzten Ziele? Wie zufrieden waren Sie mit Ihrer Arbeitsleistung bei Vollendung dieser Ziele?

Gut Schlecht

Anstrengung: Wir hart mussten Sie arbeiten (körperliche und geistig), um ihren Grad an Arbeitsleistung zu erreichen?

gering hoch

Frustration: Wie unsicher, entmutigt, irritiert, gestresst und verärgert versus sicher, bestätigt, zufrieden, entspannt und zufrieden mit sich selbst fühlten Sie sich während der Aufgaben?

gering hoch

Sonstiges:

____

IPAQ Fragebogen – Gesundheitsförderung durch Haltungswechsel am persönlichen Büroarbeitsplatz – V 1.0

Wir sind daran interessiert herauszufinden welche Arten von körperlichen Aktivitäten Menschen in ihrem alltäglichen Leben vollziehen. Die Befragung bezieht sich auf die Zeit die Sie während der **letzten 7** Tage in körperlicher Aktivität verbracht haben. Bitte beantworten Sie alle Fragen (auch wenn Sie sich selbst nicht als aktive Person ansehen). Bitte berücksichtigen Sie die Aktivitäten im Rahmen Ihrer Arbeit, in Haus und Garten, um von einem Ort zum anderen zu kommen und in Ihrer Freizeit für Erholung, Leibesübungen und Sport.

Denken Sie an all Ihre **anstrengenden** und **moderaten** Aktivitäten in den **vergangenen 7 Tagen**. **Anstrengende** Aktivitäten bezeichnen Aktivitäten die starke körperliche Anstrengungen erfordern und bei denen Sie deutlich stärker atmen als normal. **Moderate** Aktivitäten bezeichnen Aktivitäten mit moderater körperlicher Anstrengung bei denen Sie ein wenig stärker atmen als normal.

Angaben der studiendurchführenden Person:

Name: ______________________ Datum: ____________________

Unterschrift: ______________________ Probanden ID: ____________________

TEIL 1: KÖRPERLICHE AKTIVITÄT AM ARBEITSPLATZ

Im ersten Abschnitt geht es um Ihre Arbeit. Das beinhaltet bezahlte Arbeit, Landwirtschaft, freiwillige Tätigkeiten, Seminare und alle anderen unbezahlten Tätigkeiten die Sie außerhalb von zuhause verrichtet haben. Geben Sie hier keine unbezahlten Tätigkeiten an die Sie zuhause verrichtet haben, wie Arbeiten in Haus und Garten, anfallende Instandhaltungsarbeiten und Sorgen für die Familie. Dies wird in Abschnitt 3 befragt.

1. Haben Sie momentan einen Job oder verrichten Sie irgendwelche unbezahlte Arbeiten außerhalb von zuhause?

☐ Ja

☐ Nein → ***Springen Sie weiter zu Teil 2: BEFÖRDERUNG***

Die folgenden Fragen sind über die körperliche Aktivität in den **vergangenen 7** Tagen im Rahmen Ihrer bezahlten und unbezahlten Arbeit. Dies beinhaltet keine Wegstrecken zur oder von der Arbeit.

2. An wie vielen der **vergangenen 7 Tage** haben Sie anstrengende körperliche Aktivitäten wie schweres Heben, Graben, schwere Bauarbeit oder Stiegensteigen **im Rahmen Ihrer Arbeit** verrichtet? Denken Sie dabei nur an körperliche Aktivitäten die Sie für mindestens 10 Minuten ohne Unterbrechung verrichtet haben.

_____ **Tage pro Woche**

☐ Keine anstrengenden körperlichen Aktivitäten im Rahmen der Arbeit

→ **Springen Sie weiter zu Frage 4**

3. Wie viel Zeit haben Sie für gewöhnlich an einem dieser Tage mit **anstrengender** körperlicher Aktivität im Rahmen ihrer Arbeit verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

4. Denken Sie erneut nur an die körperlichen Aktivitäten die Sie für mindestens 10 Minuten ohne Unterbrechung verrichtet haben. An wie vielen der **vergangenen 7 Tage** haben Sie moderate körperliche Aktivitäten wie Tragen leichter Lasten **im Rahmen Ihrer Arbeit** verrichtet? Fußwegstrecken bitte nicht mit einbeziehen.

_____ **Tage pro Woche**

☐ Keine moderaten körperlichen Aktivitäten im Rahmen der Arbeit

→ **Springen Sie weiter zu Frage 6**

5. Wie viel Zeit haben Sie für gewöhnlich an einem dieser Tage mit moderater körperlicher Aktivität im Rahmen Ihrer Arbeit verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

6. An wie vielen der **vergangenen 7 Tage** haben Sie **Fußwegstrecken** von mindestens 10 Minuten ohne Unterbrechung im Rahmen Ihrer Arbeit zurückgelegt? Bitte keine Wegstrecken zur oder von der Arbeit mit einbeziehen.

_____ **Tage pro Woche**

☐ Keine Fußwegstrecken im Rahmen der Arbeit

Springen Sie weiter zu Teil 2: BEFÖRDERUNG

→

7. Wie viel Zeit haben Sie an einem dieser Tage für gewöhnlich mit **Wegstrecken** im Rahmen Ihrer Arbeit verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

Teil 2: KÖRPERLICHE AKTIVITÄT ZUR BEFÖRDERUNG

In diesen Fragen geht es um die Fortbewegungen von einem Ort zum anderen, wie die Wege zu Arbeit, Geschäften, Kino, usw.

8. An wie vielen der **vergangenen 7 Tage** sind Sie mit einem **motorisierten Verkehrsmittel** wie Zug, Bus, Auto oder Straßenbahn **gefahren**?

_____ **Tage pro Woche**

☐ Keine Fahrten in motorisierten Verkehrsmitteln

→ ***Springen Sie weiter zu Frage 10***

9. Wie viel Zeit haben Sie für gewöhnlich an einem dieser Tage mit **Fahrten** in Zug, Bus, Auto, Straßenbahn oder irgendeinem motorisierten Verkehrsmittel verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

Denken Sie jetzt nur an das **Fahrradfahren** und **zu Fuß Gehen**, bei dem Sie für Wege zur und von der Arbeit, für Botenwege, sowie für Wegstrecken um von einem Ort zum anderen zurückgelegt haben.

10. An wie vielen der **vergangenen 7 Tage** sind Sie für mindestens 10 Minuten ohne Unterbrechung **fahrradgefahren** um **von einem Ort zum anderen** zu gelangen?

_____ **Tage pro Woche**

☐ Kein Fahrradfahren von einem Ort zum anderen

→ ***Springen Sie weiter zu Frage 12***

11. Wie viel Zeit haben Sie für gewöhnlich an einem dieser Tage für das **Fahrradfahren** von einem Ort zum anderen verwendet??

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

12. An wie vielen der **vergangenen 7 Tage** sind Sie für mindestens 10 Minuten ohne Unterbrechung **zu Fuß gegangen** um **von einem Ort zum anderen** zu gelangen?

_____ **Tage pro Woche**

☐ Kein zu Fuß Gehen von einem Ort zum anderen

→ ***Springen Sie weiter zu Teil 3: HAUSARBEIT, HAUSINSTANDHALTUNG UND SORGEN FÜR DIE FAMILIE***

13. Wie viel Zeit haben Sie für gewöhnlich an einem dieser Tage für das **zu Fuß Gehen** von einem Ort zum anderen verwendet?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

TEIL 3: HAUSARBEIT, HAUSINSTANDHALTUNG UND SORGEN FÜR DIE FAMILIE

In diesem Abschnitt geht es um körperliche Aktivitäten die Sie in den **vergangen 7 Tagen** in und um ihr Haus verrichtet haben, wie Hausarbeit, Arbeiten in Hof und Garten, Instandhaltungsarbeiten und Sorgen für die Familie.

14. Denken Sie nur an die körperlichen Aktivitäten die Sie für mindestens 10 Minuten ohne Unterbrechung verrichtet haben. An wie vielen der **vergangenen 7 Tage** haben Sie anstrengende körperliche Aktivitäten wie Tragen schwerer Lasten, Holzhaken, Schneeschaufeln oder Graben **im Hof oder im Garten** verrichtet?

_____ **Tage pro Woche**

☐ Keine anstrengenden körperlichen Aktivitäten im Hof oder im Garten

→ ***Springen Sie weiter zu Frage 16***

15. Wie viel Zeit haben Sie für gewöhnlich an einem dieser Tage mit **anstrengender** Aktivität in Garten und Hof verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

16. Denken Sie erneut nur an die körperlichen Aktivitäten die Sie für mindestens 10 Minuten ohne Unterbrechung verrichtet haben. An wie vielen der **vergangenen 7 Tage** haben Sie moderate Aktivitäten wie Tragen leichter Lasten, Fegen, Fensterputzen und Rechen **im Hof oder im Garten** verrichtet?

_____ **Tage pro Woche**

☐ Keine moderate Aktivität im Garten oder im Hof

→ ***Springen Sie weiter zu Frage 18***

17. Wie viel Zeit haben Sie für gewöhnlich an einem dieser Tage mit **moderater** körperlicher Aktivität im Garten oder im Hof verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

18. Denken Sie erneut nur an die körperlichen Aktivitäten die Sie für mindestens 10 Minuten ohne Unterbrechung verrichtet haben. An wie vielen der **vergangenen 7 Tage** haben Sie moderate Aktivitäten wie Tragen leichter Lasten, Fensterputzen, Bodenaufwaschen und Fegen **zuhause** verrichtet?

_____ **Tage pro Woche**

☐ Keine moderaten Aktivitäten zuhause

→ ***Springen Sie weiter zu Teil 4: KÖRPERLICHE AKTIVITÄTEN IN ERHOLUNG, SPORT UND FREIZEIT***

19. Wie viel Zeit haben Sie für gewöhnlich an einem dieser Tage mit **moderaten** körperlichen Aktivitäten zuhause verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

TEIL 4: KÖRPERLICHE AKTIVITÄTEN IN ERHOLUNG; SPORT UND FREIZEIT

In diesem Abschnitt geht es um alle körperlichen Aktivitäten die Sie in den **vergangenen 7 Tagen** ausschließlich in Erholung, Sport, Leibesübungen und Freizeit verrichtet haben. Bitte keine Aktivitäten mit einbeziehen die Sie bereits angegeben haben.

20. Ohne die Fußwege die Sie bereits genannt haben, an wie vielen der **vergangenen 7 Tage** sind Sie in ihrer **Freizeit** für mindestens 10 Minuten ohne Unterbrechung **zu Fuß** gegangen?

_____ **Tage pro Woche**

☐ Kein zu Fuß gehen in der Freizeit

→ ***Springen Sie weiter zu Frage 22***

21. Wie viel Zeit haben Sie für gewöhnlich an einem dieser Tage mit **zu Fuß Gehen** in ihrer Freizeit verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

22. Denken sie nur an die körperlichen Aktivitäten die Sie für mindestens 10 Minuten ohne Unterbrechung verrichtet haben. An wie vielen der **vergangenen 7 Tage** haben Sie **anstrengende** körperliche Aktivitäten wie Aerobic, Laufen, schnelles Fahrradfahren oder schnelles Schwimmen in ihrer **Freizeit** verrichtet?

_____ **Tage pro Woche**

☐ Keine anstrengenden Aktivitäten in der Freizeit

→ ***Springen Sie weiter zu Frage 24***

23. Wie viel Zeit haben Sie für gewöhnlich an einem dieser Tage mit **anstrengender** körperlicher Aktivität in ihrer Freizeit verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

24. Denken Sie erneut nur an die körperlichen Aktivitäten die Sie für mindestens 10 Minuten ohne Unterbrechung verrichtet haben. An wie vielen der **vergangenen 7 Tage** haben sie **moderate** körperliche Aktivitäten wie Fahrradfahren bei

gewöhnlicher Geschwindigkeit, Schwimmen bei gewöhnlicher Geschwindigkeit und Doppel-Tennis in ihrer **Freizeit** verrichtet?

_____ **Tage pro Woche**

☐ Keine moderaten Aktivitäten in der Freizeit

➡ ***Springen Sie weiter zu Teil 5: IM SITZEN VERBRACHTE ZEIT***

25. Wie viel Zeit haben Sie für gewöhnlich an einem dieser Tage mit **moderater** körperlicher Aktivität in ihrer Freizeit verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

TEIL 5: IM SITZEN VERBRACHTE ZEIT

Bei den letzten Fragen geht es um die Zeit die Sie bei der Arbeit, zuhause, bei Seminaren und in der Freizeit in Sitzen verbracht haben. Dies kann Zeit beinhalten wie Sitzen am Schreibtisch, Besuchen von Freunden und vor dem Fernseher sitzen oder liegen. Keine Zeit für Sitzen in einem motorisierten Verkehrsmittel mit einbeziehen von der Sie mir bereits erzählt haben.

26. Wie viel Zeit haben Sie in den **vergangenen 7 Tagen** mit **Sitzen** an **Wochentagen** verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tag**

27. Wie viel Zeit haben Sie an den **vergangenen 7 Tagen** mit **Sitzen** an **Wochenendtagen** verbracht?

_____ **Stunden pro Tag**
_____ **Minuten pro Tags**

Das ist das Ende der Befragung, danke für Ihre Teilnahme.