Original Article

Age related differences of selected Hatha yoga practices on anthropometric characteristics, muscular strength and flexibility of healthy individuals

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ABSTRACT

Background: Physiological benefits of yoga on volunteers of a particular age group are available. However, reports on efficacy of a specific yoga package on the populace of different age groups from similar occupational background is still very limited. Therefore, the present study was conducted to appraise the effect of a specific Hatha yoga package on anthropometric characteristics, flexibility and muscular strength of healthy individuals of different age groups from similar occupational trade.

Materials and Methods: A total of 71 participants (Group All) from Indian Air Force ground personnel volunteered and age wise divided into 3 groups – (i) Group I (Gr. - I) (n_1 = 27, 20-29 years), (ii) Group II (Gr. - II) (n_2 = 21, 30-39 years) and (iii) Group III (Gr. - III) (n_3 = 23, 40-49 years). All the participants undergone selected Hatha yoga training for 1 h daily for a period of 12 weeks. Parameters were recorded before and after the training. Pre and post training differences were assessed by Student's *t*-test.

Results: Body weight (All, Gr. - II and Gr. - III [all $P < 0.05$]), body mass index (Gr. - II and Gr. - III [both $P < 0.01$]) and fat% (Gr. - II and III [both $P < 0.05$]) were decreased significantly. Neck circumference was increased significantly in Gr. - I ($P < 0.05$) but decreased significantly in Gr. - III ($P < 0.05$). Chest circumference (All ($P < 0.001$), in Gr. - I and II [both $P < 0.05$]), grip strength (All [left: $P < 0.01$ and right: $P < 0.05$], in Gr. - I [left: $P < 0.05$ and right: $P < 0.01$], in Gr. - II [right: $P < 0.05$] and in Gr. - III [left: $P < 0.05$ and right: $P < 0.01$]), back leg strength (group wise $P < 0.001$, $P < 0.05$, $P < 0.01$ and $P < 0.05$ respectively) and flexibility (all $P < 0.001$) were increased significantly.

Summary and Conclusion: Hatha yoga can improve anthropometric characteristics, muscular strength and flexibility among volunteers of different age group and can also be helpful in preventing and attenuating age related deterioration of these parameters.

Key words: Fat%; flexibility; strength; yoga.

INTRODUCTION

Hatha yoga, an ancient Indian science of health and spirituality, facilitate the enrichment of health related quality-of-life to the practitioner by improving physical and mental health by balancing body, mind and emotions. With the practice of *asana*, *pranayama*, *mudra*, *bandha*, *shuddhi kriyas* and meditation Hatha yoga help in the improvement of all aspects of health and physical performance.[1] Regular practice of yoga has been reported to modulate cardiopulmonary function, muscular efficiency, physical performance and biochemical profile of individuals.[2-6] Yoga could also improve the overall exercise performance[4,7] by controlling pulmonary function,[8] heart rate,[9] metabolic rate,[10] cardiovascular and anaerobic power[11] and relaxation.[12] In addition to these effects, yoga could also be helpful in relieving physical symptoms and perception of stress when compared with physical exercise.[2] Practice of Hatha yogic *asanas* and *pranayamas* has a positive effect on the improvement of physical fitness by improving cardiorespiratory endurance and neuromuscular functioning.

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Until date, studies reporting effect of yoga package, comprising of selected *shuddhi kriyas*, *asanas*, *pranayamas* and meditation, on physiological health of volunteers of a particular age group are available. A systematic study considering physiological effect of a specific yoga package on the populace of different age groups from similar occupational background is still a virgin area to undertake.

In this scenario, an endeavor has been taken in the present study to observe whether a specific Hatha yoga package could help to improve anthropometric characteristics, flexibility and muscular strength of healthy individuals of different age groups from similar occupational trade. The data from the present study might be helpful in identifying the potentiality of a specific Hatha yoga package for the improvement of physical and physiological health of sedentary individuals of different age groups. The parameters considered in the present piece of work to assess anthropometric characteristics, muscular strength and flexibility are internationally accepted and cited ones to assess one's physical fitness, strength and flexibility. Hence, these were assessed in this study to evaluate the physical status of sedentary individuals of different age groups.

MATERIALS AND METHODS

Volunteers

Seventy-nine (n = 79) male Indian air force ground workforce, aged between 20 and 49 years volunteered in this study. They had no previous experience of practicing yoga and were also free from any clinical disorders or medication. Age wise they were divided into three groups – (i) Group I (Gr. - I) (n_1 = 28, aged 20-29 years), (ii) Group II (Gr. - II) (n_2 = 24, aged 30-39 years) and (iii) Group III (Gr. - III) (n_3 = 27, aged 40-49 years) [Figure 1]. Individual written informed consent was obtained from each volunteer as per declaration of Helsinki and the entire work was carried out after receiving permission from the Institutional Ethical Committee. All of them were explained the purpose of the study and their role therein. One, three and four volunteers from Gr. - I, Gr. - II and Gr. - III respectively, dropped out due to various reasons and were not included in the final analysis. Thus, 27, 21 and 23 volunteers from Grs. - I, II and III respectively, (n = 71 | Group – All) completed the entire study. The volunteers were requested to refrain from eating, drinking or doing any kind of strenuous physical work at least for 2 h before the onset of experiments. Diet pattern of the participants was similar in nature, calorie intake wise, supplied from a common mess.

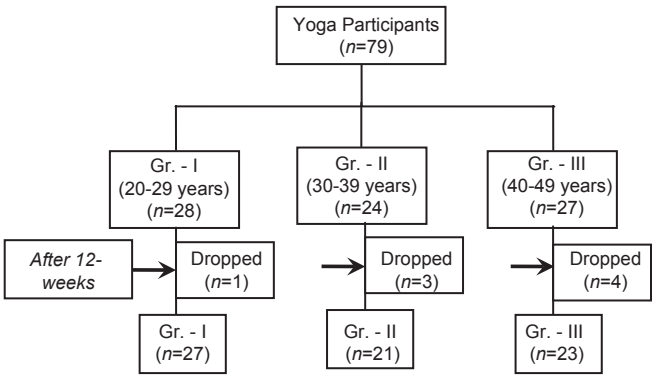

Figure 1: Flow diagram of the study recruitment and follow-up

Yogic training

All the volunteers undergone selected Hatha yoga training (HYT) for 1 h daily (6 days/week) in the morning (05:30-06:30 h) under the supervision of a qualified yoga teacher for a period of 12-weeks (3 months). Yogic session included prayer, yogic *sukshma* and *sthulavayama*, *suryanamaskar*, *shuddhi kriyas* (yogic internal cleansing practices), *yogasanas*, *pranayamas* and meditation. The sequence and duration of the yoga practiced are presented in Table 1. This schedule of training would be abbreviated hereinafter as "HYT." The yoga teacher also ensured the performance in and adherence to, yoga sessions of the volunteers, as these factors are known to influence the outcome of the training. They maintained regular attendance and thorough and routine practice on record and hence as to sidestep these factors from affecting the outcome.

Experimental procedures

All the volunteers participated in a pre-post design study. Every experiment was carried out before and after the yoga training period, to appraise the effect of the said training. Their daily routine such as morning drill, PT and other duties remained unaltered.

Anthropometric assessment

All the anthropometric parameters were obtained from the volunteers with a minimal clothing and barefoot. The standing body height was measured to the nearest 0.1 cm from sole of the feet to the vertex in erect body position, with the help of a stadiometer. Body weight (in kg) was measured with an empty bladder and stomach using standard digital weighing machine (ID150H, Delmar, India). Body surface area (BSA) was calculated by using Du Bois formula.[13] Body mass index (BMI) was calculated as the ratio of weight to height squared. Ponderal index (PI) was calculated as the ratio of weight to height cubed. Conicity index (CI) was calculated by using a standard formula.[14]

All circumferences (in cm) were measured with a tape with the volunteers standing upright and facing the investigator, having their shoulders relaxed. Neck circumference (NC) was measured at the level at cricoid cartilage in anterior and midpoint between external occipital protuberance

Table 1: Contents of yogic package practiced by the volunteers for 12-weeks training program

Practices	Duration (min)
Prayer	1
Yogic Sukshma Vyama	5
Yogic Sthula Vayama	5
Surya Namaskar (2 rounds)	5
Shuddhi Kriya	
Kapalbhati	2
Yogasana	20
Meditative Asanas	
Padmasana	
Vajrasana	
Cultural Asanas	
Standing Posture Asanas	
Tadasana	
Sitting Posture Asanas	
Yogamudra	
Gomukhasana	
Paschimottanasana	
Prone Lying Posture Asanas	
Bhujangasana	
Dhanurasana	
Supta Vajrasana	
Sarvangasana	
Supine Lying Posture Asanas	
Supta Pawanmuktasana	
Matsyasana	
Halasana	
Karnapidasana	
Uttanapadasana	
Relaxative Asanas	
Savasana	
Pranayama	10
Anulom-viloma	
Bhastrika	
Bhramari	
Omkar meditation	10

and tip of spinal process of 7th cervical spine (vertebral prominence at the root of neck) in posterior. Chest circumferences at full inspiration and extreme expiration were measured at upper chest on the level of junction between the deltopectoral groove and tip of anterior axillary fold. The waist circumference was measured midway between the iliac crest and the lower-most margin of the ribs. The hip circumference was measured at the maximum circumference of the buttocks, the volunteers standing with feet placed together.

Biceps, triceps, subscapular and suprailiac skinfold thickness (in mm) were measured[15] using GPM Skinfold Caliper (DKSH, Switzerland). For the biceps skinfold thickness, with the right arm pendant the biceps fat pad was measured at the level of vertical fold at the posterior midline of the upper arm. For the triceps skinfold thickness, the triceps fat pad was measured midway between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of ulna while the arm is relaxed. For the subscapular and suprailiac skinfold thicknesses, the fat pads below inferior angle of the scapula and superiorly on the iliac crest directly in the midaxillary line, respectively were measured. All skinfold thicknesses were measured to the nearest 1 mm. The mean of three readings were recorded at each site. Subscapular to triceps ratio (S:T), central (sum of subscapular and suprailiac) and peripheral (sum of biceps and triceps) skinfold thicknesses were also calculated. Body density was calculated was calculated according to Siri.[16] Percentage body fat was calculated using the standard equation[17] Total fat and lean body mass (LBM) was also calculated.

Muscle strength

Hand grip strength (HGS) in kg was measured by using Hand Grip Dynamometer (Grip – D, TKK 5401, Takei, Tokyo, Japan), after adjusting grip size.

Back muscle strength from the maximal isometric strength of the trunk muscles was measured in standing posture with 30° lumbar flexion using a digital back muscle strength meter (Back – D, TKK 5402; Takei, Tokyo, Japan). The volunteers was asked to pull the bar straight as much as possible without bending the knees and lifting heels. For both the experiments every participant performed three trials with a rest of 30 s between each trial and best score was recorded.

Flexibility

Trunk and neck extension test

Trunk and neck flexibility (T and N) of volunteers was measured by trunk-and-neck extension test.[18] The participants were instructed to lie prone on the floor with the hands clasped together behind the head. They were asked to raise their trunk as high as possible while keeping their lower portion of the body in contact with the floor. A minimum of three trials were performed after warm up. The difference between final distance in trunk-and-neck extension position and starting distance in lying position from the floor is recorded as the final score.

Modified sit and reach test

Low back flexibility or flexibility of hip and trunk (H and T) of participants was measured by modified sit-and-reach test.[19] The volunteers were asked to sit on the floor with the back and head against a wall; legs fully extended with the bottom of the feet against the sit-and-reach box. They were requested to place the hands on top of each other, stretching the arms forward while keeping the head and back against the wall and knees as straight as possible. The distance from the fingertips to the box edge was measured with a measuring scale (two feet). That was zero or starting distance. After that seat-and-reach test was performed.

Volunteers were asked to slowly bend and reach forward as far as possible (head and back moved away from the wall), sliding the fingers along with measuring scale. After warm up minimum three trials were performed. The difference between best of three, final distance from starting distance in seat-and-reach position was recorded as the final score.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS for Windows release 13.0, IBM, USA and values were expressed as mean ± SD. Two-tailed Student's *t*-test for paired samples was used to test the significance of difference between the means. The computed *t* was then compared with the critical *t* scores for different levels of significance to accept or reject H0. Statistical significance was set at $P \leq 0.05$.

RESULTS

Group All

Anthropometric characteristics, muscular strength and flexibility of group all volunteers is presented in Table 2. Body weight of air force volunteers improved significantly ($P < 0.05$) after HYT. BSA, BMI and CI did not show any significant change after yogic practices, though we observed a gross trend of improvement in these parameters after yogic practice. PI of these participants was improved significantly ($P < 0.05$). Triceps, suprailiac and subscapular skinfold thickness decreased significantly ($P < 0.01$, $P < 0.01$ and $P < 0.05$ respectively) after yoga practice. Biceps skinfold thickness also decreased, but the value was statistically not significant. Central, peripheral, sum of all skinfold thickness and LBM of the volunteers decreased significantly (All $P < 0.05$) after 12-weeks yoga practice. Body density increased significantly ($P < 0.001$); while S: T, central to periphral skinfold ratio (C:P), fat% and total fat were lowered after HYT – but the data was statistically not significant. LBM% registered statistically non-significant increment. Chest circumference (during both inspiration and expiration) of the volunteers was increased significantly (both $P < 0.001$) after yoga training. Neck, waist and hip circumference and waist-hip ratio did not show any significant change after yoga practice, but a trend of improvement was observed. Handgrip strength (left and right) of the participants improved significantly ($P < 0.01$ and $P < 0.001$ respectively) after HYT. Back leg strength (BLS) of air force volunteers was also improved significantly ($P < 0.001$). T and N and H and T flexibility improved significantly (both $P < 0.001$) after 12 weeks yoga training.

Gr. - I (20-29 years)

Table 3 represents the anthropometric characteristics, muscular strength and flexibility of Gr. - I volunteers.

Table 2: Anthropometric characteristics, muscular strength and flexibility of group all

Parameters	Before	After
Body weight (kg)	72.5±10.5	68.8±8.6*
BSA (m^2)	1.84±0.14	1.80±0.12
BMI (kg/m^2)	24.1±4.1	23.2±3.0
PI (kg/m^3)	14.6±2.0	13.9±1.7*
CI	1.30±0.12	1.29±0.11
Body fat		
Biceps (mm)	6.0±2.7	5.6±2.8
Triceps (mm)	12.2±5.1	10.1±3.8**
Suprailiac (mm)	13.2±6.7	10.3±5.3**
Subscapular (mm)	19.2±8.2	16.5±7.1*
S:T	1.11±0.42	1.03±0.35
Central SFT (C)	32.5±14.1	26.8±11.8*
Peripheral SFT (P)	18.2±7.3	15.7±6.0*
C:P	1.80±0.44	1.71±0.43
SKFT	50.1±21.2	43.1±16.6*
Density (kg/m^3)	1.05±0.02	1.06±0.01***
Fat %	20.3±7.4	18.7±6.5
LBM %	79.7±7.4	81.3±6.5
Total fat (kg)	15.3±6.9	13.3±5.6
LBM (kg)	57.2±5.7	55.4±5.1*
Circumference		
Neck (cm)	34.7±3.0	34.3±2.6
Chest (inspiration, cm)	92.1±7.9	96.8±7.3***
Chest (expiration, cm)	85.9±7.8	90.8±7.7***
Waist (cm)	91.9±10.4	89.0±9.0
Hip (cm)	93.9±6.1	92.4±5.3
W/H ratio	0.99±0.11	0.96±0.10
Muscular strength (kg)		
LGS	37.5±4.8	40.4±5.9**
RGS	39.2±5.5	43.5±5.7***
BLS	112.8±18.2	125.0±18.0***
Flexibility (cm)		
Trunk and neck	37.6±7.6	58.9±8.7***
Hip and trunk	28.6±7.2	35.8±6.9***

Values are expressed as mean±SD. *$P<0.05$; **$P<0.01$; ***$P<0.001$. BSA = Body surface area; BMI = Body mass index; PI = Ponderal index; CI = Conicity index; S:T = Subscapular to triceps skinfold ratio; SFT = Sum of skinfold thickness; C:P = Central to peripheral skinfold ratio; SKFT = Sum of all skinfold thickness; LBM=Lean body mass; W/H = Waist hip ratio; LGS = Left hand grip strength; RGS = Right hand grip strength; BLS = Back leg strength; SD = Standard deviation

Body weight, BSA, BMI, PI and CI of volunteers of this age group did not demonstrate any significant difference after 12 weeks of yoga practice, though a trend of improvement was observed. Suprailiac skinfold thickness of the volunteers was decreased significantly ($P < 0.05$) as a result of HYT. Biceps, triceps and subscapular skinfold thickness, S:T, sum of central and peripheral skinfold thickness, C:P, sum of all skinfold thickness, fat%, total fat and LBM were decreased non-significantly. Neck and chest (both in inspiration and expiration) circumference of the participants increased significantly (All $P < 0.05$) after HYT. Waist and hip circumference and waist-hip ratio decreased, but the data was statistically not significant. Handgrip strength (both left and right) of the volunteers increased significantly ($P < 0.05$ and $P < 0.01$ respectively) after yoga practice. BLS of these participants was also improved significantly ($P < 0.05$). T and N and H and T flexibility of the air force volunteers in this age group increased significantly (both $P < 0.001$).

Gr. - II (30-39 years)

Anthropometric characteristics, muscular strength and flexibility of Gr - II volunteers is presented in Table 4. Body weight, BMI and PI of the practitioner in this age group decreased significantly ($P < 0.05$, $P < 0.01$ and $P < 0.01$ respectively) after HYT. BSA of those volunteers was also decreased, but the data was statistically not significant. Biceps skinfold thickness of the volunteers did not show any significant change, but a trend of improvement was observed. Triceps, suprailiac, subscapular skinfold thickness, sum of central and sum of all skinfold thickness of the volunteers decreased significantly (All $P < 0.05$). S:T, sum of peripheral skinfold thickness, C:P and LBM of the volunteers decreased, but the data was statistically not significant. Body density and LBM% of the participants increased significantly (both $P < 0.05$) after 12 weeks of yoga practice. Fat% and total fat of these practitioners decreased significantly (both $P < 0.05$). Chest (both in inspiration and expiration) circumference of the volunteers increased significantly (both $P < 0.05$) after HYT. Neck, waist and hip circumference and waist-hip ratio decreased, but the data was statistically not significant. Right handgrip strength of the participants increased significantly ($P < 0.05$) after 12 weeks yoga practice. Left hand grip strength was also increased, but the data was statistically not significant. BLS of these volunteers in this age group improved significantly ($P < 0.01$). T and N and H and T flexibility of the participants improved significantly (both $P < 0.001$) after yoga practice.

Gr. - III (40-49 years)

Table 5 represents the anthropometric characteristics, muscular strength and flexibility of Gr. - III volunteers. Body weight and BMI of the volunteers decreased

Table 3: Anthropometric characteristics, muscular strength and flexibility of Group I

Parameters	Before	After
Body weight (kg)	63.8±6.2	62.7±7.3
BSA (m^2)	1.74±0.11	1.73±0.12
BMI (kg/m^2)	21.9±1.8	21.5±1.9
PI (kg/m^3)	12.9±1.2	12.6±1.2
CI	1.25±0.12	1.24±0.1
Body fat		
Biceps (mm)	3.93±1.12	3.71±1.05
Triceps (mm)	7.87±2.32	7.25±2.46
Suprailiac (mm)	7.27±2.54	5.86±1.95*
Subscapular (mm)	10.81±2.76	10.21±3.08
S:T	0.96±0.31	0.86±0.27
Central SFT	18.07±4.57	16.07±4.77
Peripheral SFT	11.8±3.3	11.0±3.1
C:P	1.58±0.38	1.51±0.38
SKFT	28.5±6.9	28.4±7.4
Density (kg/m^3)	1.072±0.007	1.072±0.007
Fat %	11.78±2.90	11.74±3.02
LBM %	88.22±2.90	88.26±3.02
Total fat (kg)	7.63±2.39	7.51±2.67
LBM (kg)	56.21±4.59	55.17±5.14
Circumference		
Neck (cm)	33.4±2.2	34.8±2.7*
Chest (inspiration, cm)	90.9±8.8	95.9±7.7*
Chest (expiration, cm)	83.9±8.7	88.8±7.8*
Waist (cm)	83.6±9.8	82.0±7.9
Hip (cm)	91.7±3.3	90.4±5.6
W/H ratio	0.93±0.12	0.90±0.10
Muscular strength (kg)		
LGS	35.6±4.2	38.1±4.5*
RGS	38.4±5.1	42.2±4.7**
BLS	110.9±18.7	122.1±19.0*
Flexibility (cm)		
Trunk and neck	40.6±8.7	64.2±7.9***
Hip and trunk	32.0±7.1	38.9±6.7***

Values are expressed as mean±SD. *P<0.05; **P<0.01; ***P<0.001. BSA = Body surface area, BMI = Body mass index; PI = Ponderal index; CI = Conicity index; S:T = Subscapular to triceps skinfold ratio; SFT = Sum of skinfold thickness; C:P = Central to periphral skinfold ratio; SKFT = Sum of all skinfold thickness; LBM=Lean body mass; W/H = Waist hip ratio; LGS = Left hand grip strength; RGS = Right hand grip strength; BLS=Back leg strength; SD = Standard deviation

Table 4: Anthropometric characteristics, muscular strength and flexibility of Group II

Parameters	Before	After
Body weight (kg)	78.6±9.8	72.9±7.5*
BSA (m^2)	1.91±0.13	1.85±0.11
BMI (kg/m^2)	26.9±2.5	24.9±1.9**
PI (kg/m^3)	15.7±1.4	14.6±1.1**
CI	1.31±0.12	1.31±0.11
Body fat		
Biceps (mm)	7.90±2.46	7.24±3.39
Triceps (mm)	15.66±4.13	13.10±3.25*
Suprailiac (mm)	18.77±6.42	15.12±4.87*
Subscapular (mm)	25.56±5.53	22.23±5.10*
S:T	1.26±0.47	1.19±0.38
Central SFT (C)	44.33±10.29	37.36±8.21*
Peripheral SFT (P)	23.56±5.15	20.66±5.22
C:P	1.93±0.45	1.86±0.37
SKFT	67.89±13.45	58.01±12.29*
Density (kg/m^3)	1.043±0.005	1.047±0.005*
Fat %	24.61±2.08	22.92±2.10*
LBM %	75.39±2.08	77.08±2.10*
Total fat (kg)	19.47±3.86	16.87±3.16*
LBM (kg)	59.12±6.22	56.30±5.05
Circumference		
Neck (cm)	35.2±3.3	34.7±2.2
Chest (inspiration, cm)	92.7±7.6	97.4±7.4*
Chest (expiration, cm)	87.0±7.2	93.0±7.6*
Waist (cm)	96.4±6.5	92.6±6.3
Hip (cm)	94.6±6.4	93.6±4.6
W/H ratio	1.02±0.08	0.99±0.08
Muscular strength (kg)		
LGS	38.3±3.9	40.1±4.7
RGS	39.6±5.7	43.3±5.3*
BLS	114.0±12.5	126.5±13.2**
Flexibility (cm)		
Trunk and neck	36.4±6.1	55.6±7.9***
Hip and trunk	27.0±6.4	34.5±6.1***

Values are expressed as mean±SD. *P<0.05; **P<0.01; ***P<0.001. BSA = Body surface area; BMI = Body mass index; PI = Ponderal index; CI = Conicity index; S:T = Subscapular to triceps skinfold ratio; SFT = Sum of skinfold thickness; C:P = Central to periphral skinfold ratio; SKFT = Sum of all skinfold thickness; LBM = Lean body mass; W/H=Waist hip ratio; LGS = Left hand grip strength; RGS = Right hand grip strength; BLS=Back leg strength; SD = Standard deviation

significantly ($P < 0.05$ and $P < 0.01$ respectively) after yoga training for 12 weeks. BSA and PI also decreased after 12-weeks, but the data was statistically not significant. Triceps, suprailiac, subscapular skinfold thickness, sum of central and sum of all skinfold thickness of the volunteers decreased significantly (All $P < 0.05$) after HYT. Biceps skinfold thickness, S: T, peripheral skinfold thickness, C: P and LBM of the volunteers also decreased, but the data was statistically not significant. Body density and LBM% of the volunteers increased significantly ($P < 0.01$ and $P < 0.05$ respectively). Fat% and total fat of the practitioner decreased significantly ($P < 0.05$ and $P < 0.01$ respectively) after 12 weeks yoga training. NC of the volunteers in this age group decreased significantly ($P < 0.05$) after HYT. Chest (both in inspiration and expiration) circumference was increased, but the data was statistically not significant. Waist and hip circumference and waist-hip ratio also decreased, but the data was statistically not significant.

Table 5: Anthropometric characteristics, muscular strength and flexibility of Group III

Parameters	Before	After
Body weight (kg)	77.1±8.3	72.2±6.9*
BSA (m^2)	1.88±0.11	1.83±0.10
BMI (kg/m)	26.7±2.5	24.8±2.2**
PI (kg/m)	15.7±1.6	14.8±1.6
CI	1.33±0.12	1.33±0.12
Body fat		
Biceps (mm)	6.7±2.8	6.3±2.3
Triceps (mm)	14.0±4.7	11.1±3.2*
Suprailiac (mm)	15.1±4.8	11.7±4.1*
Subscapular (mm)	23.4±6.0	19.5±6.0*
S:T	1.15±0.43	1.09±0.35
Central SFT	38.48±9.23	31.21±9.53*
Peripheral SFT	20.73±7.0	17.36±4.99
C:P	1.94±0.40	1.84±0.45
SKFT	59.21±15.66	48.57±13.38*
Density (kg/m)	1.04±0.01	1.05±0.01**
Fat %	26.46±3.78	23.68±3.85*
LBM %	73.54±3.78	76.32±3.85*
Total fat (kg)	20.44±3.83	17.18±3.59**
LBM (kg)	56.65±6.30	54.98±5.13
Circumference		
Neck (cm)	35.6±3.0	33.3±2.6*
Chest (inspiration, cm)	93.1±7.3	97.2±7.1
Chest (expiration, cm)	87.1±7.2	91.2±7.5
Waist (cm)	97.5±7.3	94.1±6.8
Hip (cm)	96.0±7.5	93.6±5.2
W/H ratio	1.02±0.10	1.01±0.09
Muscular strength (kg)		
LGS	39.0±5.7	43.3±7.3*
RGS	39.6±5.9	45.1±6.8**
BLS	114.0±22.2	127.1±20.5*
Flexibility (cm)		
Trunk and neck	35.2±6.5	55.8±7.4***
Hip and trunk	25.9±6.7	33.3±6.6***

Values are expressed as mean±SD. *P<0.05; **P<0.01; ***P<0.001. BSA = Body surface area, BMI = Body mass index; PI = Ponderal index; CI = Conicity index; S:T = Subscapular to triceps skinfold ratio; SFT = Sum of skinfold thickness; C:P = Central to periphral skinfold ratio; SKFT = Sum of all skinfold thickness; LBM=Lean body mass; W/H = Waist hip ratio; LGS = Left hand grip strength; RGS = Right hand grip strength; BLS = Back leg strength; SD = Standard deviation

Handgrip strength (both left and right) of the volunteers in this age group improved significantly ($P < 0.05$ and $P < 0.01$ respectively) after 12 weeks yoga practice. BLS of these volunteers also improved significantly ($P < 0.05$). T and N and H and T flexibility of the study participants improved significantly (both $P < 0.001$) after HYT.

DISCUSSION

The present study was designed to determine the effect of a specific 12 weeks HYT program on anthropometric characteristics, flexibility and muscular strength of healthy individuals among different age groups. It has been reported earlier that practice of Hatha Yoga, an ancient Indian culture and the way of life, helps to improve physical and mental performance of its practitioner. The salient findings of this study were body weight, BMI, PI, skinfold thicknesses, fat%, body circumferences, muscular strength and flexibility improved compared with baseline values in the healthy individuals of different age groups from similar occupational trade.

Body weight is an important parameter for the determination of nutritional requirements, drug dose administration, pulmonary tidal volume estimation and hemodynamic assessments. As gaining or reduction of body weight above or below normal is associated with many lifestyle related diseases, maintenance of proper body weight is important irrespective of age and sex. In the present study body, weight of all the volunteers decreased and also in different age groups, with highest reduction was observed in the age group of 30-39 years (7.2%) [Figure 2]. This decrement was likely contributed by reduction in total body fat in all volunteers. Ray *et al.*, also reported that body weight of middle aged men was lowered after practicing yoga.[5] Yogic *sukshma* and *sthulavyama*, *suryanamaskar* and practice of different *asanas* help in the reduction of body weight of the participants.[20]

Before practicing yoga BMI of all the volunteers and participants in the age group 20-29 years were found under "normal range" and volunteers of age group 30-39 years and 40-49 years were "overweight" as per classification of

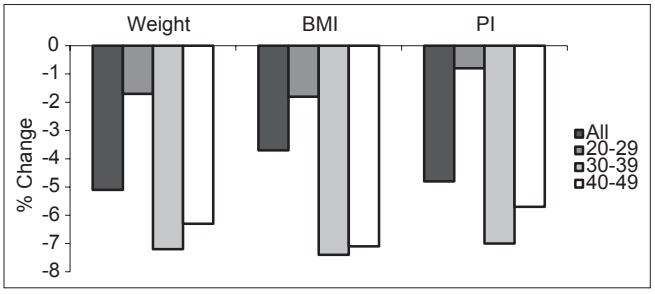

Figure 2: Percentage change of weight, BMI and PI among all and volunteers of different age groups. BMI = Body mass index; PI = Ponderal index

World Health Organization (2004).[21] After HYT BMI of all participants and volunteers of age group 20-29 years was remain in "normal range." But BMI of participants in the age group 30-39 years and 40-49 years were changed to "normal range" with a reduction of 7.4% and 7.1% in BMI, respectively. It has been demonstrated that for every 4 kg/m^2 increase in BMI, ischemic heart disease risk increases by at least 26%.[22] In the present study, BMI was reduced to 2 kg/m^2 and 1.9 kg/m^2 for the age group 30-39 years and 40-49 years respectively. PI which reflects a person's weight change in proportion with height also decreased after 12-weeks of HYT that is due to reduction of body weight of the volunteers. Decrement of PI was 4.8%, 7% and 5.7% in all volunteers, in the age group 30-39 years and in the age group 40-49 years respectively [Figure 2].

Skinfold thickness of the volunteers was reduced after yoga training in all age groups. Triceps SKT of the participants was lowered by 17.2% in all volunteers and 7.9%, 16.3% and 20.7% in the age group 20-29 years, 30-39 years and 40-49 years respectively [Figure 3]. After practicing yoga suprailiac SKT was lowered by 22% in all after 12-weeks and group wise 19.4%, 19.4% and 22.5% respectively. Rush *et al.*, in their study have reported that in Asian Indians, abdominal fat increased with increasing age.[23] We also observed suprailliac skinfold thickness and waist circumference was highest in senior age participants. Subscapular skinfold thickness was lowered by 14.1% in all volunteers after yogic intervention. Reduction in this skinfold thickness was also observed in Gr. - I, II and III by 5.5%, 13% and 16.7% respectively. It was also observed that reduction of suprailiac skinfold thickness was higher among all skinfold thicknesses [Figure 3]. This might be due to different forward and backward bending *asanas* and *suryanamaskara*, which gives more activity in the trunk region and thereby reduces the excessively deposited fat in that region.[24] Central skin fold thickness which is a sum of subscapular and suprailiac skin fold thickness was reduced by 17.5% in all volunteers and 11.1%, 15.7% and 18.9% in the participants of age group 20-29 years, 30-39 years and 40-49 years respectively. Peripheral SKT which is a sum of biceps and triceps skinfold thickness was also decreased to 13.7% after yogic practice. Sum of all skinfold thickness was decreased by 14%, 14.5% and 18% in all, 30-39 years and 40-49 years age group respectively after HYT. Bera and Rajapurkar showed a significant improvement in body density in male high school students after practicing yoga for 1 year.[11] In our study, we also found body density increased significantly in all and in senior age group (30-39 and 40-49 years) participants after 12-weeks which might be due to lowered total body fat. But body density of younger age group (20-29 years) did not show any change. Higher amount of body fat is associated with increased risk of adverse health events and greater mortality.[25] Fat% and total body fat were increased with age and highest in the volunteers of age group of 40-49 years. Body fat% and thus total body fat was reduced after 12-weeks Hatha yoga practice in all volunteers with highest reduction observed in the age group 40-49 years (10.5% and 15.9% respectively). Thus, HYT for 12 weeks preferentially reduces the body fat% and absolute fat weight and thereby significantly lowered the body weight and increased body density. Our findings of weight loss complemented with reduction in total body fat signpost that HYT is a potential adjunct for management of obesity in adult.

It was observed from the present study that yoga training for 12 weeks changes neck and chest circumferences in volunteers of different age group. NC, an upper body obesity index, is a simple screening measure for identifying overweight and obese individuals. It has also been established that higher NC is positively correlated with the risk of coronary heart disease.[26] Before practicing yoga NC of participants of the age group 40-49 years was 35.6 cm, which is considered to be above the cut-off point

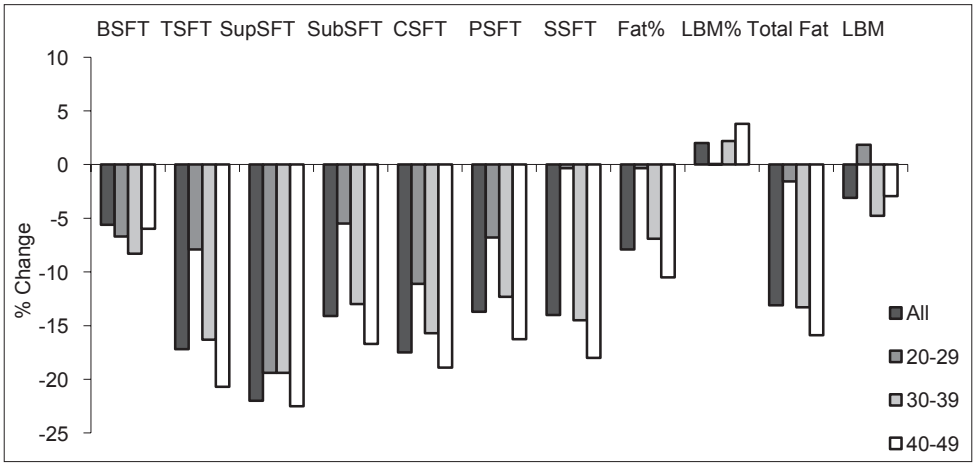

Figure 3: Percentage change of anthropometric parameters among all and volunteers of different age groups. BSFT = Biceps skinfold thickness; TSFT = Triceps skinfold thickness; SupSFT = Suprailiac skinfold thickness; SubSFT = Subscapular skinfold thickness; CSFT = Sum of central skinfold thickness; PSFT = Sum of peripheral skinfold thickness; LBM = Lean body mass

of "overweight/obesity."[27] This fact is also evident from the BMI of the volunteers of that particular age group. After practicing HYT, NC of those volunteers decreased by 6.5% [Figure 4]. As a practice of yoga is for the holistic health benefit, neck circumference was significantly increased (4.2%) in volunteers of age group 20-29 years. Chest circumference during inspiration and expiration both are increased significantly after yoga training. Increased chest circumference, an indicator of body size and health, might be due to practice of different *asanas* and *suryanamaskar*. A non-significant decrement of waist and hip circumference was also observed after yoga practice and it was also supported by the significant reduction in suprailiac skinfold thickness in all volunteers.

HGS is a measure of the isometric strength of the hand and forearm muscles including their tendons and strength of wrist. This strength is important for different jobs and activities such as holding, lifting, catching, throwing etc., In the present study, left hand grip strength was improved by 7.7%, 7%, 4.7% and 11% in All, Gr. - 1, Gr. - 2 and Gr. - 3 respectively after 12-weeks. Right hand grip strength was also improved in all four study groups and improvement was 11%, 9.9%, 9.3% and 13.9% respectively [Figure 5] after HYT. A study by Madanmohan *et al.*, also reported improvement in HGS of students after practicing yoga.[28] Isometric contraction which is maintained during the steady state in different postures in *suryanamaskar* and different *asanas* might improve HGS in volunteers.[29] Back muscles act to support the spine and maintain the stability of the spine. These muscles are important for structural support, movement and material handling such as lifting. Poor back muscle strength and endurance is one of the reason behind the development of low back pain, a very common life-style related disorder, categorized broadly as musculoskeletal disorder. An improvement of 10.8% in BLS was observed after practicing yoga in comparison with baseline values in all participants. With highest improvement was observed in the age group 40-49 years (11.5%), followed by 30-39 years and 20-29 years of age group (11% and 10.1% respectively). Back muscle strengthening *asanas* may help to increase back muscle strength. Ray *et al.*, in their study have reported that 6 months yoga practice improve muscular efficiency by delaying the onset of fatigue and increasing endurance in middle aged men.[5] Yogic *asanas* is a type of controlled physical activity which is a unique combination of isometric muscular contraction and stretching exercises might improve the muscular strength. Stretching can increase muscular flexibility and could cause changes in the development of maximum strength.[30] Muscle stretching could also promote the rate of increment of protein synthesis in muscle.[31] The combined action of isometric muscular contraction and stretching help in the muscle fibre hypertrophy and thereby improve muscular strength. The significant improvement in hand grip and back leg muscular strength also might be due to improvement in muscular blood flow which might be due to decreased vascular tone in the arteries resulting from stimulation of parasympathetic activity by yogic practice for 12 weeks.[32] Yogic practices also help to improve the endurance capacity of muscles thereby reducing the chance of age related musculoskeletal disorders.

Hatha yoga which is a combined action of both static and dynamic stretching practices is a proper and safe method to improve overall flexibility of an individual. Trunk and neck and low back and hamstring flexibility (sit and reach) was improved in all volunteers after practicing Hatha yoga for 12-weeks. Cheema *et al.*, have showed that low back and hamstring flexibility improved after practicing yoga.[33] However in the present study, we analyzed the effect of a single HYT protocol on the trunk and neck and low back and hamstring flexibility of volunteers from different age group. Flexibility decreases with age due to increased stiffness and rigidity of the soft-tissue structures of the

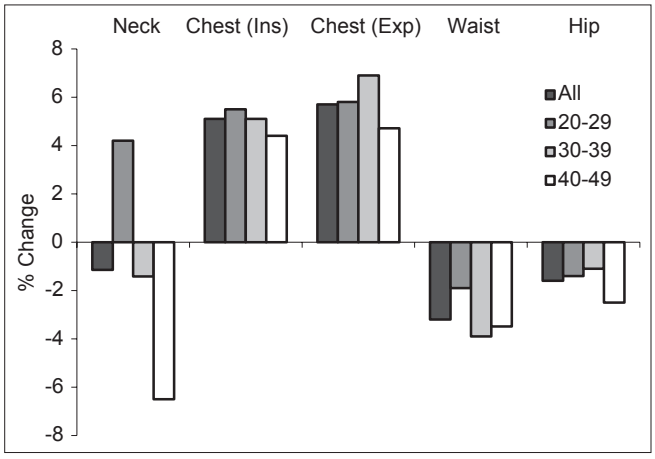

Figure 4: Percentage change of circumferences among all and volunteers of different age groups

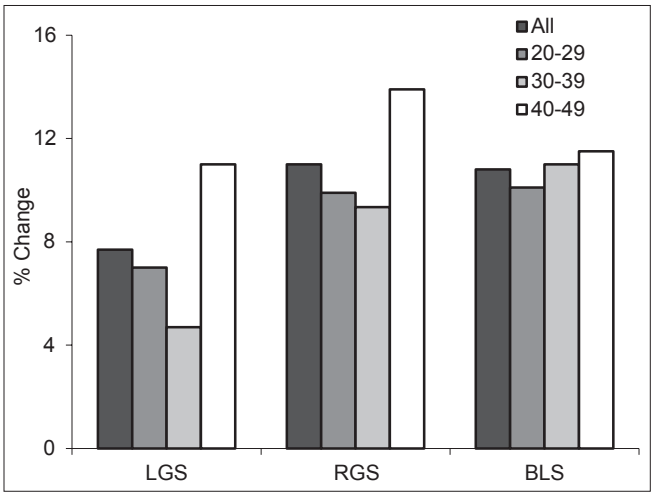

Figure 5: Percentage change of muscular strength among all and volunteers of different age groups. LGS = Left hand grip strength; RGS = Right hand grip strength; BLS = Back leg strength

joint capsule, muscle and its facia, tendons, ligaments and skin of different joints and leads to physical issues such as pain syndromes or balance disorders.[34] It was observed that before practicing yoga trunk and neck and H and T was lowest in the age group 40-49 years (only 35.2 cm and 25.9 cm respectively). Similarly, the highest improvement (58.5% and 28.6% respectively) was also observed in that age group [Figure 6]. Maintenance of the final posture of *asanas* more specifically prone and supine lying posture *asanas* [Table 1] and stretching exercises in *suryanamaskar* contributes to improvement in overall flexibility of these volunteers.

SUMMARY AND CONCLUSION

Outcome of this work implies the explicatory influence of the HYT program on physiological welfares among volunteers of different age groups, 20-29 years, 30-39 years and 40-49 years as pointed out hereunder, which include:

- Decreased body weight, BMI, PI, skinfold thickness, fat %
- Increased hand grip and back leg muscular strength
- Improved flexibility of lower back, trunk and neck.

It could also be commented, in the light of the observations from the present work, that practice of Hatha yoga is also helpful in preventing and attenuating age related deterioration of physical health, muscular strength and flexibility.

This works extends the scope of further investigation of similar yoga training program with smaller age group, different type of populations and different occupations where there is variable requirement of physical activity and differential grades of stress, which would, in turn, definitely benefit the mankind.

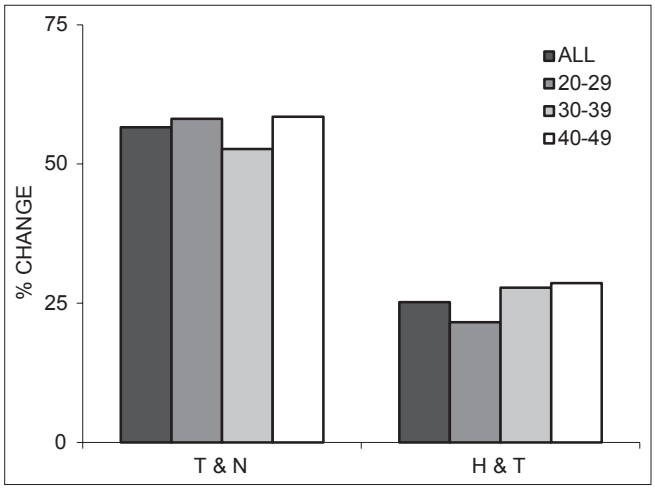

Figure 6: Percentage change of flexibility among all and volunteers of different age groups. T and N = Trunk and neck flexibility; H and T = Hip and trunk flexibility

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