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Effects of physical activity intervention on reducing neck and upper extremity pain intensity for female office computer workers

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ABSTRACT

The computer usage among office workers had increased tremendously in past recent years and the surge in computer usage has created a surge in work-related musculoskeletal disorders (WRMSDs) on arm, neck, and shoulder. For prevalence of musculoskeletal symptoms in relation to gender and age, females had higher risk and prevalence of upper limb complaints and the prevalence of WRMSDs generally increases with age. Systematic review studies had reported effectiveness of various physical activity (PA) interventions on improvements of upper extremity musculoskeletal disorders (UEMSDs) or neck pain for office workers. However, the degree of adherence of PA interventions with WHO guidelines (e.g. 150–300 min of moderate-intensity activity per week) is scare among literature. Accordingly, this study assessed the effects of PA intervention (adhere to WHO PA guidelines) on reducing neck and upper extremity pain intensity for female office computer workers of different age groups. Wearable sensing devices and subjective assessment tools were also used to estimate various physiological and psychological responses during PA intervention. Fifteen females in three different groups with computer usage ≥ 4 h/day were recruited. Comparing the pain intensity data collected before and after the 12 weeks PA intervention administered in this study, no statistically significant differences were found though the reductions of pain intensity were observed for each age group. This result was consistent with previous findings assessed with subjects free of musculoskeletal disorders (MSDs) in the upper extremities or neck regions. Similar PA effect on heart rate is also observed in this study where the heart rate decreased after 12 weeks PA intervention indicating improvements of cardiovascular function. In addition, PA intervention might help the middle-aged and older females with lesser magnitudes of muscular demands in the posterior deltoid muscle. To further explore the PA intervention effect on reducing musculoskeletal pain, symptomatic subjects should also be recruited and comparable PA intervention (e.g. type and duration of PA) should be implemented to verify the effect.

Keywords: Work-related musculoskeletal disorders, Physical activity, Office computer worker, Aging worker, Physiological strain.

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1. INTRODUCTION

In conjunction with the Industry 4.0, the computer usage among office workers had increased tremendously in past recent years (Padmanathan et al., 2018). Mani et al. (2016) showed that office computer workers use computers on an average of up to 6–12 h a day. Feng et al. (2021) also reported that daily computer usage for male and female office computer workers are 7.90 ± 3.03 h and 7.80 ± 2.23 h, respectively. The surge in computer usage has also created a surge in work-related musculoskeletal disorders (WRMSDs). Scientific reports reviewed by Kaliniene et al. (2016) and Mohan et al. (2019) indicated that computer users mostly report complaints about pain in the neck area. In addition, complaints about pain in other anatomical body regions (shoulders, upper extremities, back) are also prevalent among computer users (Ardahan and Simsek, 2016; Kaliniene et al., 2016; Padmanathan et al., 2018; Mohan et al., 2019). For example, 395 government office officials with average computer using durations 6.57 ± 2.03 h/day reported musculoskeletal symptoms in the neck (67.85%), back (66.33%), lower back (59.49%), right shoulder (45.32%) and left shoulder (43.54%) regions (Ardahan and Simsek, 2016). The prevalence of complaints of arm, neck, and shoulders of 181 computer professionals (computer usage > 2 h/day) was 58.6% with neck complaints topped the list followed by shoulder, wrist, hand, elbow, upper arm, and lower arm complaints in the descending order (8.8%–48.9%) (Mohan et al., 2019). In three public service sectors where the majority (78.9%) of 513 office workers worked with a computer more than 6 h/day, the reported prevalence rates of shoulder, elbow, wrist/hand, upper and low back pain were 50.5%, 20.3%, 26.3%, 44.8%, and 56.1%, respectively (Kaliniene et al., 2016). Since the chance of sustaining MSDs is increasing when office computer workers spend long time on their computers and the direct and indirect costs of WRMSDs have been reported to be high in Europe, Australia, and the United States (Mani, 2018), appropriate intervention(s) should be investigated and recommended to reduce the risk of developing WRMSDs for office computer workers. In Taiwan, intervention strategies should also be adopted in the computer work environments to reduce upper extremity/neck MSDs due to the high ratio of neck and upper extremity workers' compensation claims (TWBLI, 2022).

Van Eerd et al. (2016) performed a systematic review for evidences of effective interventions to prevent upper extremity musculoskeletal disorders (UEMSDs) in workplace settings. Among 61 eligible studies (screened through 9909 references published between 2003 and April, 2013), the interventions were grouped into 30 different categories by the authors. These 30 interventions were further evaluated for their level of evidences and direction of effects to prevent UEMSDs. Considering the methodological quality of articles and evidences of intervention effects, Van Eerd et al. (2016) recommended one intervention category (in 7 studies) with strong level of evidence and positive effect and three interventions categories (in 12 studies) with moderate level of evidence and positive effect to be adopted in the workplace to manage and prevent UEMSDs if applicable. The one intervention with strong level of positive effect is to prescribe “resistance training exercise programmes” on relieving upper extremity related symptoms/pain and disabilities. One of the three interventions with moderate level of positive effect consisted of prescribing “stretching exercise programmes (including upper extremity components)” in 6 studies. Recently, two review articles (Louw et al., 2017; Chen et al., 2018) also showed the effectiveness of strengthening exercise (resistance training) on reducing neck pain for symptomatic office workers. In addition, Tersa-Miralles et al.’s (2022) review article suggested that exercise interventions (with a wide variety of exercise routines) has benefits for treating musculoskeletal disorders of the lower back, neck, and general regions of the body.

Physical activity (PA) is defined by WHO (2022) as “any bodily movement produced by skeletal muscles that requires energy expenditure” which includes walking, cycling, wheeling, doing sports or active recreation, etc. Benefits of regular PA can lower the risk of heart disease, stroke, hypertension, musculoskeletal injuries, especially for mid-life and older adults (WHO, 2022), etc. For adults age 18–64 years old to achieve health benefits, PA durations ranged from 150–300 min (moderate-intensity activity) or 75–150 min (vigorous-intensity activity) per week are recommended (CSEP 2023, WHO, 2022). Van Eerd et al.’s (2016) review article has shown that PA interventions (e.g. resistance training exercise and stretching exercise programmes) were effective with strong or moderate level of evidence in reducing pain, pain intensity, or symptoms on neck/shoulder/upper extremity regions for laboratory technicians, office workers, nursery school teachers, industrial workers, public administrators, Central registry office employees, computer operators/users, call-center operators, data entry operators, and newspaper employees. Louw et al.’s (2017) and Tersa-Miralles et al.’s (2022) studies also showed the effectiveness of PA interventions on improving discomfort or reducing pain/pain intensity for UEMSDs among office workers. Among these effective PA intervention studies, the computer usage time per day were only reported in two studies (4.88 ± 1.36 h). In addition, the PA durations administered among these studies ranged from 20 min to 120 min per week were less than 150 min of moderate-intensity activity per week recommended by WHO (2022). It is necessary to assess the effectiveness of PA intervention complied with WHO PA duration recommendations on reducing musculoskeletal pain/pain intensity for office workers with computer usage of long periods each day.

Among computer workers, several studies (Bekiari et al., 2011; Ye et al., 2017; Mohan et al., 2019; Moreira et al., 2021) stated that the prevalence ratios of upper extremity musculoskeletal complaints and/or levels of pain for females are higher than their male colleagues. The reasons can be attributed to muscle activity relative to muscle capacity required for the tasks are greater than males, lack of muscle relaxation from extra works such as housekeeping, lower bone mineral density, etc. In the case of age, higher prevalence of musculoskeletal symptoms was observed for older computer workers (Ye et al., 2017; Moreira et al., 2021) and older workers in general (Briggs et al., 2018; Hoe et al., 2018). The U.S. Bureau of Labor Statistics projected that the labor force for US population ages 16–24 will decline from 53.9% in 2020 to 49.6% in 2030 while the labor force participation rate for ages 55–74 will increase from 32.4% in 2020 to 38.6% in 2030 (USBLS, 2021). In Taiwan, the share of labor force for population ages 55 and over is also projected to increase from 15.7% to 23.5% from 2019 to 2030 (TWDGBAS, 2020). Aging labor force can also impact the likelihood of the occurrence of UEMSDs in office computer workplaces.

As stated above, this study assessed the effectiveness of PA intervention (adhering to WHO PA guidelines) on reducing neck and upper extremity pain intensity in female office computer workers of different age groups. In addition, wearable sensing devices and subjective assessment tools were used to measure various physiological and psychological responses during PA intervention. Then, recommendations could be made based on the results to keep female office computer workers safe, healthy, and productive in the work environment.

2. METHODS

2.1 Subjects

Five female office computer workers in each age category (total 15 subjects) with computer usage ≥ 4 h/day (of an 8-h work day) were recruited from Colleges located in Taichung City, Taiwan. The three age categories were young adults (ages 20–35 years), middle-aged adults (ages 36–55 years), and older adults (aged older than 55 years) (Petry, 2002). The mean age, height, and weight of the subjects in each category were 22.6 ± 0.6 years, 49.8 ± 1.8 years, and 61.0 ± 3.4 years, 161.3 ± 3.4 cm, 155.9 ± 5.7 cm, and 156.1 ± 2.7 cm, and 62.7 ± 8.2 kg, 63.0 ± 10.4 kg, and 54.5 ± 6.0 kg, respectively. The maximum voluntary contraction (MVC) grip and palmar pinch strength were estimated using a Jamar grip dynamometer and a Jamar pinch gauge following the testing protocols recommended by Sung and Liu (2022). Institutional Review Board of Jen-Ai hospital (at Dali District, Taichung, Taiwan) had approved this study and informed consent agreement was obtained from each subject participating this study. All subjects reported free of MSDs in the upper extremities within the prior 3 months through an interview during the recruiting process.

2.2 PA Interventions

The PA intervention lasted 12 weeks was performed using a laboratory-owned shoulder-upper extremity fitness training equipment (Fig. 1). The duration and frequency for the intervention activities were 50 min/session and 3 times/week (150 min total, in bouts of 10 min or more) to meet the guidance recommended by WHO (2022). Each PA intervention session starts with a 15-min stretching exercise followed by 20-min rhythmic coordination exercise and 15-min functional strengthening exercise with training parameters (default setting) listed in Table 1. When performing each training exercise (e.g. stretching exercise with adjusting screen as shown in Fig. 1), the participant grabbed the handles and moved her dominant hand side handle down (right-handed subject in this case) to guide the blue dot to the starting angle position (centre line of the green target) to start the training session. Then, the green target will start moving up and down between the starting and stopping angle positions with specified target speed (degrees/s). The participant then used the motor signal of the green target perceived by the eyes to coordinate both hands and guide the blue dot following the movements of the green target as accurate as possible.

Fig. 1. A laboratory-owned shoulder-upper extremity fitness training equipment with parameters adjusting screen for stretching exercise

Table 1. Training parameter settings for each PA intervention exercise

Parameter / PA exercise	Target speed (degrees/s)	Resistance level (L1–L20)	Range of movement (degrees) (starting-stopping angles)
Stretching exercise	45	L3	150 (15-165)
Rhythmic coordination exercise	60	L4	110 (35-145)
Functional strengthening exercise	30	L10	110 (35-145)

2.3 Musculoskeletal Pain/Pain Intensity

A revised Nordic Questionnaire (Kuorinka et al.,1987) in traditional Chinese was used to record musculoskeletal pain in four body regions including neck, shoulders, elbows, and hands. Intensity of pain was subjectively rated using a 10-point (0–9) ordinal scale where 0 corresponded to "no pain at all" and 9 corresponded to "worst possible pain" (Zebis et al., 2011).

2.4 Physiological Strains Measurement

Wearable real-time physiological data measuring system (Sung, 2022) designed in-house was used record heart rate and ear canal temperature of the participant during PA intervention session with 1 Hz sampling rate.

2.5 Muscular Demands (EMG signal recording and data processing)

A laboratory-owned BIOPAC MP150 System was used to collect and process the electromyography (EMG) signals. Bipolar surface EMG electrodes were positioned over the following four forearm and upper arm muscles: (1) biceps brachii (BB), (2) triceps brachii (TB), (3) anterior deltoid (AD), and (4) posterior deltoid (PD), of the participant's upper limb of the dominant hand. These are major muscle groups involved in shoulder-upper extremity fitness training exercises indicated by the equipment vendor. A ground electrode was placed at the lateral epicondyle of the participant's dominant hand. The EMG signals are bandpass filtered (20–450 Hz) and pre-amplified (gain: 1000) with 1k Hz sampling rate (Sung and Liu, 2022).

To measure the muscular demand of each muscle, the EMG signals were first processed to get the root mean square (RMS) parameter for the entire intervention session ($RMS_{PASession}$), for the rest condition measured 60 min before starting of the intervention session (RMS_{rest}), and for the maximum voluntary contraction (RMS_{MVC}) condition measured right after the RMS_{rest} is determined. The RMS_{MVC} was determined from three standard manual muscle tests (Kendall et al., 2005) to elicit the maximum voluntary contraction of each muscle. Then, the percentage of maximal voluntary contraction (%MVC) calculated using equation 1 for each muscle was used to express the muscular demand of that muscle.

$$\%MVC = \frac{RMS_{PASession} - RMS_{rest}}{RMS_{MVC} - RMS_{rest}} \quad (1)$$

2.6 Subjective Evaluation of PA Intervention Levels

At the end of PA intervention sessions, each subject was asked to provide a subjectively evaluation of task demands using Borg rating of perceived exertion (Borg RPE) scale ranged between 6 (no exertion at all) to 20 (maximal exertion) (Borg, 1998).

2.7 Experimental Procedure

One 1-hr session was held before starting of the experiments for the researcher to introduce the purposes of this study, to collect anthropometry datum of each subject, and to ask the permission of each participant to sign the consent form. Another 2-hr practice session was given for each subject to familiarize the experimental procedures and to acquaint them with three training exercises supervised by a physiotherapist.

2.7.1 PA Intervention for Weeks 1 and 13

Each participant attended one 2.5-h experiment in weeks 1 and 13. In the first 1.5 h of the 2.5-h experiment session, the surface EMG electrodes were attached to the four muscles to determine the RMS_{rest} and RMS_{MVC} of each muscle group and the real-time physiological strain monitoring system was worn. In addition, the intensity of upper extremity and neck pain experienced for the previous three months was surveyed and recorded. In the last hour of the 2.5-h session, the participant performed 50 min PA intervention with a 15-min stretching exercise followed by 20-min rhythmic coordination exercise and 15-min functional strengthening exercise. Datum of physiological strains and EMG signals were recorded during the 1-h intervention session. In week 1, each participant also attended two more 1-h experiment sessions on different days to perform 50 min PA intervention with a 15-min stretching exercise followed by 20-min rhythmic coordination exercise and 15-min functional strengthening exercise.

2.7.2 PA Intervention for Other Weeks

During these weeks, each participant attended three 1-h experiment sessions on different days to perform 50 min PA intervention with a 15-min stretching exercise followed by 20-min rhythmic coordination exercise and 15-min functional strengthening exercise.

2.8 Statistical Analysis

The independent variables in this experiment are age group and PA intervention (12 weeks). The dependent variables are intensities of upper extremity and neck pain, physiological responses (heart rate, ear canal temperature, and muscular demands), and subjective responses (Borg RPE score).

Descriptive statistics were computed for the dependent variables and anthropometry data. Repeated measures ANOVAs were used to determine whether there are significant differences among independent variables on dependant variables. In addition, Bonferroni post-hoc analysis was then performed to determine which pairs of means are significantly different. All data were analyzed for statistical significance at $p \leq 0.05$ using the IBM SPSS V.21 (IBM corp.) statistical software.

3. RESULTS

The mean and standard deviations of the MVC grip strength and MVC palmar pinch strength measured for young adults, middle-aged adults, and older adults are shown in Table 2. These estimated grip data fall within the normative data range reported by Mathiowetz et al. (1985) and Mohammadian et al. (2014). The repeated-measured ANOVA analysis shows statistically significant age effect on grip strength (F = 8.272, $p < 0.01$) and palmar pinch strength (F = 11.288, $p < 0.01$). Fisher's least significant difference (LSD) pairwise comparisons indicate that the grip and palmar pinch strength estimated for young adults are 62.5 N ($p < 0.01$) and 55.0 N ($p < 0.01$) higher than middle-aged adults and 47.8 N ($p < 0.05$) and 39.1 N ($p <$ 0.05) higher than older adults, respectively.

Table 2. The mean and standard deviations of MVC grip strength and MVC palm pinch strength estimated in this study

	Grip strength (Newton)	Palmar pinch strength (Newton)
Young adults	278.3 ± 54.8	163.7 ± 30.8
Middle-aged adults	215.8 ± 30.1	108.7 ± 18.0
Older adults	230.5 ± 28.8	124.6 ± 23.4

Table 3. Means and standard deviations of heart rate and ear canal temperature

Age group	Week/session		Heart rate (bpm)		Ear canal temperature (°C)	
			Mean	SD	Mean	SD
Young	Week 1	Baseline	75.0	6.2	36.86	0.07
		PA session	93.7	10.2	36.93	0.12
	Week 13	Baseline	74.6	5.3	36.84	0.03
		PA session	88.0	8.6	36.90	0.04
Middle-aged	Week 1	Baseline	73.2	5.0	36.83	0.11
		PA session	87.9	4.6	36.85	0.13
	Week 13	Baseline	72.1	4.8	36.89	0.12
		PA session	84.6	5.4	36.84	0.14
Older	Week 1	Baseline	76.3	8.8	36.82	0.11
		PA session	96.3	8.1	36.82	0.08
	Week 13	Baseline	75.7	8.2	36.88	0.18
		PA session	91.0	8.3	36.83	0.12

Table 3 contains the means and standard deviations of heart rate and ear canal temperature for age groups and week/sessions recorded in this study. The heart rate measured during PA intervention sections in week 1 and week 13 ranged from 80.0 ± 3.2 beats per mins (bpm) to 104.7 ± 8.0 bpm and 76.2 ± 9.0 bpm to 98.7 ± 8.5 bpm for young age group, from 81.9 ± 3.2 bpm to 94.5 ± 6.5 bpm and 78.3 ± 5.3 bpm to 91.6 ± 6.7 bpm for middle-aged group, and from 84.5 ± 8.2 bpm to 105.3 ± 12.3 bpm and 80.0 ± 4.8 bpm to 101.4 ± 8.7 bpm for older age group, respectively. The ear canal temperatures measured during PA intervention sections for all age groups in week 1 and week 13 ranged from 36.64 ± 0.21°C to 37.09 ± 0.33°C and 36.67 ± 0.30°C to 37.05 ± 0.19°C, respectively.

The paired samples t-tests showed that there are no statistically significant differences on the means of baseline heart rate (p = 0.553, two-tailed) and baseline ear canal temperature (p = 0.329, two-tailed) between week 1 and week 13. Hence, the heart rates and ear canal temperatures recorded during PA intervention instead of their differences with baseline values were used for statistical analysis.

Table 4 shows the repeated-measured ANOVA results on heart rate and ear canal temperature. PA intervention after 12 weeks showed significant effect on heart rate (F = 12.703, $p < 0.05$). In addition, slightly significant age effect on ear canal temperature was also found in this study (F = 3.000, p = 0.051). No interaction effect between age and PA intervention (week) on heart rate and ear canal temperature was found in this study. Engaging PA intervention for twelve weeks decreased heart rate by 4.7 bpm ($p < 0.05$) for these 15 female subjects. In addition, the LSD post-hoc analysis shows that the ear canal temperature measured for young adults is 0.09°C higher ($p < 0.05$) than the older age adults.

Table 4. The repeated-measured ANOVA results on heart rate and ear canal temperature

Source of variance	Heart rate		Ear canal temperature	
	F	Sig.	*F*	Sig.
Age	3.009	0.106	3.000	0.051
PA intervention	12.703	0.023	0.043	0.847

Table 5 contains the means and standard deviations of muscular demands of four muscle groups measured during PA intervention at week 1 and week 13 for three age group females. For young adults, the muscular demands recorded of these four muscles ranged from 11.06 ± 4.32%MVC to 27.84 ± 18.69%MVC and 13.05 ± 9.84%MVC to 26.85 ± 9.60%MVC at week 1 and week 13 during PA intervention, respectively. For middle-aged adults, the muscular demands recorded of these four muscles ranged from 31.11 ± 18.21%MVC to 55.03 ± 18.62%MVC and 21.83 ± 20.25%MVC to 58.08 ± 17.20%MVC at week 1 and week 13 during PA intervention, respectively. For older adults, the muscular demands recorded of these four muscles ranged from 25.93 ± 10.01%MVC to 42.64 ± 14.05%MVC and 12.23 ± 11.59%MVC to 44.25 ± 21.83%MVC at week 1 and week 13 during PA intervention, respectively.

The repeated measures ANOVA results on muscular demands (Table 6) indicate that there are significant differences among age groups on muscular demands of biceps brachii (F = 11.042, $p < 0.01$) and anterior deltoid (F = 5.758, $p < 0.05$) muscle groups. In addition, a slightly significant PA intervention effect on muscular demands of the anterior deltoid was also found in this study (F = 6.765, p = 0.06). No statistically significant interaction effects between age and PA intervention were found on muscular demands of these four muscle groups. LSD pairwise comparisons show that the muscular demands of biceps brachii for middle-aged females are 25.43%MVC and 26.93%MVC higher than young and older adults ($p < 0.05$) (Fig. 2). In addition, the muscle demands of anterior deltoid for middle-aged adults are 29.77%MVC ($p < 0.05$) higher than young adults.

Table 5. The means and standard deviations of muscular demands of four muscle groups measured during PA intervention at week 1 and week 13 for three age group females

Muscle	Age group	Young		Middle-aged		Older	
	PA intervention	Week 1	Week 13	Week 1	Week 13	Week 1	Week 13
Biceps brachii (%MVC)	Mean	27.84	18.94	47.03	50.61	25.93	17.85
	SD	15.69	10.61	19.26	21.35	10.01	10.04
Triceps brachii (%MVC)	Mean	26.22	22.63	31.11	31.72	38.12	32.86
	SD	19.64	8.61	18.21	4.86	13.88	15.69
Anterior deltoid (%MVC)	Mean	26.72	26.85	55.03	58.08	42.64	44.25
	SD	7.85	9.60	18.62	17.20	14.05	21.83
Posterior deltoid (%MVC)	Mean	11.06	13.05	32.69	21.83	28.41	12.23
	SD	4.32	9.84	21.75	20.25	13.55	11.59

Table 6. The repeated-measured ANOVA results on muscular demands

Muscle	Age		PA intervention	
	F	Sig.	*F*	Sig.
Biceps brachii	11.042	0.005	1.604	0.274
Triceps brachii	1.633	0.254	0.691	0.452
Anterior deltoid	5.758	0.028	0.403	0.560
Posterior deltoid	2.200	0.173	6.765	0.060

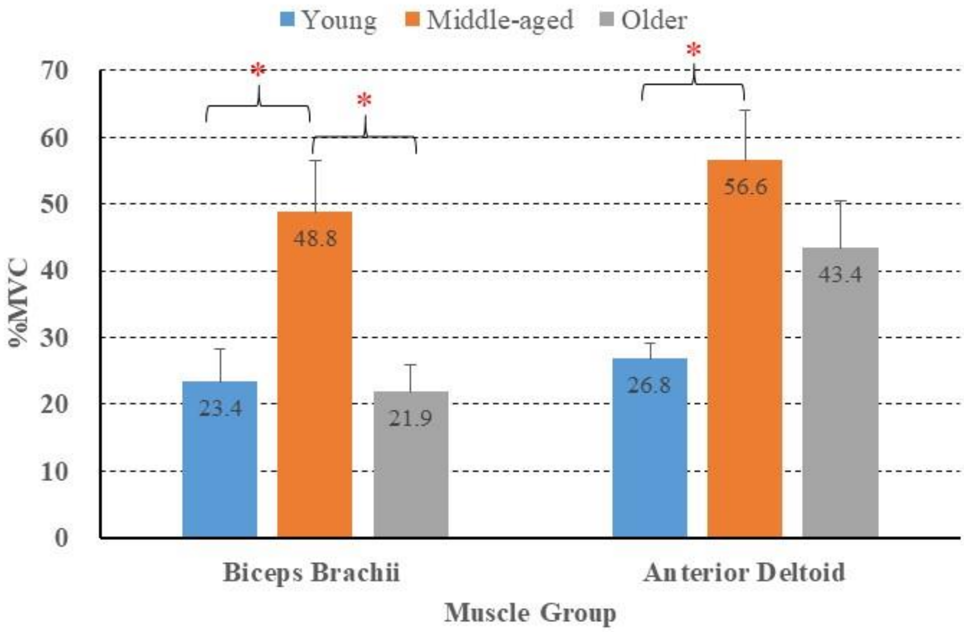

Fig 2. Age effect on muscular demands of biceps brachii and anterior deltoid muscles

Table 7. The means and standard deviations of pain intensity and RPE score reported right after PA intervention at week 1 and week 13 for three age group females

Age group	Pain intensity		RPE	
	Week 1	Week 13	Week 1	Week 13
Young adults	1.30 ± 1.20	0.90 ± 1.02	11.80 ± 2.77	11.60 ± 2.97
Middle-aged adults	1.10 ± 0.89	0.70 ± 0.84	10.80 ± 2.28	10.80 ± 2.28
Older adults	2.70 ± 1.79	2.40 ± 1.34	14.00 ± 1.00	12.80 ± 1.10

The subjective reported pain intensity (average of four body regions) and Borg RPE scores are shown in Table 7. The scores reported by the fifteen female subjects at weeks 1 and 13 right after PA intervention sessions ranged from 1.10 ± 0.89 to 2.70 ± 1.79 and 0.70 ± 0.84 to 2.40 ± 1.34 for pain intensity and from 10.80 ± 2.28 to 14.00 ± 1.00 and 10.80 ± 2.28 to 12.80 ± 1.10 for rating of perceived exertion, respectively. No statistically significant effects of age group, PA intervention, and their interaction on the pain intensity and Borg RPE scores are found.

4. DISCUSSION

Geneva et al. (2019) performed a systematic review of articles published in PubMed from 1935 to December 2017 where the normal ear canal temperatures were found ranged from 35.76 to 37.52°C for adults ages 18 and older. The ear canal temperatures recorded from 15 females in this study (Table 2) during rest (baseline) and PA intervention session at week 1 and week 13 all fall within the data range reported. For the age effect, Geneva et al. (2019) stated that adults with age equal and greater than 60 had lower ear canal temperature than adults with age smaller than 60 by 0.18°C on average. This study also showed the similar trend that the ear canal temperatures estimated for older adults (aged 56–65) were 0.09°C lower than those of younger adults (aged 20–35).

The baseline heart rates of these 15 females measured (from 72.1 ± 4.8 to 76.3 ± 8.8 bpm) were also found within 25th to 75th percentile of the reference data examined for U.S. females aged 20–65 years old from 1999–2008 (Ostchega et al., 2011). Carter et al. (2003) tested the effect of 12 week running program, with an intensity of 70%–90% of subject's maximum heart rate performed 4 times a week lasted 45–60 min, on heart rate (pre- and post-training) for 24 subjects (12 males and 12 females) aged from 19 to 45 years. Their results indicated that the subjects' heart rates decreased by 2.7 and 8.1 bpm measured at rest and during submaximal exercise after 12 weeks of endurance training, respectively. Similar trend was found in this study where the heart rate measured for all subjects during physical activity decreased by 4.7 bpm after twelve weeks of PA intervention. However, no significant heart rate decrements (0.7 bpm, two-tailed tests $p = 0.553$) were found measured during rest after PA intervention. Lower intensity PA (40%–68% of subject's maximum heart rate), computed from week 1 heart rate data collected during intervention session, implemented in this study may cause the smaller reduction in heart rate decrements compared to Carter et al.'s (2003) study. The significant decrease in heart rate may indicate that the PA level administered in this study can improve cardiovascular function of these females (Carter et al., 2003).

At the start of the experiment, three muscle groups were activated higher than the posterior deltoid during PA session for young subjects. For the middle-aged and older subjects, greater activities were observed during PA session on biceps brachii/anterior deltoid and triceps brachii/anterior deltoid muscles, respectively. After 12 weeks intervention, anterior deltoid was activated to a higher degree than the other three muscles during PA session in each age group. To perform three training exercises in this study, the subjects moved both arms forward, grabbed the handles, and guided one handle upward and the other handle downward in the sagittal plane. The anterior deltoid involved in shoulder flexion movement (moving handle upward) contributes more than the posterior deltoid associated with shoulder extension movement (moving handle downward) before and after the intervention indicating shoulder flexion plays a major role during the shoulder extension-flexion coordination movements of both arms. In addition, the PA intervention involving shoulder flexion and extension movements affects the subjects to elicit the greater activation of the anterior deltoid muscle (Wattanaprakornkul et al., 2011; Chang et al., 2023). The intervention might also help the middle-aged and older females to perform PA administered in this study with lesser magnitudes of muscular demands in the posterior deltoid muscle.

In terms of age effect, the muscular demands required for middle-aged females to perform PA with default training parameters in biceps brachii are greater than young and older females and in anterior deltoid are greater than young females, respectively. Since total muscle strength/EMG activity was found strongly correlated with hand strength (Wind et al., 2010; Trinidad-Fernández et al., 2020) and the estimated hand (grip) strength for middle-aged females were lowest among these three age groups, higher muscular demands were expected and observed in these middle-aged females. In addition, the muscle activity relative to muscle capacity of these two muscle groups required for the PA seems to be greater for these middle-aged females.

Systematic review articles (Van Eerd et al., 2016; Louw et al., 2017; Chen et al., 2018; Tersa-Miralles et al., 2022) had shown significant effect of PA interventions on improvements of UEMSDs or neck pain for office workers with upper extremity or neck musculoskeletal symptoms/disorders. The recommended physical activities to be implemented include resistance training, stretching exercise, strengthening exercise, general fitness training, etc. In this study, the reduction of pain intensity score recorded for young adults, middle-aged adults, and older adults are 0.4, 0.4, and 0.3, respectively. However, the effect of PA intervention on the reduction of pain intensity was not significant. Chen et al.'s (2018) review article found evidences of strengthening exercise effect in reducing pain intensity for symptomatic office workers, but cannot validate the effect for office workers in general due to inclusion of pain-free workers. The no significant PA intervention effect observation found in this study was consistent with Chen et al.'s (2018) finding since only subjects free of MSDs in the upper extremities or neck regions were recruited in this study.

Previous review studies (Van Eerd et al., 2016; Louw et al., 2017; Tersa-Miralles et al., 2022; Chang et al., 2023) have found physical activity as a protective factor for UEMSDs and neck pain for office workers. However, Van Eerd et al. (2016) stated that they were not conservative to classify an effective intervention as only one single study showing positive effect on UEMSDs prevention while no effect was reported from several other studies in order to benefit office workers. These systematic review articles also indicated that more high-quality research with strong evidences are needed to further explore the PA intervention effect due to risk of bias presented from the studies reviewed. Moreira et al. (2021) and Dalager et al. (2023) stated that the inconsistent findings were obtained since the degree of adherence of PA interventions with WHO guidelines (e.g. 150–300 min of moderate-intensity activity per week) is scare among literature. In addition, the inconsistent PA effects could be attributed to different types and duration of intervention implemented across different studies (Machado-Matos and Arezes, 2016).

This study was limited by the small sample size of participants which had also been reported as limitation for majority of the related studies assessing the PA effect

(Tersa-Miralles et al., 2022). The no PA intervention effect on the reductions of pain intensity observed in this study may have been influenced by inclusion of subjects free of MSDs in the upper extremity and neck regions only. To further test the PA intervention effect on pain or pain intensity reduction, larger size of subjects with MSDs should be recruited and classified as intervention versus control groups. The levels (e.g. via workloads evaluation) of different PA interventions could also be assessed and duration of WHO guidelines to be followed to draw conclusive evidences comparable across different studies. In addition, workloads (physical and mental) associated with office computer tasks should be assessed to further clarify age effect on physiological and psychological responses (e.g. age effect on muscular demands found in this study) to provide adequate protection for computer office workers of all age groups.

5. CONCLUSION

The effectiveness of various PA interventions on reductions of musculoskeletal symptoms for upper extremity and neck had been reported previously for symptomatic office workers. However, the degree of adherence of PA interventions with WHO guidelines (e.g. 150–300 min of moderate-intensity activity per week) is scare among literature. This study assessed the effects of PA intervention (adhere to WHO PA guidelines) on reducing neck and upper extremity pain intensity for female office computer workers of different age groups. No significant PA intervention effects on musculoskeletal pain intensity or perceived exertion were found for these free of MSDs females though reductions were noticed especially for the older adults. A significant reduction in heart rate measured during PA session after 12 weeks intervention was observed. Performing the PA administered in this study may improve cardiovascular function for female office computer workers. PA intervention might also help the middle-aged and older females with lesser magnitudes of muscular demands in the posterior deltoid muscle. To further explore the PA intervention effect on reducing musculoskeletal pain, symptomatic subjects should also be recruited and comparable PA intervention (e.g. type and duration of PA) should be implemented to verify the effect.

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REFERENCES

Ardahan, M., Simsek, H. 2016. Analyzing musculoskeletal system discomforts and risk factors in computer-using office workers. Pakistan Journal of Medical Sciences, 32(6), 1425–1429.

Bekiari, E.I., Lyrakos, G.N., Damigos, D., Mavreas, V., Chanopoulos, K., Dimoliatis, I.D. 2011. A validation study and psychometrical evaluation of the Maastricht Upper Extremity Questionnaire (MUEQ) for the Greek-speaking population. Journal of Musculoskeletal and Neuronal Interactions, 11, 52–76.

Borg, G. 1998. Borg's perceived exertion and pain scales, Human Kinetics, Champaign, IL, USA.

Briggs, A.M., Woolf, A.D., Dreinhöfer, K., Homb, N., Hoy, D.G, Giles, D.K., Åkessong, K., Marchh, L. 2018. Reducing the global burden of musculoskeletal conditions. Bull World Health Organ, 96, 366–368.

Carter, J.B., Banister, E.W., Blaber, A.P. 2003. The effect of age and gender on heart rate variability after endurance training. Medicine & Science in Sports & Exercise, 35, 8, 1333–1340.

Chang, L.R., Anand, P., Varacallo, M. 2023. Anatomy, shoulder and upper limb, Glenohumeral Joint. In: StatPearls [Internet]. StatPearls Publishing, Treasure Island (FL): Aug. 8, 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK537018/

Chen, X., Coombes, B.K., Sjøgaard, G., Jun, D., O'Leary, S., Johnston, V. 2018. Workplace-based interventions for neck pain in office workers: Systematic review and meta-analysis. Physical Therapy, 98(1), 40–62.

CSEP 2023, Canadian physical activity guidelines for adults (18–64 years): An integration of physical activity, sedentary behaviour, and sleep, on the Internet at https://csepguidelines.ca/adults-18–64/ (accessed October 10, 2023), Canadian Society for Exercise Physiology.

Dalager, T., Welch, A., O'Leary, S.P., Johnston, V., Sjøgaard, G. 2023. Clinically relevant decreases in neck/shoulder pain among office workers are associated with strength training adherence and exercise compliance: Explorative analyses from a randomized controlled trial. Physical Therapy, 103(2), pzac166.

Feng, B., Chen, K., Zhu, X., Ip, W.Y., Andersen, L.L., Page, P., Wang, Y. 2021. Prevalence and risk factors of self-reported wrist and hand symptoms and clinically confirmed carpal tunnel syndrome among office workers in China: a cross-sectional study. BMC Public Health, 21(1), 57.

Geneva, I.I., Cuzzo, B., Fazili, T., Javaid, W. 2019. Normal body temperature: A systematic review. Open Forum Infectious Diseases, 6(4), ofz032.

Hoe, V.C.W., Urquhart, D.M., Kelsall, H.L., Zamri, E.N., Sim, M.R. 2018. Ergonomic interventions for preventing work-related musculoskeletal disorders of the upper limb and neck among office workers. Cochrane Database of Systematic Reviews, 10, CD008570.

Kaliniene, G., Ustinaviciene, R., Skemiene, L., Vaiciulis, V., Vasilavicius, P. 2016. Associations between musculoskeletal pain and work-related factors among public service sector computer workers in Kaunas County, Lithuania. BMC Musculoskeletal Disorders, 17(1), 420.

Kendall, F.P., Kendall McCreary, E., Provance, G.P., Rodgers, M.M., Romani, W. 2005. Muscles-testing and function with posture and pain. ISBN13 : 9780781747806, Lippincott Williams & Wilkins, North America.

Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sorensen, F., Andersson, G., Jørgensen, K. 1987. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Applied Ergonomics, 18, 233–237.

Louw, S., Makwela, S., Manas, L., Meyer, L., Terblanche, D., & Brink, Y. 2017. Effectiveness of exercise in office workers with neck pain: A systematic review and meta-analysis. The South African journal of physiotherapy, 73(1), 392.

Machado-Matos, M., Arezes, P.M. 2016. Impact of a workplace exercise program on neck and shoulder segments in office workers, DYNA, 83, 196, 63–68.

Mathiowetz, V., Kashman, N., Volland, G., Weber, K., Dowe, M., Rogers, S. 1985. Grip and pinch strength: normative data for adults, Archives of Physical Medicine and Rehabilitation, 66(2), 69–74.

Mani, K. 2018. Ergonomics education for office computer workers: An evidence-based strategy. In book: Anatomy, posture, prevalence, pain, treatment and interventions of musculoskeletal disorders, edited by Orhan Korhan, 47–62, Intech Open.

Mani, K., Provident, I., Eckel, E. 2016. Evidence-based ergonomics education: Promoting risk factor awareness among office computer workers. Work, 55(4), 913–922.

Mohammadian, M., Choobineh, A., Haghdoost, A., Hasheminejad, N. 2014. Normative data of grip and pinch strengths in healthy adults of Iranian population, Iranian Journal of Public Health. 43(8), 1113–1122.

Mohan, V., Inbaraj, L. R., George, C. E., Norman, G. 2019. Prevalence of complaints of arm, neck, and shoulders among computer professionals in Bangalore: A cross-sectional study. Journal of family medicine and primary care, 8(1), 171–177.

Moreira, S., Ferreira, M.S., Criado, M.B., Machado, J., Mesquita, C., Lopes, S., Santos, P.C. 2021. Occupational health: Does compliance with physical activity recommendations have a preventive effect on musculoskeletal symptoms in computer workers? A cross-sectional study. International Journal of Environmental Research and Public Health, 18(14), 7604.

Ostchega, Y., Porter, K.S., Hughes, J., Dillon, C.F., Nwankwo, T. 2011. Resting pulse rate reference data for children, adolescents, and adults: United States, 1999–2008. National Health Statistics Reports, 24(41), 1–16.

Padmanathan, V., Halim, I., Zaid, R., Wei, T. 2018. Physical risk factors and observational tools for computer office workers–an overview. International Journal of Mechanical Engineering and Technology, 9, 694–704.

Petry, N.M. 2002. A comparison of young, middle-aged, and older adult treatment-seeking pathological gamblers. Gerontologist, 42(1), 92–99.

Sung, P.C. 2022. Efficacy of real-time audio biofeedback on physiological strains for simulated tasks with medium and heavy loads. International Journal of Applied Science and Engineering, 19, 2022308.

Sung, P.C., Liu, Y.P. 2022. Assessments of forearm muscular demands and perceived exertions for different massage techniques of the Swedish-type massage. International Journal of Applied Science and Engineering, 19, 2021522.

Tersa-Miralles, C., Bravo, C., Bellon, F., Pastells-Peiró, R., Rubinat Arnaldo, E., Rubí-Carnacea, F. 2022. Effectiveness of workplace exercise interventions in the treatment of musculoskeletal disorders in office workers: a systematic review. BMJ Open, 12(1), e054288.

Trinidad-Fernández, M., González-Molina, F., Moya-Esteban, A., Roldán-Jiménez, C., González-Sánchez, M., Cuesta-Vargas, A.I. 2020. Muscle activity and architecture as a predictor of hand-grip strength. Physiological Measurement, 41(7), 075008.

TWDGBAS 2020. Taiwan Labor Force Projections of years 2019–2030, on the Internet at https://ws.ndc.gov.tw/001/administrator/18/relfile/0/8591/4ba41efa-5410-4bf3-b32c-f60b0fb90c4f.pdf (accessed October 24, 2023). Directorate General of Budget, Accounting and Statistics of Executive Yuan, Taiwan.

TWBLI 2022. Occupational disease case benefits under labor insurance, on the Internet at https://statdb.mol.gov.tw/html/mon/26090.htm (accessed September 15, 2023). Bureau of Labor Insurance, Ministry of Labor, Taiwan.

USBLS 2021. The Economics Daily: Number of people 75 and older in the labor force is expected to grow 96.5 percent by 2030, on the Internet at https://www.bls.gov/opub/ted/2021/number-of-people-75-and-older-in-the-labor-force-is-expected-to-grow-96-5-percent-by-2030.htm (accessed September 30, 2023). Bureau of Labor Statistics, U.S. Department of Labor.

Van Eerd, D., Munhall, C., Irvin, E., Rempel, D., Brewer, S., van der Beek, A.J., Dennerlein, J.T., Tullar, J., Skivington, K., Pinion, C., Amick, B. 2016. Effectiveness of workplace interventions in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence. Occupational and Environmental Medicine, 73, 62–70.

Wattanaprakornkul, D., Halaki, M., Boettcher, C., Cathers, I. and Ginn, K.A. 2011. A comprehensive analysis of muscle recruitment patterns during shoulder flexion: An electromyographic study. Clinical Anatomy, 24, 619–626.

Wind, A.E., Takken, T., Helders, P.J., Engelbert, R.H. 2010. Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? European Journal of Pediatrics, 169(3), 281–287.

WHO 2022. Physical Activity, on the Internet at https://www.who.int/news-room/fact-sheets/detail/physical-activity (accessed October 15, 2023), World Health Organization.

Ye, S., Jing, Q., Wei, C., Lu, J. 2017. Risk factors of non-specific neck pain and low back pain in computer-using office workers in China: A cross-sectional study. BMJ Open, 7, e014914.

Zebis, M.K., Andersen, L.L., Pedersen, M.T., Mortensen, P., Andersen, C.H., Pedersen, M.M., Boysen, M., Roessler, K.K., Hannerz, H., Mortensen, O.S., Sjøgaard, G. 2011. Implementation of neck/shoulder exercises for pain relief among industrial workers: a randomized controlled trial. BMC Musculoskeletal Disorders, 12, 205.