

Effect of yoga on musculoskeletal discomfort and motor functions in professional computer users

Shirley Telles*, Manoj Dash and K.V. Naveen
Swami Vivekananda Yoga Research Foundation [a Yoga University], Bangalore, India

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Abstract. The self-rated musculoskeletal discomfort, hand grip strength, tapping speed, and low back and hamstring flexibility (based on a sit and reach task) were assessed in 291 professional computer users. They were then randomized as Yoga (YG; $n = 146$) and Wait-list control (WL; $n = 145$) groups. Follow-up assessments for both groups were after 60 days during which the YG group practiced yoga for 60 minutes daily, for 5 days in a week. The WL group spent the same time in their usual recreational activities. At the end of 60 days, the YG group ($n = 62$) showed a significant decrease in the frequency, intensity and degree of interference due to musculoskeletal discomfort, an increase in bilateral hand grip strength, the right hand tapping speed, and low back and hamstring flexibility (repeated measures ANOVA and *post hoc* analysis with Bonferroni adjustment). In contrast, the WL group ($n = 56$) showed an increase in musculoskeletal discomfort and a decrease in left hand tapping speed. The results suggest that yoga practice is a useful addition to the routine of professional computer users.

1. Background of the study

There is extensive evidence that working with computer terminals and keyboards is associated with the development and exacerbation of a variety of work-related disorders involving the back, neck, and upper limbs [2]. These conditions are known as cumulative trauma disorder (CTD). The National Institute for Occupational Safety and Health (NIOSH) estimated that 15–20 percent of the workforce in the United States is at risk of developing CTD [20]. In India a survey of 500 professional computer users showed that over 50 percent of them had symptoms of established CTD [25].

Many investigators have identified the risk factors that are closely related with CTD of the upper extremities. These include repetitive motion, excessive force,

and maintenance of awkward or constrained postures for prolonged periods [1,16,27].

Various solutions to CTD include modifying workstations, using alternative keyboards and pointing devices, and adopting software solutions to minimize the key presses required to execute elaborate routines [33]. However these are only partial solutions to CTD. It is essential to keep professional computer users aware about injurious keyboard techniques, as well as postures and working styles which place them at risk [14, 22].

Apart from this there have been studies to evaluate the impact of lifestyle on the prevention of CTD while complementary treatments have been used in the management of this condition. A cross-sectional survey of 134,072 respondents in Canada, showed that being physically active during leisure time was associated with a lower prevalence of work-related upper body CTD compared to the general prevalence of 5.9 percent in the Canadian population [24].

In the management of CTD various combinations of exercise and health awareness strategies have been

*Address for correspondence: Shirley Telles, Ph.D., Patanjali Yogpeeth, Maharishi Dayanand Gram, New Delhi-Haridwar Highway, Bahadrapad, Haridwar 249 402, India. Tel.: +91 1334 240008; Fax: +91 1334 244805; E-mail: shirleytelles@gmail.com.

tried. For example, daily exercises which emphasize postural awareness to correct poor posture and provide a basic physiological understanding of the disorder have been found effective in reducing stiffness and pain of the upper back and neck in CTD [23]. There is also some evidence to indicate that splinting, laser acupuncture, yoga and therapeutic ultrasound may be effective in the short to medium term (i.e., up to 6 months) management of carpal tunnel syndrome [10]. This was based on an assessment of two systematic reviews, sixteen randomized controlled trials (RCTs) and a single before-and-after study using historical controls. An earlier RCT did indicate the benefits of yoga over splinting for carpal tunnel syndrome [9]. In this trial the benefit was derived from practicing eleven yoga postures intended to strengthen, stretch, and balance each joint in the upper body, practiced along with relaxation given twice weekly, for eight weeks. Following yoga the participants showed a significant decrease in pain and an increase in grip strength whereas a control group (who were given a wrist splint to supplement their treatment) showed no change.

The hand grip strength measures muscle strength and endurance in the hand and forearm muscles. Experienced computer users with symptoms of discomfort in the hand-wrist and forearm-elbow had lower pinch grip strength than those who were asymptomatic [15]. In a separate study on normal volunteers and patients with rheumatoid arthritis, the hand grip strength of both hands measured with a grip dynamometer increased in normal adults, children and in rheumatoid arthritis patients following yoga practice which included yoga postures (*asanas*), voluntarily regulated yoga breathing (*pranayamas*), and meditation (*dhyana*) [5]. An equal number of normal adults, children, and patients with rheumatoid arthritis who did not practice yoga showed no increase in hand grip strength, suggesting that there was no re-test effect. Given the fact that symptomatic computer users did have a lower pinch grip strength and that hand grip strength has been shown to improve with yoga practice [5,28] in the present study hand grip strength was assessed in professional computer users following yoga.

In an earlier study another aspect of motor function, viz., motor speed, was also found to improve following thirty days of practicing a combination of yoga postures, breathing techniques and meditation every day [4]. The number of successive, rapid alternating movements in a given time, as in a tapping speed task, is a standard measure to clinically evaluate motor speed [26]. Following thirty days of yoga the tapping

speed increased in the first ten seconds of the thirty-second tapping speed task. This showed that motor speed for repetitive finger movements increased following yoga, but since the increase was not sustained for thirty seconds, it suggested that endurance was not improved. In the present study it was considered relevant to study the tapping speed based on a report that in contrast to earlier biomechanical theories, the key press force and key press speed were negatively associated with musculoskeletal discomfort [18]. In particular, slower key press speeds were associated with higher levels of right shoulder discomfort and fatigue.

The effect of yoga practice on the hand grip strength and tapping speed have not been studied in professional computer users who are potentially at risk of developing CTD

2. Methods

2.1. Purpose of the study

The present randomized controlled trial was conducted to assess the effect of sixty days of yoga practice on musculoskeletal discomfort, motor functions (viz., strength and motor speed) and hip and lower back flexibility in professional computer users. This research may help to develop a yoga module attending to the specific requirements of professional computer users.

2.2. Sampling

Two hundred and ninety one persons working in a software company in Bangalore, India were recruited for the study. All the participants in the study used a computer for at least 6 hours each day, for 5 days in a week. Persons of both sexes with ages ranging between 21 and 49 years participated in the trial. The following conditions were the basis for excluding participants from the trial: (i) those who reported symptoms of musculoskeletal discomfort (neck/shoulder and hand/arm) during a clinical examination, requiring the use of analgesics and (ii) subjects who were left hand dominant. Hand dominance was assessed using the Edinburgh handedness inventory [21]. All subjects were right hand dominant. None of the participants had to be excluded based on the criteria mentioned above.

Both groups had comparable job assignments and responsibilities based on rating by the human resource personnel from the software company. All of them were involved in software development and had com-

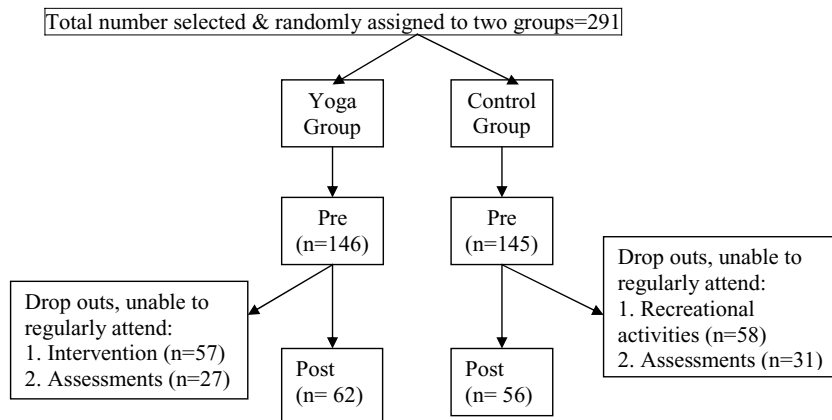


Fig. 1. The trial profile of the randomized controlled study.

parable experience in it, having spent comparable time working in software development and also having tasks of comparable complexity assigned to them.

The details of the study were explained to the participants and their consent to participate in the study was obtained. The project was approved by the ethics committee of the research foundation and had the approval of the human resource department of the software company.

2.3. Design

The 291 participants were randomized as two groups using a standard random number table prior to their assessment. The two groups were then designated as (i) intervention (i.e., yoga, $n = 146$) and (ii) wait list control ($n = 145$), by a person from the software company who had no other part in the study. The yoga (YG) and wait list control (WL) groups were comparable with respect to their age [group average (\pm S.D.) 32.8 (\pm 8.6) years and 31.9 (\pm 10.2) years, respectively], gender distribution [11 females in YG group and 13 in WL group], the type of work they did, their workstations and the number of hours they used a computer each day.

Both groups were assessed at baseline and after 60 days. During the 60 days the YG group had an hour of yoga practice each day, for five days in a week. While the YG group practiced yoga the WL group spent the time in the recreation center of the software company where 60 percent of them talked to their friends, 12 percent spent time playing indoor games, 12 percent exercised in the gym and 16 percent watched television. The WL group had already been spending this time each day doing the same activities and hence during

the 60 day period they were following their usual routine. Hence the wait-list control group served mainly to assess the changes related to repeated-testing after 60 days. During the 60 days there were 84 drop outs from the trial in the YG group and 89 from the WL group. The large number of drop outs was mainly due to the fact that the participants had demanding work schedules which interfered with their participating in: (i) the intervention (YG group) or recreational activities (WL group) and/or (ii) the assessments (both YG and WL groups). Most of the participants who were considered as 'drop-outs' had been posted to other companies elsewhere during the two month study period. To be considered as regular in their participation they had to have a minimum of 38 days of attendance during the 60 day period. The trial profile is given in Fig. 1.

These details as well as the trial profile have been provided in an earlier report of the effects of this yoga program on symptoms of visual discomfort (i.e., of 'dry eye') [29].

2.4. Assessments

2.4.1. Musculoskeletal and hand discomfort

The Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) The Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) is a questionnaire which combines a body map diagram with questions about the seven day prevalence of musculoskeletal pain, its' severity, and if it interfered with performing job duties. This questionnaire was used in a 1999 study of musculoskeletal discomfort among keyboard users [12]. Since this survey was based on another instrument called the Nordic Musculoskeletal Questionnaire (NMQ), it was concluded that the CMDQ had

the same validity [12]. The CMDQ has face validity and test-retest reliability, though this was studied over a three week period [12]. The main limitations of this instrument are the lack of clinical validity testing for it specifically and the fact that it is primarily developed for use in upper body disorders. The tool does not assess if the musculoskeletal discomfort is work-related.

The CMDQ was used to assess: (i) frequency of pain episodes during the last work week at: neck; shoulder; elbow; arm; wrist; hands and fingers, (ii) the intensity of pain expressed as level of discomfort and (iii) the interference with the ability to work. The symptoms were considered during the week before assessment. The scores were analyzed by weighting the rating scores to more easily identify the most serious problems and summing the rating values for each person for the whole body, right hand and left hand separately as follows. For frequency the rating was: Never = 0, 1–2 times/week = 1.5, 3–4 times/week = 3.5, Every day = 5, and Several times every day = 10. The level of discomfort scores were analyzed as: Slightly = 1, Moderately uncomfortable = 2, and Very uncomfortable = 3. The Interference scores were rated as: Not at all = 1, Slightly interfered = 2, and Substantially interfered = 3.

The person who administered the questionnaire and scored the response sheets was not aware to which group the subjects belonged.

2.4.2. Hand grip strength

Hand grip strength of both hands was assessed using a hand grip dynamometer (Lafayette Instruments, Model No. 76618, Indiana, USA). Subjects were tested in 6 trials, 3 for each hand alternately, with a gap of 10 seconds between trials. During the assessment subjects were asked to keep their arm extended at shoulder level, horizontal to the ground, with extension at the elbow as has been described earlier [5]. The maximum value obtained during the three trials was used for statistical analysis.

2.4.3. Tapping speed

Tapping speed was measured using an apparatus consisting of an 18 inch fiber-resin board with two rectangular metal plates on either end, 11 inches apart (Lafayette Instruments, Model No. 32012, Indiana, USA). The apparatus has a metal stylus connected to it and contacts between the stylus and the two metal plates are registered on an impulse counter. Subjects were instructed to use their right hand to hold the stylus and tap on the steel plate which is on the right side

of the board, and to use their left hand for the board on the left side. They were asked to tap as rapidly as possible. The apparatus was kept on a table at the level which the keyboard was kept and tapping was carried out with the wrist supported and the stylus held as a pen is held. Assessments were made for both hands, and the order of testing a particular hand was alternated for different subjects. Tapping speed was assessed in three contiguous periods of 10 seconds. This was done separately for each hand.

2.4.4. Low back and hamstring flexibility

Low back and hamstring flexibility were assessed using a standard sit-and-reach apparatus (Lafayette Instruments, Model No. 01285, Indiana, USA) and following a standard method [7]. The test involves sitting on the floor with legs out straight ahead. Bare feet are placed with the soles flat against the box, shoulder-width apart. Both knees are held flat against the floor by the tester. With hands on top of each other and palms facing down, the subject reaches forward along the measuring line as far as possible, sliding a plate with a marker, along the scale as far forward as possible. After one practice reach, the second reach is held for at least two seconds while the distance is recorded. It is made sure that there are no jerky movements, and that the fingertips remain level and the legs flat. The distance to which the plate and indicator are slid forward are recorded to the nearest cm.

2.5. Intervention

The yoga sessions were taught by an instructor who had completed a one year diploma in yoga at an university recognized by the Indian government. He had taken up the diploma after graduation. After this he had been teaching yoga to people with normal health for ten years at the time the project commenced. The yoga sessions were conducted in a room set aside for the employees' recreational use which was located within the company premises. The yoga sessions were conducted during a 1 hour period set aside for recreation between 17.30 and 18.30 hours each day. The participants' yoga practice and attendance of the sessions were monitored by the yoga instructor.

The 60 minute yoga program included yoga postures (*asanas*, 15 minutes), exercises for the joints and back (*sithilikarana vyayama*, 10 minutes), regulated breathing (*pranayamas*, 10 minutes), visual cleansing exercises (*trataka*, 10 minutes), and guided relaxation (15 minutes). These techniques were selected based on pre-

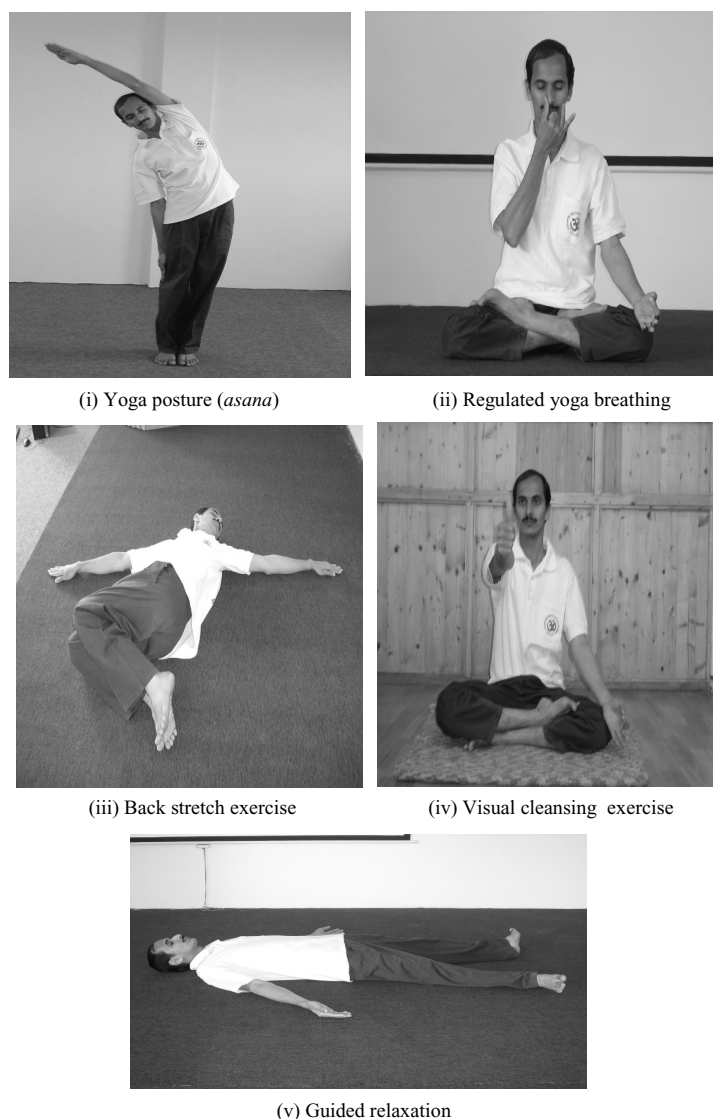


Fig. 2. This shows a single individual practicing (i) a yoga posture or *asana*, (ii) voluntarily regulated yoga breathing (*pranayama*), (iii) a back stretch exercise (*sithilikarana vyayama*), (iv) a visual cleansing exercise (*trataka*), and (v) guided relaxation.

vious research which has shown that practicing them reduced musculoskeletal discomfort [11], increased grip strength [5] and tapping speed [4]. Figure 2 shows a single individual practicing (i) a yoga posture or *asana*, (ii) voluntarily regulated yoga breathing (*pranayama*), (iii) a back stretch exercise (*sithilikarana vyayama*), (iv) a visual cleansing exercise (*trataka*), and (v) guided relaxation.

2.6. Data analysis

The data were analyzed using SPSS Version 10.0.

2.6.1. Musculoskeletal and hand discomfort

Three repeated measures analyses of variance (ANOVA) were carried out separately for the frequency, discomfort and level of interference, with one Between-subjects factor, viz., Groups (with two levels, i.e., YG and WL groups) and two Within-subjects factors, viz., Assessments (with two levels, i.e., day 1 and day 60) and Sites (with three levels, i.e., whole body, right hand and left hand).

Post-hoc analyses using pair wise comparisons between day 1 and day 60, for the whole body, right hand and left hand were done separately, with Bonferroni adjustment.

2.6.2. Hand grip strength and tapping speed

The hand grip strength data were analyzed with repeated measures analyses of variance (ANOVA) with one Between-subjects factor, viz., Groups (with two levels, i.e., YG and WL groups) and two Within-subjects factors, viz., Assessments (with two levels, i.e., day 1 and day 60) and Hands (with two levels, i.e., right hand and left hand).

For the tapping speed the number of contacts made in specified time intervals were analyzed with an ANOVA which had one Between-subjects factor, viz., Groups (with two levels, i.e., YG and WL groups) and three Within-subjects factors, viz., Assessments (with two levels, i.e., day 1 and day 60), Hands (with two levels, i.e., right hand and left hand) and Time (with three levels, i.e., 10 sec., 20 sec. and 30 sec.).

Post-hoc analyses for pair wise comparisons between mean values were done with Bonferroni adjustment.

2.6.3. Low back and hamstring flexibility

The data were analyzed with an ANOVA for repeated measures with one Between-subjects factor, viz., Groups (with two levels, i.e., YG and WL groups) and one Within-subjects factor, viz., Assessments (with two levels, i.e., day 1 and day 60).

Post-hoc analyses for pair wise comparisons between mean values were done with Bonferroni adjustment.

3. Results

3.1. The repeated measures ANOVA

3.1.1. Musculoskeletal discomfort

The repeated measures ANOVA showed a significant difference between the two groups i.e., YG and WL groups ($F = 7.448$, $DF = 1.116$, $p < 0.01$). There was also a significant difference between the three sites i.e., body as a whole, right hand and left hand ($F = 146.799$, $DF = 1.125$, 130.460 , $p < 0.001$; *Huynh-Feldt* $\epsilon = 0.562$) and the three indicators of discomfort i.e., frequency, severity and interference ($F = 67.107$, $DF = 1.200$, 139.929 , $p < 0.001$; *Huynh-Feldt* $\epsilon = 0.603$). There was a significant interaction between assessments [day 1 and day 60] and sites ($F = 6.928$, $DF = 1.376$, 153.806 , $p < 0.01$); *Huynh-Feldt* $\epsilon = 0.663$); and between sites and indicators of discomfort ($F = 36.617$, $DF = 1.283$, 148.779 , $p < 0.001$; *Huynh-Feldt* $\epsilon = 0.321$). This suggests that these factors were not independent of each other [34].

3.1.2. Hand grip strength and tapping speed

The repeated measures ANOVA showed a significant difference in hand grip strength between Assessments ($F = 9.658$, $DF = 1,116$, $p < 0.01$) and Hands ($F = 11.524$, $DF = 1,116$, $p < 0.01$). There was no difference between the YG and WL group.

The tapping speed showed a significant difference between Hands ($F = 27.854$, $DF = 1,116$, $p < 0.001$) and Time, that is 10, 20 and 30 seconds ($F = 21.451$, $DF = 2, 232$, $p < 0.001$). The interaction between Assessments and Hands ($F = 5.755$, $DF = 1,116$, $p < 0.05$) was also significantly different. This suggests that the effect of one factor was not independent of a particular level of the other factor(s) [34]. There was no difference between the YG and WL group.

3.1.3. Low back and hamstring flexibility

The repeated measures ANOVA showed a significant difference between the two groups i.e., YG and WL groups ($F = 4.934$, $DF = 1,116$, $p < 0.05$). There was a significant difference in sit and reach scores between assessments ($F = 58.556$, $DF = 1,116$, $p < 0.001$).

3.2. Post-hoc analyses

3.2.1. Musculoskeletal discomfort

Post-hoc analyses by pair wise comparisons with Bonferroni adjustment for the YG group showed a significant decrease following two months of yoga compared to before, in the frequency of discomfort for the whole body ($p < 0.001$), right hand ($p < 0.001$) and the left hand ($p < 0.01$). The level of discomfort also decreased at the three sites mentioned above ($p < 0.01$ in all cases). There was also a decrease in the extent to which discomfort interfered with their routine work in the three sites mentioned above ($p < 0.01$ for the whole body and the right hand; $p < 0.05$ for the left hand).

In contrast, the WL group showed a significant increase in frequency of discomfort for the whole body ($p < 0.001$), the right hand ($p < 0.001$) and the left hand ($p < 0.001$). The level of discomfort also increased at the three sites mentioned above ($p < 0.001$ in all cases) respectively. There was also an increase in the extent to which discomfort interfered with their routine work at the same three sites ($p < 0.001$ in all cases).

The groups mean values and standard deviations are given in Table 1.

Table 1
Scores in the Cornell musculoskeletal and hand discomfort questionnaire in yoga [YG] and wait list control [WL] groups

Sites	Day	Yoga			Wait list control		
		Frequency	Level	Interference	Frequency	Level	Interference
Whole Body	1	18.53 ± 18.19	11.56 ± 9.32	11.74 ± 9.35	16.95 ± 17.34	10.25 ± 8.31	10.54 ± 9.06
	60	8.37 ± 11.02***	5.40 ± 6.55***	5.60 ± 6.88***	24.2 ± 18.79***	15.16 ± 9.46***	13.77 ± 9.20***
Right hand	1	4.96 ± 5.95	3.06 ± 3.65	3.37 ± 3.84	3.31 ± 3.73	2.16 ± 2.17	2.48 ± 2.67
	60	2.10 ± 3.38***	1.44 ± 2.23***	1.73 ± 2.74***	7.62 ± 7.16***	4.68 ± 4.03***	4.30 ± 3.62***
Left hand	1	3.88 ± 5.59	2.61 ± 3.63	2.77 ± 3.92	1.41 ± 2.11	0.96 ± 1.48	1.23 ± 2.05
	60	1.85 ± 3.28**	1.16 ± 2.04**	1.44 ± 2.55*	6.14 ± 6.55***	4.12 ± 3.95***	3.29 ± 3.17***

Values are Mean ± S.D.

* $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$, Post-hoc analyses with Bonferroni adjustment comparing Day 60 with Day 1.

3.2.2. Hand grip strength and tapping speed

Post-hoc analyses with Bonferroni adjustment by pair wise comparisons of values after yoga compared with before showed a significant increase in hand grip strength scores for the YG group on day 60 compared to day 1 for the right hand ($p < 0.05$) and for the left hand ($p < 0.01$). In contrast, there was no significant change in the WL group.

The groups mean values with standard deviations are given in Table 2.

Tapping speed of the YG group showed a significant increase for the right hand speed at 10 seconds ($p < 0.05$) and 30 seconds ($p < 0.05$). In the WL group tapping speed significantly decreased for the left hand at 10 seconds ($p < 0.001$) on day 60 compared to day 1. The groups mean values with standard deviations are given in Table 2.

3.2.3. Low back and hamstring flexibility

Post-hoc analyses by pair wise comparisons with Bonferroni adjustment showed a significant increase in the values obtained in the Sit and Reach Task for the YG group on day 60 compared to day 1 ($p < 0.001$). In contrast, there was no significant change in the WL group.

The groups mean values with standard deviations are given in Table 2.

4. Discussion

In the present study eight weeks of yoga practice significantly decreased self-reported musculoskeletal discomfort in 62 professional computer users. Also, they showed an increase in the bilateral hand grip strength, the tapping speed of the right hand, and an increase in low back and hamstring flexibility based on a standard sit and reach task. In contrast, after sixty days of no-intervention and carrying on with their routine recreational activities 55 professional computer users

who formed the WL group showed an increase in musculoskeletal discomfort and a decrease in left hand tapping speed.

Earlier, musculoskeletal discomfort and pain of the hands, neck and back were shown to be associated with different psychosocial factors [8]. For example, increased physical workload, such as an increase in work pressure and greater time spent at a computer was related to symptoms in the neck, shoulder, hand and wrist [3]. Conversely neck and low back discomfort were associated with mental distress related to either of two extremes viz., monotonous work [13] or a high mental work demand [30]. This suggests that greater mental workload has a bigger impact on discomfort of the neck and back, whereas upper limb discomfort may be more closely related to a physical work load.

The decrease in discomfort following yoga was comparable for the whole body, the right hand and the left hand. In contrast, the WL group showed an increase in the level of discomfort after eight weeks. The level of discomfort was high for the left hand (277.4 percent) and for the right hand (106.7 percent) compared to the body as a whole (40.4 percent). Hence while the musculoskeletal discomfort increased to a greater extent in both hands than in the rest of the body, in the WL group, the improvement in the YG group was comparable at all three sites. Here, musculoskeletal discomfort was assessed using a subjective rating scale, not some more objective method. Given the fact that it was more likely that the WL (control group) felt deprived of the additional care in the form of interaction with the yoga teacher, which the yoga group had, this could possibly have made the control group more likely to experience and express subjectively rated discomfort. This is specially possible since additional care (in this case interaction with the yoga therapist), is known to have psychological benefits [6].

In another study, experienced computer users with symptoms of discomfort in the hand-wrist and forearm-elbow had no difference in their hand grip strength

Table 2
Tapping speed in subjects during 0–10 seconds, 10–20 seconds, 20–30 seconds, Average of 30 seconds, grip strength and scores for the sit and reach task in YG and WL groups

Variables	Hand	Yoga		Wait-list control	
		Day 1	Day 60	Day 1	Day 60
Tapping speed at 10 Sec.	RIGHT	32.6 ± 8.2	34.5 ± 7.5*	33.2 ± 7.9	32.0 ± 7.2
	LEFT	35.8 ± 7.3	36.7 ± 6.8	36.1 ± 6.5	33.1 ± 6.3***
Tapping speed at 20 Sec.	RIGHT	32.8 ± 9.3	34.1 ± 7.8	32.7 ± 7.9	32.6 ± 8.2
	LEFT	35.7 ± 7.2	36.5 ± 6.2	35.8 ± 6.3	34.4 ± 5.8
Tapping speed at 30 Sec.	RIGHT	31.5 ± 7.6	33.4 ± 7.0*	30.4 ± 7.7	31.2 ± 6.8
	LEFT	33.9 ± 5.7	34.1 ± 6.5	34.0 ± 6.7	33.3 ± 5.8
Grip strength	RIGHT	31.3 ± 8.8	32.8 ± 8.9*	32.0 ± 8.3	33.0 ± 8.0
	LEFT	30.2 ± 9.1	32.0 ± 9.0**	31.2 ± 8.4	32.2 ± 7.2
Scores for the sit and reach task	–	25.0 ± 7.1	35.0 ± 8.7***	27.2 ± 9.4	26.8 ± 7.4

Values are group means ± S.D.

* $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$, Post-hoc analyses with Bonferroni adjustment comparing Day 60 with Day 1.

but had lower pinch grip strength than those who were asymptomatic [15]. These observations are comparable to those of the WL group in the present study that showed no change in hand grip strength after eight weeks with no specific intervention.

In an earlier study a combination of yoga practices which included postures, breathing techniques, and meditation, increased the hand grip strength in physical activity instructors, over a three month period [28]. In another study the hand grip strength also increased in children after 10 days of practice and adults after 30 days of practice [5]. In the same report, patients with rheumatoid arthritis showed an increase in hand grip strength after a 15 day period of yoga practice. Increased hand grip strength following varying durations of yoga practice may be related to the availability of energy and oxidation of glucose, as these factors are known to influence grip strength [19].

While increased hand grip strength after yoga suggests an increase in muscle strength and endurance, similar results were not seen in another study which examined the impact of yoga on a thirty seconds tapping speed task [4]. In this earlier study, following a month of yoga practice the tapping speed, which is correlated with motor speed for repetitive movements increased within the first ten seconds of the task. However when the participants continued the task for three contiguous 10 second periods, the tapping speed was significantly lower in the last 10 seconds for both yoga and control groups at both pre and post assessments. Hence for this repetitive and continuous task yoga practice did not reduce fatigue. Here, the increase in tapping speed could have been an initial spurt of speed which was not sustained. In contrast, in the present study, the increase in tapping speed in the YG group was seen after 10 and 30 seconds, with a non-significant

trend of increase at 20 seconds. Hence these results suggest that the increase in motor speed was sustained over 30 seconds. Motor speed is determined by muscle strength, endurance, and co-ordination. An increase in some, or all, of these factors may have contributed to the increase in tapping speed. However the increase in right hand tapping speed, with no increase for the left hand is difficult to explain. This is especially difficult to explain as frequent use of a computer keyboard was shown to increase left hand performance scores on a dexterity task [30].

In contrast to the YG group the WL group showed a decrease in left hand tapping speed during the first ten seconds, at the end of eight weeks. This may have been related to work fatigue during the eight week period. However, the decrease in the initial speed could also be related to psychological factors [31,32] and poor motivation for the task in the absence of an intervention [6]. The latter point is related to the fact that in the absence of being given an intervention the WL group may not have felt that their performance was likely to change and hence may not have been enthusiastic at re-test.

The increased scores in the sit and reach task following yoga are suggestive of an increase in hamstring and low back flexibility. Improved flexibility is associated with a lower risk of developing muscle tension and pain [17]. This may have also contributed to the decreased musculoskeletal discomfort following yoga.

There were two main limitations to the study. One limitation was the large numbers of drop-outs from both groups. The main reason why participants dropped out of the study was because they had job assignments for which they were posted elsewhere in or outside India. Out of 57 drop-outs from the YG group, who were not able to regularly attend the intervention, 6 of them dropped out as they preferred to use the 60 minute peri-

od kept aside for recreation for some activity other than yoga. The majority dropped out as they were posted elsewhere. A second limitation is that the intervention was for 60 minutes, for 5 days each week. This would require special commitment for the participants to set aside this amount of time on all working days. The yoga program was designed to address at least three problems which are known to arise in computer users. These are musculoskeletal discomfort, symptoms of visual discomfort, and mental stress. However future research needs to be carried out to determine whether the duration of the program could be shortened and still get the same benefits.

5. Conclusion

In summary the present trial showed that yoga practiced for an hour a day, 5 days in a week, for sixty days decreases self rated musculoskeletal discomfort, improves muscle strength and speed and low back and hamstring flexibility. These results suggest that yoga is a useful addition to the routine of professional computer users. Based on this, employees of software companies would need to commit 5 hours a week for yoga practice and their employers would need to facilitate this in terms of providing a place to practice yoga, time, and arranging for informed instruction on yoga.

6. Recommendations for future studies

In the present study the yoga program was for 60 minutes, 5 days in a week. Future research could be planned to determine the usefulness of a shorter duration yoga program. Also, it would be useful to determine whether practicing yoga for some days as part of a group and for the remaining days at home using pre-recorded instructions and maintaining a diary, would also be effective. These options could make it easy for more participants to comply with the program.

The present randomized controlled trial was limited to a sixty day follow-up period. Further studies could be planned with a longer duration follow-up period. It would also be desirable to study whether yoga practice prevents the development of CTD in professional computer users.

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