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**Original Article**

# Trapezius muscle activity and body movement at the beginning and the end of a workday and during the lunch period in female office employees

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**Abstract: The aim of this study was to analyze the activity of the trapezius muscle and the arm acceleration during the course of a workday in office employees. It was examined if there are significant changes in trapezius muscle activity in the afternoon compared to the morning work period and relationships to the level of arm acceleration during lunchtime. Nineteen female office employees were recruited. A one hour period of the work in the morning, afternoon, and lunchtime were compared. The measures of the trapezius muscle activity and muscle rest time (TR) did not significantly differ between working in the morning (TR: median 10%; range 1%–49) or working in the afternoon (TR: median 18%; range 2%–34%). The 90$^{th}$ percentile of arm acceleration during lunch time significantly correlated with less trapezius muscle activity in the afternoon compared to the morning values (RT: Spearman R=0.80; $p$<0.01). Differences in the duration and level of trapezius muscle activity were bigger between the subjects than between different work periods or between lunchtime and work. Furthermore it seems that higher arm accelerations during lunch may be beneficial in reducing trapezius activity in the afternoon compared to the morning values.**

**Key words:** EMG, Muscle activity, Trapezius muscle, Office work, Active break

## Introduction

Musculoskeletal disorders (MSDs) are a big health problem in the working population[1)], can lead to a significant reduction of the quality of life[2)], may cause a reduced productivity at work[3, 4)], and lead to substantial health costs[1, 5)]. Neck pain is one of the highly prevalent MSDs[6)] and often was observed in computer employees. The one-year prevalence rate of neck pain in office employees is between 51% and 58%[7–9)]. Neck pain is more frequent in women than in men[7, 9)]. According to Nordander, *et al.*[10)], at least in women, trapezius myalgia is the most prevalent diagnosis in patients suffering from neck pain.

Several authors analyzed the activity of the trapezius muscle in office employees[11–13)] and it was reported that the activity of the trapezius muscle correlates with neck pain or predicts its development[14–16)]. Considering workload in general, physical[17)], psychosocial[18)] and mental loads[19)] could augment the activity of the trapezius muscle. However, a review discussing the association of various loads to neck pain[20)] found for most of the analyzed factors no clear evidence. In office work, the physical load is generally known to be small. Nevertheless there is evidence that even during low-level muscle activity overexertion of single muscle fibers may occur and therefore pain may develop[15)]. The prevailing hypothesis explaining such a development is the so-called Cinderella-Hypothesis proposed by Hagg[21)]. It states that a low-level activation of

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long duration in the trapezius muscle can keep the same muscle fiber active over the whole time leading to over-exertion and eventually neck pain may develop. Especially during static muscle activation, it was shown that single muscle fibers were active over a long time[22]. In relation to computer work Zennaro, *et al.*[23] showed that while working at an improperly adjusted desk the number of active motor units of the trapezius muscle is augmented and that the length of activity is increased. Additionally, Zennaro, *et al.*[11] found that during a 30 min task with a computer mouse a few motor units of the trapezius muscle were active over the whole period. Interestingly, this behavior of motor units was only found in a part of the subjects. The authors also explained that it would have been possible to fulfill this task without activity in the trapezius muscle. Based on the study by Zennaro[11] and taking into account further studies showing that the hours spent with computer work per day are correlated with neck pain[16, 24–26], it would be interesting to know, how the trapezius muscle behaves in the course of a full day of computer work. It may be assumed that some subjects exhibit little or no rest time and that the amount of rest time decreases over the course of a working day.

The commonly used method to detect the activity of the trapezius muscle is electromyography (EMG) and most often standardized RMS values (root mean square) are calculated[27]. Within the EMG signal the most important parameter to describe such a constant activation of the muscle might be the rest time of the trapezius muscle[28, 29]. If rest time is missing, muscle activation of long duration will happen[30]. A study by Luttmann, *et al.*[31] examined the rest time of the trapezius muscle during a workday and found that the trapezius muscle rest time decreased in the course of the workday in five of ten subjects, increased in one subject and in four subjects, no rest time was observed over the whole day. However, this study did not include all work tasks. The analysis was only made considering the parts of the workday classified as one of the "tasks with the lowest muscular activity". To the best of our knowledge, no study compared complete tasks of office work between the beginning and the end of the workday and none simultaneously included measurements of physical workload or motor behaviors.

To evaluate physical exposures at work implies a lot of difficulties. The most widely used method is still the self-administered questionnaire, however most measures lack sufficient precision[32]. Observing and rating a video of randomly selected workers representing a task group was shown to reliably predict the risk of shoulder and neck pain[33]. Such measures still do not take into account variation in exposures and/or behavior of individual subjects. An interesting option to improve this problem is the use of accelerometers and to continuously evaluate the acceleration of single body parts. In a previous study and using such an approach we could describe changes of physical activities during day and night shifts in Swiss and Japanese nurses[34]. In the prevention of work-related neck pain one approach that is often discussed is to interrupt the office work by active breaks[35–37]. Sundelin and Hagberg[36] found that active pauses induced a higher variation in trapezius muscle activity than passive pauses and were preferred by the subjects. Samani, *et al.*[37] found a higher variability in trapezius muscle activity during active pauses. The so-called "resetting property" of muscles may be used to disrupt the monotonic drive of the trapezius muscle in sustained contractions. Studies on vibration effects have shown that brief instances of voluntary changes in muscle contraction contribute to the elimination of residual effects induced by monotonic exposure to vibration[38, 39]. Hence, it may be assumed that a change in motor activity during the lunch break may produce a resetting of the sensorimotor system.

Therefore, the aim of this study was to compare the activity of the trapezius muscle between the morning and the late afternoon of a workday as well as during the lunch period in office employees. Furthermore we aimed to analyze if a more active lunch period counteracts an increasing trapezius muscle activity towards the end of a working day.

## Subjects and Methods

*Study design*

The data reported in this paper are part of a measurement from the beginning of the work on one day, until the waking up in the next morning (an analysis of the full data including leisure time activities and night is in preparation). All subjects were employed as office workers and therefore had similar work tasks during the whole day. A one hour period in the morning and a one hour period in the afternoon were analyzed to compare the physiological parameters between the morning and the afternoon work period. The variables trapezius muscle rest time, percentiles of trapezius muscle activity, arm acceleration rest time and percentiles of arm acceleration, and the average heart rate were analyzed within and between the subjects and compared between the morning and the afternoon of a workaday. Additionally, the arm acceleration allowed us to estimate the general activity during work and during the lunch break and to evaluate its change over the workday.

*Subjects*

19 female office employees (38±12 years) participated in the study. They all worked as office employees with a regular working time of at least 80% (>32 hours/week), and worked at least since one year on the job. Subjects fulfilling one of the following criteria were excluded: skin disease, clinical findings of a musculoskeletal disorder, drug abuse, intake of psychotropic drugs or intake of muscle relaxants. The study was approved by the ethical committee of the Federal Institute of Technology Zurich (Switzerland) and all subjects gave their written informed consent. Subjects were instructed according to the Helsinki declaration, participated voluntarily and were free to discontinue their participation at any time without explanation.

*Procedure and apparatus*

The measuring devices were attached in the morning before the start of work and the subjects wore the measurement device until the start of work in the next morning. The activity of the descending part of trapezius muscle, the acceleration of the upper arm, and heart rate were measured. Before start of the work, before lunch break and after finishing the work the subjects answered a question about neck pain. The wording of the question was: "Do you feel pain in the neck or the shoulder area?". The scale used ranged from one to five, whereas one meant "no pain" and five meant "very strong pain". The EMG electrodes were placed on a line from the acromion to the cervical vertebra 7 (C7), based on the recommendations of SENIAM[40]. The midpoint of the two electrodes was 2 cm medial of the midpoint of this line and the electrode-electrode distance was 2 cm. The reference electrode was placed on C7. For the electrocardiogram (ECG) a two electrodes lead was used. One electrode was placed on the left side of the chest wall below the breast, the other one below the clavicle. On the top third of the dominant upper arm an accelerometer was placed and fixed with double-sided tape. To reduce movement artifacts the cables were taped to the skin and the recording device was worn around the waist. The recording device (PS11-UD, THUMEDI GmbH & Co. KG, Thum-Jahnsbach, Germany) used a sampling rate of 2048 Hz. Pre-gelled Ag/AgCl electrodes (35×26 mm, Kendall Arbo, Covidien, England) were used and the subjects' skin was prepared with abrasive paste (Nuprep, Weaver and Company, Aurora, CO, USA). EMG data was filtered with an analogue 3rd order high pass filter with a cut off frequency of 4 Hz (−3 dB) and a 10th order anti-aliasing filter adjusted to 650 Hz (−3 dB). Subsequently, a digital high pass filter at 12 Hz, a digital band replacement filter at 50 Hz, 100 Hz, 150 Hz, 200 Hz, 250 Hz, 300 Hz and 350 Hz, and two algorithms which used low and very low frequencies (7−13 Hz and 0.5−1.7 Hz) were applied. The flatness (ripple) of the transfer function from 20 Hz−500 Hz of the device is ± 0.1 dB and the intrinsic effective noise of the entire system was about 250 nV (12−650 Hz). Using the same measuring device, a two-electrode electrocardiogram (ECG) was acquired to remove ECG artifacts by a template-based algorithm[41].The registered ECG was used to calculate the heart rate, too. Upper arm acceleration was registered with a one-dimensional accelerometer that was connected to the measurement device PS11-UD. To determine reference values for the EMG measures before the start of the measurement, a submaximal reference contraction, slightly modified from the description by Mathiassen, *et al.*[27] was performed. The subjects hold their arms in a horizontal position laterally extended in 90° abduction for 20 s. This procedure was repeated three times with a 40 s break in between.

*Analysis*

All data were processed with Matlab R2012b. The root mean square (RMS) signal (window length 500 ms, 50% overlap) of the EMG was normalized with the reference voluntary electrical activation (RVE) of submaximal reference contractions and the RVE value was calculated as the mean of the most constant 10 s of every of the three reference contractions. As a result, the EMG was expressed in % RVE. Subjects with RVE values out of the range 55 $\mu$V−140 $\mu$V were excluded[42]. Data of the arm acceleration and the heart rate were processed by the device and reduced on a sampling rate of 4 Hz.

To answer the hypotheses, three parts out of the workday were analyzed. We analyzed one hour in the morning, as a proxy for the beginning of the workday and one hour in the late afternoon as a surrogate for the end of the workday. To avoid phenomena of arriving at work, getting a coffee or tidying up in the evening, we excluded the first 30 min and the last 30 min of the workday (s. Fig. 1). As we did not report the exact lunchtime of the subjects, we analyzed the period from 11:30 until 13:30 as lunchtime. Thus we were sure that this period includes the lunchtime of every subject. The subjects did not receive any instructions on their behavior during lunch break.

For the morning, lunchtime, and late afternoon periods

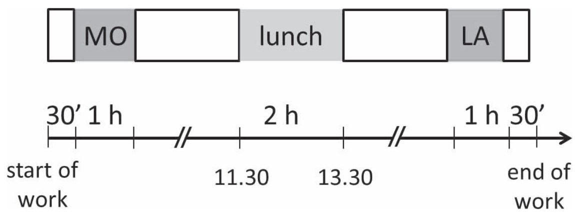


**Fig. 1. Location of the measurement periods morning (MO) and late afternoon (LA) during the workday of the subjects.**

**Table 1. Age and neck pain levels for the study sample and the excluded subjects**

| | Study Sample | Excluded subjects |
|---|---|---|
| Age [yr] | 38 ± 13 | 38 ± 13 |
| Neck pain at the start of work[a] | 1.1 ± 0.3 | 1.2 ± 0.4 |
| Neck pain at the end of work[a] | 1.2 ± 0.4 | 1.0 ± 0.0 |

[a] Pain scale 1 ("no pain") to 5 ("very strong pain")

the registrations of the normalized EMG signal, the heart rate, and the arm acceleration were described by the 10th, the 50th and the 90th percentile. For the EMG and the arm acceleration, we additionally calculated the rest time. The rest time of the EMG was defined as the percentage of the duration with the EMG below 5% RVE (based on the definition of Hansson, *et al.*[43)]). For the arm acceleration, the rest time was defined as the percentage of time with a value below 90 mm/s$^2$. This limit was set as motionless after visual inspection of the dataset.

*Statistics*

Due to the rather small sample size and slight deviations from a normal distribution non-parametric statistics were calculated using IBM SPSS Statistics 22. The following dependent variables were examined: trapezius muscle rest time, percentiles of trapezius muscle activity, arm acceleration rest time and percentiles as well as the median of the heart rate. Results of the two-sided Wilcoxon rank test were used to check for significant differences between the morning and the late afternoon values. None of these tests was significant so that adaptations of the significance level to compensate for bias due to multiple comparisons were not needed. To describe the correlations of the morning and afternoon values within subjects two-sided Spearman rank correlations were calculated. The strength of correlations between the parameters of the trapezius muscle and the arm acceleration were tested by a two-sided Spearman rank correlation. The magnitude of the variances explained by the time of the day (morning, lunch or late afternoon), by differences between the individuals and by their interaction were determined calculating an analysis of variance with a two factorial design including the interaction between individuals and time of the day. It was calculated using SAS 9.3 and the average and 95% confidence intervals were determined by bootstrapping with 500 repetitions. To analyze the influence of active lunch breaks Spearman rank correlations were calculated between the 90th percentile of arm acceleration during lunch and the quotient of the late afternoon EMG parameters divided by the ones of the morning period.

## Results

Nineteen female subjects participated in the study. Because of an error of the measurement device, one subject had to be excluded. Seven additional subjects had to be excluded because of too small or too high RVE values. Especially in subjects with very low RVE values, which may occur in subjects with a substantial fat layer under the skin, a calculation of rest time is not practical (see Nicoletti and Läubli[42)]). The remaining 12 subjects were included in the analysis. Age and level of neck pain of the study sample and the excluded subjects are shown in Table 1.

*Comparisons between the measurements during the work periods*

EMG, heart rate, and arm acceleration were compared between the morning and the late afternoon. None of these parameters showed a significant difference between the two measurement periods (s. Table 2 and 3). Figure 2 shows selected parameters of the morning and late afternoon periods for the twelve single subjects.

We observed a noteworthy difference of the trapezius muscle rest time between the subjects (s. Table 2 and Fig. 2a). Trapezius muscle rest time in the morning varied between 1% of time and 49% of time and in the late afternoon between 2% of time and 34% of time. The direction and size of the differences between the trapezius muscle rest time of the morning and the late afternoon strongly varied among the twelve subjects. In some subjects trapezius muscle rest time in the morning was higher than in the late afternoon; in other subjects it was higher in the late afternoon than in the morning and in some subjects, nearly no change was visible. Calculated over all subjects, no systematic change of trapezius muscle rest time from the morning to the late afternoon was found (s. Table 2). The 10th, the 50th and the 90th percentile of trapezius muscle activity showed similar results (s. Fig. 2b). All the inves-

**Table 2. Median and range during the morning period (MO), the lunch time (Lunch), the late afternoon period (LA), and the quotient late afternoon/morning (Quotient) for the parameters of trapezius muscle activity (EMG), the parameters of arm acceleration (ACC), and the heart rate (HR).**

| Parameter | MO | Lunch | LA | Quotient |
|---|---|---|---|---|
| EMG, rest time | 10.0 (1.4/48.5) | 7.8 (3.0/41.5) | 18.0 (1.8/33.6) | 1.1 (0.3/3.8) |
| EMG, 10th percentile | 4.9 (2.2/17.0) | 5.5 (2.0/11.3) | 4.3 (1.8/11.3) | 0.9 (0.4/3.3) |
| EMG, 50th percentile | 22.4 (5.1/37.8) | 26.0 (5.9/47.5) | 17.5 (6.7/59.0) | 1.1 (0.4/1.9) |
| EMG, 90th percentile | 61.6 (11.7/124.6) | 75.2 (37.4/113.5) | 72.0 (28.9/129.1) | 1.1 (0.6/3.1) |
| ACC, rest time | 33.1 (13.1–48.2) | 25.0 (14.7/54.0) | 37.2 (6.3/54.7) | 1.0 (0.5/1.7) |
| ACC, 10th percentile | 72.0 (70.0/82.0) | 73.0 (68.0/82.0) | 72.0 (70.0/102.0) | 1.0 (1.0/1.2) |
| ACC, 90th percentile | 640 (277/1,105) | 983 (389/2,865) | 644 (322/1,454) | 1.0 (0.7/2.3) |
| HR, 50th percentile | 75.0 (59.0/103.0) | 80.5 (58.0/96.0) | 75.0 (60.0/97.0) | 1.0 (0.9/1.1) |

**Table 3. P values of the Wilcoxon test of the comparison between the measures from morning (MO) and late afternoon (LA), R values of the Spearman correlation (morning with late afternoon), and the amount of the variances explained by the time of the day (morning, lunch or late afternoon), by differences between the individuals and by their interactions (median and 95% confidence intervals determined by bootstrap analysis) for the parameters of trapezius muscle activity (EMG), the parameters of arm acceleration (ACC), and the heart rate (HR).**

| Parameter | P (MO-LA) | R (MO-LA) | Percentage of variance explained by differences | | |
|---|---|---|---|---|---|
| | | | between subjects [%] | in time [%] | Subject x time [%] |
| EMG, rest time | 0.81 | 0.72** | 78% (54%/91%) | 1% (0%/10%) | 20% (9%/42%) |
| EMG, 10th percentile | 0.16 | 0.67* | 73% (42%/88%) | 3% (0%/11%) | 24% (9%/53%) |
| EMG, 50th percentile | 0.94 | 0.86*** | 67% (41%/90%) | 2% (0%/16%) | 30% (9%/50%) |
| EMG, 90th percentile | 0.33 | 0.70* | 82% (50%/94%) | 2% (0%/12%) | 15% (6%/41%) |
| ACC, rest time | 0.72 | 0.25 | 61% (25%/79%) | 4% (0%/25%) | 33% (19%/60%) |
| ACC, 10th percentile | 0.33 | 0.43 | 74% (54%/78%) | 2% (0%/17%) | 25% (17%/36%) |
| ACC, 90th percentile | 0.75 | 0.50 | 25% (16%/37%) | 23% (5%/43%) | 51% (32%/71%) |
| HR, 50th percentile | 0.79 | 0.81** | 92% (82%/96%) | 1% (0%/6%) | 7% (4%/14%) |

tigated parameters showed important differences between the subjects, but between the morning and the late afternoon values on average no significant differences were observed.

Comparisons between the morning and the late afternoon parameters of the arm acceleration did not reveal any significant differences (s. Fig. 2c and 2d, s. Table 2 and 3). The amount and changes of the rest time of the arm acceleration differed between the subjects, as in some subjects it was higher towards the late afternoon, in some lower and in one subjects it was stable. Similar results were found for the 10thand the 90th percentile of the arm acceleration. The heart rate showed no difference between the morning and the late afternoon and seemed to be stable over the workday in all subjects.

*Explained variance by the subject, the time and their interaction*

In all analyzed parameters, a considerable amount of the variance could be explained through differences between subjects and by the interaction between the subject and the time (morning, lunch or afternoon) (s. Table 3). The explained part of the variance between subjects was especially high for the heart rate (50th percentile), and two parameters of the trapezius muscle activity (90th percentile and rest time). Only for the peak arm acceleration (90th percentile) a considerable part of the explained variance was due to differences between the three measurement periods, it was higher during the lunch period. With the exception for the heart rate a considerable part of the explained variance was caused by the interaction between the factors time and subjects.

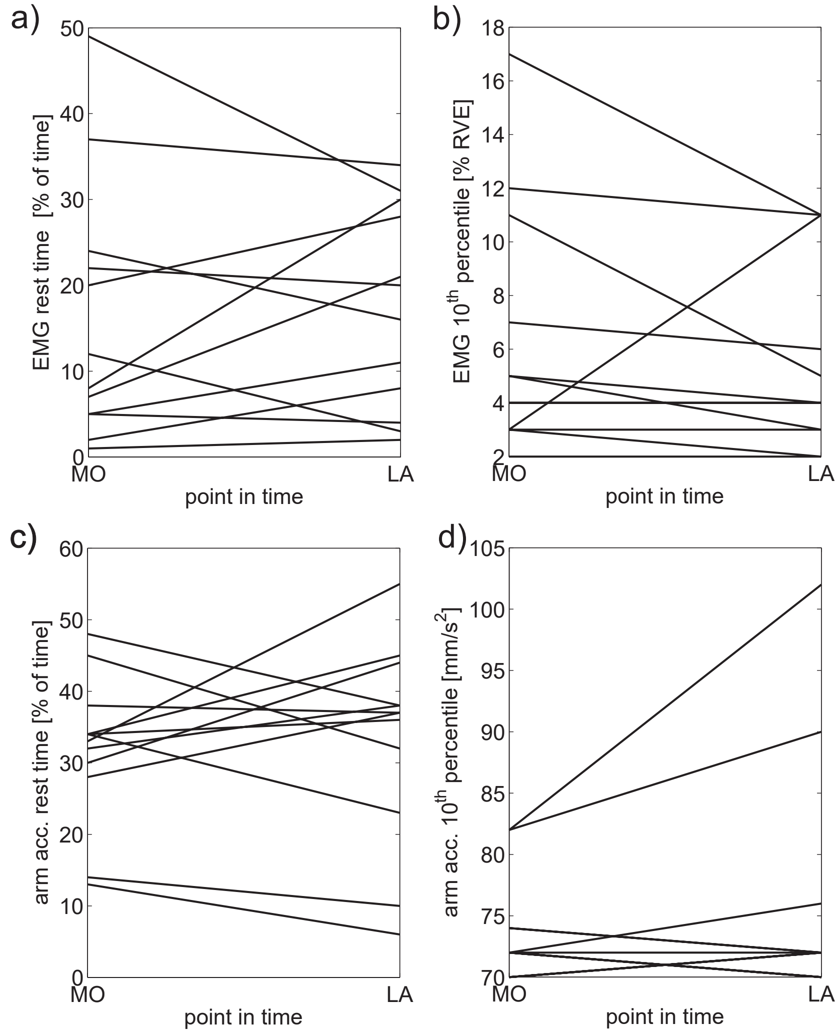


**Fig. 2. Values from the measures in the morning and in the late afternoon for the single subjects for a) the rest time of trapezius muscle, b) the 10th percentile of trapezius muscle activity, c) the rest time of arm acceleration, and d) the 10th percentile of arm acceleration.**

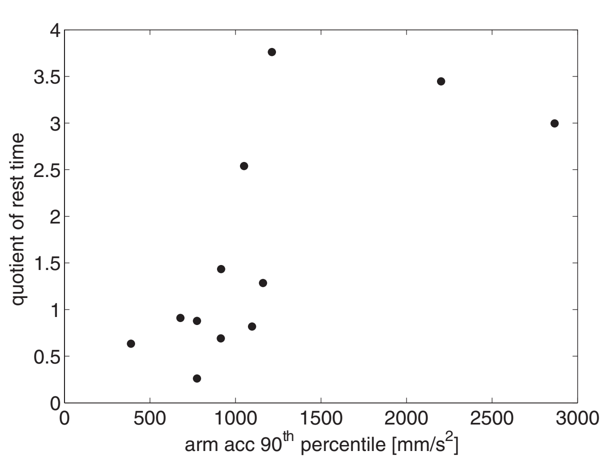


**Fig. 3. Quotient of trapezius muscle rest time (late afternoon values divided by morning values) and the 90th percentile of arm acceleration.**

*Influence of the arm acceleration during lunch time on relative differences between the work periods*

Significant correlations were found between the 90th percentile of arm acceleration during lunch time and the quotient of trapezius muscle parameters (trapezius muscle parameters of the late afternoon period divided by the ones determined for the morning period) (s. Fig. 3 for trapezius muscle rest time). A higher peak acceleration during the lunch period correlated with a longer rest time and a reduced activity of the trapezius muscle in the late afternoon compared to the morning. The spearman correlation coefficients for the relationship between the 90th percentile of arm acceleration during the lunch break and the quotient of the trapezius muscle rest time was 0.80 ($p<0.01$), for the 10th percentile of trapezius muscle activity −0.53

($p=0.08$), for the 50th percentile of trapezius muscle activity $-0.84$ ($p<0.01$), and for the 90th percentile of trapezius muscle activity $-0.71$ ($p<0.01$).

*Correlations between trapezius muscle activity and arm acceleration during the work periods*

Correlations between the parameters of the trapezius muscle activity and the arm acceleration were calculated in the morning and in the late afternoon. No correlations were found in the late afternoon. In the morning, two significant correlations were found between the 50th percentile of trapezius muscle activity and the rest time of the arm acceleration ($R=-0.69$) and between the 90th percentile of trapezius muscle activity and the rest time of the arm acceleration ($R=-0.68$).

## Discussion

At the beginning and the end of a workday and during lunch time the activity of the trapezius muscle, the heart rate, and the arm acceleration of female office employees were analyzed. The measures of the morning and the late afternoon work periods did not significantly differ from each other, but substantial dissimilarities between the subjects were observed. Significant correlations between the morning and afternoon work periods were found for all measures of trapezius muscle activity and for the heart rate but not for the measures of the arm acceleration. A higher peak arm acceleration at lunch time was significantly correlated with an increased trapezius rest time and a reduced muscle activity in the late afternoon work period in comparison to the morning levels.

In order to compare the beginning and the end of the workday, we chose one hour in the morning and one hour in the late afternoon (s. Fig. 1). To double-check the robustness of this analysis, the same procedure was done with the data from two hours in the morning and two hours in the afternoon. As we got similar results, we decided to only use the data of one hour.

In each of the three measuring periods the levels and durations of the trapezius muscle activity strongly differed between the examined subjects. For example, rest time was very short in one person (one percent of the one hour measuring period) and in another it lasted nearly 50% of the same measurement period. An analysis of the explained variance due to differences between the subjects, between the three measurement periods (work in the morning, in the late afternoon, and lunch period), or by their interaction revealed that for the measures of trapezius activity 67% until 82% of the variance was explained by differences between the single subjects. At least considering the measuring day the level and duration of trapezius activity were indicative for the examined subjects. Other authors already found substantial differences between subjects during computer work in controlled laboratory tasks. Westgaard and Bjorklund[44] showed that subjects reacted with strongly differing levels of activity of the trapezius muscle on standardized laboratory experiments with identical movements and explained it through a variable response of different subjects to the same stressor and as a consequence of general arousal of some subjects. Similarly, Zennaro, *et al.*[11] found big differences in the trapezius muscle activity between the subjects in a 30 min task on the computer. In this field study, the correlation of the morning and the late afternoon can be due to the same working tasks, to the same reaction of trapezius muscle to different loads or to a combination of these two possibilities. Due to the inclusion criteria that all subjects are employed as office workers, we expect the big differences in trapezius muscle rest time and activity in this study not mainly to be due to the work tasks. However, we were not able to strictly control the work the subjects did and therefore an influence of different work tasks cannot be excluded. Possible explanations could also be that some subjects had different habitual head positions, or a workstation with a bad ergonomic situation. Another possibility is the visual strain, a parameter that was discussed by Aaras, *et al.*[45]. Nevertheless, due to the mostly missing correlation of parameters of the muscle activity and parameters of arm acceleration and the remarkably high variability between the subjects (e.g. the range in trapezius muscle rest time was from almost no (1%) until nearly 50% of time), the differences in trapezius muscle activity seem not mainly due to physical load. Furthermore, literature[46] showed that different tasks of an office employee did not show relevant differences in the trapezius muscle activity. Another explanation could be the different reaction of trapezius muscle to the same external load in different subjects that was found in 1987 by Westgaard and Bjorklund[44] and interpreted as a different level of general arousal, but since then this hypothesis seems not to have further been investigated. In this study, the observed significant individual differences in the duration and level of trapezius activity in subjects with similar computer work might be explained by an individual reaction mode of the trapezius muscle to similar work tasks but further studies on this topic are needed. Considering this hypothesis the findings of Hagg and Astrom[28] are of interest, who showed that secretaries with more trapezius muscle rest time had less neck pain. It has repeatedly been shown that static sustained muscle contraction of the trapezius muscle for prolonged periods may underlie muscle pain development in spite of rather low relative muscle load[47]. Such activation patterns may be causally related to injury development via various intrinsic mechanisms[48].

In some subjects trapezius muscle rest time was minimal and it is plausible to assume that such a constant activity may induce a hypertrophy of the fatigue resistant muscle fibers[49]. It is highly probable that in the long run lack of rest time may lead to sustained overload of these smallest motor units of the muscle, may provoke homeostatic disturbances, and eventually trapezius myalgia[50]. Therefore, it may be practical to concentrate preventive measures towards subjects exhibiting continuous trapezius activity and it seems to be beneficial to promote active movements with high peak accelerations during lunchtime and during breaks.

The rest time of trapezius muscle was correlated between the morning and the afternoon and did not significantly differ between the morning and afternoon periods. (s. Fig. 2a). It was higher in the afternoon than in the morning in five subjects, lower in the afternoon than in the morning in three subjects and was constant in four subjects. Between the morning and late afternoon work periods differences of the levels ($10^{th}$, the $50^{th}$ and the $90^{th}$ percentile) of trapezius muscle activity also were not significant and any indications of fatigue were not evident. Kimura, *et al.*[51] showed that after four 25-min sessions with typing muscle fatigue could be documented by a significant decrease in muscle fiber conduction velocity and median frequency (MDF) ($P=0.026$) as well as an increase in root mean square (RMS) ($P = 0.039$) and subjective fatigue. They explained that fatigue only could be demonstrated when the hand was loaded by a weight of one kilogram. In preliminary experiments without such a load they found neither subjective nor objective signs of trapezius muscle fatigue. The subjects of this study were not loaded by additional loads and systematic changes of the trapezius muscle data were not found. A review showed that fatigue often could only be detected if the activity level was at least 15 % of the maximal voluntary contraction (MVC)[52]. As shown by an own study[53], 100% RVE approximately corresponds to 17% MVC. The median of the trapezius muscle activity in this study over all subjects and both points in time was 21% RVE±14% RVE. This shows that the activity levels were far below the 15% MVC so that eventual muscular fatigue may not be depicted by conventional surface EMG methods.

The rest time, the $10^{th}$, and the $90^{th}$ percentile of arm acceleration showed no difference between the morning and the late afternoon, but in the rest time and the $10^{th}$ percentile of arm acceleration a considerable part of the variance could be explained through differences between the subjects and as shown in Fig. 1, the absolute values and the progression from the morning to the late afternoon varied between the subjects. As the acceleration did not change in the progression of the day, neither the work tasks nor the behavior of the subjects seemed to significantly change. A tendency was found that a completely motionless arm was correlated with a reduced trapezius muscle activity. Stronger dependencies between the amount of arm acceleration and the activity of the trapezius muscle were found in literature. Mork and Westgaard[54] reported that 20% of the intra-individual variance of the trapezius muscle activity was explained by the arm movements, but no correlations were found to the arm elevation.

The 50th percentile of the heart rate showed no change between morning and late afternoon. It was stable over the workday but significantly different between the subjects. As the heart rate can be altered by physical[55] as well as psychological loads[56], it seems that the physical and the psychological loads were fairly stable over the workday.

To explore if a higher activity level during a lunch break would exhibit beneficial effects on trapezius muscle load, Spearman correlations were computed between the measures of the arm acceleration during the lunch period and changes in trapezius muscle activity in the afternoon work compared to the morning period. Indeed, highly significant relationships were found for the $90^{th}$ percentile of arm acceleration and all measures of trapezius activity, indicating that bursts of strong arm accelerations were correlated with more trapezius muscle rest time and less activity in the late afternoon. In this study the $90^{th}$ percentile of arm acceleration during the lunch period can be considered an indicator of strong accelerations and exactly these strong accelerations showed a significant relationship with increased rest time at the end of the work period. Such a finding is in line with observations by Andersen, *et al.*[57], that forceful resistance training was highly effective to improve work-related myalgia in computer work. These first results might indicate that movement during the lunch break can have positive influences on the muscle activity in the afternoon and could be highly recommended.

## Limitations

A clear limitation of this study is the small number of subjects. Nineteen subjects were measured. This number of subjects would have allowed a more refined analysis of the results, including an analysis of variance. Due to a high variation in the values of the reference contractions and the resulting normalization values (RVE), it was necessary to exclude six subjects. Another subject had to be excluded because of an error of the measuring device. With the remaining twelve subjects, a bias because of a deviation of the normal distribution could not be excluded. Therefore we only used simple, non-parametric statistical procedures. The measured upper arm acceleration is a reliable measure for the upper arm but only is indicative for the acceleration of the upper body and of course does not give any information on the head movement. Even if the arm itself is not purposely moved the acceleration is an indicator for any accelerations of the body and accelerations of the arm accompany most movements such as walking, standing up, or lively discussions.

Furthermore, it has to be mentioned, that the analysis relies on the measurement of one workday. As shown by Delisle, *et al.*[58] the best reliability is reached when two days are measured and averaged. Therefore it is possible, that the influence of the subject could be overestimated in this study. As in all studies using surface EMG, some caution in the interpretation of the results is needed. Using this technique it is not possible to show results for single motor units[59].

## Conclusions

In this study with asymptomatic female computer workers we observed a large variance in trapezius muscle activity and rest time, e.g. trapezius muscle rest time varied between 1% and 49% of time. No systematic progression was detected over the work day, but different progressions for the single subjects. In some of the subjects trapezius muscle rest time was minimal and it is plausible to assume that such a constant activity may has been alleged to constitute a risk for the development of trapezius myalgia. Therefore, it may be practical to concentrate preventive measures towards subjects exhibiting continuous trapezius activity and it seems to be beneficial to promote active movements with high peak accelerations during lunchtime and during breaks.

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