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Psychophysiological changes in autogenic training and their usefulness for stress-related psychosomatic diseases

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Abstract

Psychophysiological changes resulting from the practice of autogenic training (AT) are reviewed. AT is known to reduce negative affect, including anxiety, depressed mood, and anger. AT also positively alters self-cognition and facilitates self-acceptance. During AT practice, several cortical areas are activated, such as the postcentral gyrus (an area involved in somatosensory functions) and the prefrontal cortex and insula (areas involved in interoception, emotion, and self-awareness). AT attenuates the sympathetic-adrenomedullary system and the hypothalamic-pituitary-adrenocortical axis. AT also facilitates cardiac vagal function. In contrast, AT inhibits vagal activity innervating the gastrointestinal tract. AT increases mechanical nociceptive thresholds and reduces pain in patients with syndrome X, migraine-type headache, and irritable bowel syndrome. Modulation of the pain-modulatory system in the brain may at least in part, cause this pain-inhibitory effect. These effects are beneficial for treating and for preventing stress-related disorders. It is also possible that regular practice of AT may reduce health care costs.

産業ストレス研究(Job Stress Res.), 21, 161-168(2014)

[特集　産業ストレスとリラクセーション]

リラクセーション法，ストレスマネジメント法としてのヨーガ，気功

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Yoga and Qigong as Relaxation Training and Stress Management

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Abstract Recently, yoga, qigong and tai chi chuan have been widely practiced to reduce stress and improve fitness in healthy subjects. The roles of these meditative movement therapies are similar as treatments for stress-related diseases and symptoms.

Therefore, this article mainly reviews the beneficial effects of yoga on stress-related diseases and / or symptoms and its possible mechanisms. Generally, regular practice of yoga reduces anxiety, depression, perceived stress and pain and improves insomnia and fatigue, leading to the improvement of quality of life in distressed subjects, patients with stress-related diseases and patients with chronic diseases. Several studies have suggested that yoga can reduce the dose of medication and healthcare costs. Yoga has also been demonstrated to increase γ-aminobutyric acid levels within the brain and have inhibitory effects on the hypothalamic-pituitary-adrenocortical axis and the sympathetic adrenomedullary system. It also increases the heart rate variability and decreases inflammatory mediators. These effects of yoga may account for, at least in part, its beneficial effect on subjects who feel stress or patients with stress-related diseases.

Key words: Yoga (ヨーガ), qigong (気功), relaxation (リラクセーション), stress management (ストレスマネージメント)

1. はじめに

ヨーガや気功は，①ゆっくりとした動き（もしくは一定の姿勢の保持）に，②呼吸（多くの場合，通常より長い呼気）をあわせ，③そこで生じる身体の中の感覚（内受容，interoception）に意識を向けると言う，リラクセーションや瞑想状態を誘導する運動という要素を含む。したがってヨーガや気功を定期的に練習すると④身体内部から発せられる警告信号（interoceptive awareness）を受け取りやすい状態を作り，身体感覚に基づく自己調整と健康管理が容易となる。この状態は，多くの就労者が職場でとる反応，行動（闘争か逃走か，fight or flight）とは対極である。つまり職場では③外部環境の変化に適応，対処し，自らの設定した目標（数字）にむかって行動するため，視覚や聴覚の情報に意識を集中し，②筋肉の収縮，伸展と同期

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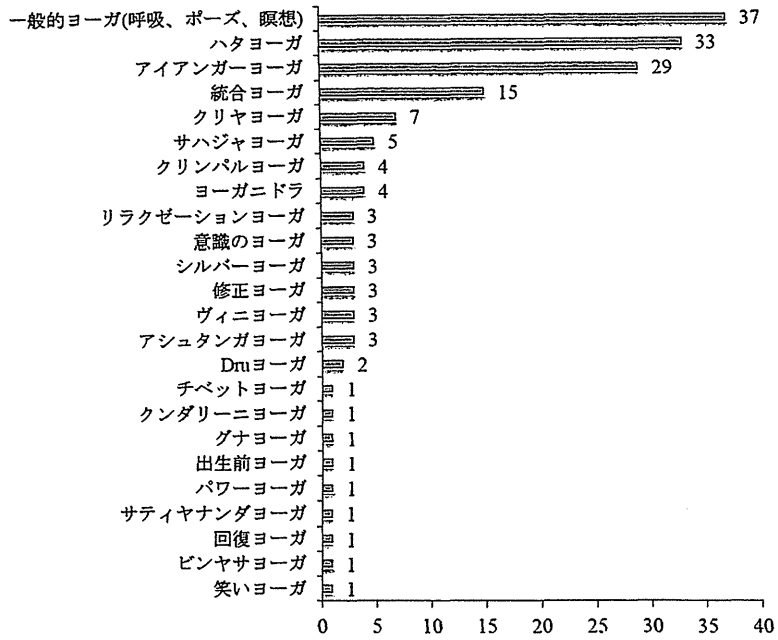

図1：医学研究で用いられているヨーガの種類（文献28より一部改変して引用）

しない，はやく浅い呼吸で，①あくせくと動く。したがって覚醒レベルは上昇し，内受容は抑制される。この状態が長期間続くと，社会的にはよく適応し，成功を収めるかもしれないが，④疲労感などの身体内部からの警告信号を無視する，克服する，感じなくするような対処行動をとりがちとなり，数字を参考にした健康管理は行なっても，身体感覚に基づく自己調整や健康管理は困難なものとなる（失体感症）。

したがってヨーガや気功は，就労者のストレスマネジメント，健康管理の一環として有用であると同時に，数字による健康管理では達成できない重要な要素を含んでいる。実際，ヨーガや気功は心身症をはじめとするストレス関連疾患や，難治性，慢性疾患患者の抱えるストレスに対する治療法として用いられる機会が増えてきている。そこで本稿では，ヨーガや気功の奏効機序に関する基礎研究と，ランダム化比較試によって明らかにされてきた臨床効果について概説する。

なおヨーガと気功は動きながら瞑想状態に至るという共通点から瞑想的運動療法（meditative movement therapy）と総称されることが増えてきた。またストレス対策としての奏効機序，医学的効果，そして医学的治療法としての位置づけも似ているため，本稿ではヨーガを中心に解説する。

2．医療の中で用いられるヨーガ

ヨーガの教典である「ヨーガ・スートラ」によると，ヨーガとは心の作用を抑制である。それは本来，解脱を達成するたに必要なのものであり，そこに至る具体的な方法として8つの要素（8支則）が説かれている。この中のどの要素を強調するか，どのようなポーズを，どのような強度で用いるか，誰がはじめたやり方かなどによって，ハタヨーガ，アシュタンガヨーガ，アイアンガーヨガなど，様々な呼称がついている。医療として用いられ，また研究されているのは，8つの要素のうち，主にアーサナ（体位法），プラナヤーマ（呼吸法），瞑想法の3つ，もしくはそれらを組み合わせたものが多い（図1）。そのため本稿でも，この3つの組み合わせによるヨーガの効果について紹介する。

3．ヨーガの抗ストレス作用

ストレス関連疾患患者，もしくは健康な人がストレス状況におかれた時，不安感や抑うつ気分，落胆などの陰性感情，疲労感が増加する。覚醒レベルは亢進し，刺激に対して過敏に反応したり不眠状態になる。身体症状に対して破局的な思考をするなどの認知の変化が生じる。交感神経・副腎髄質系および視床下部-下垂体-副腎皮質系の活動が亢進する一方，心臓迷走神経活動

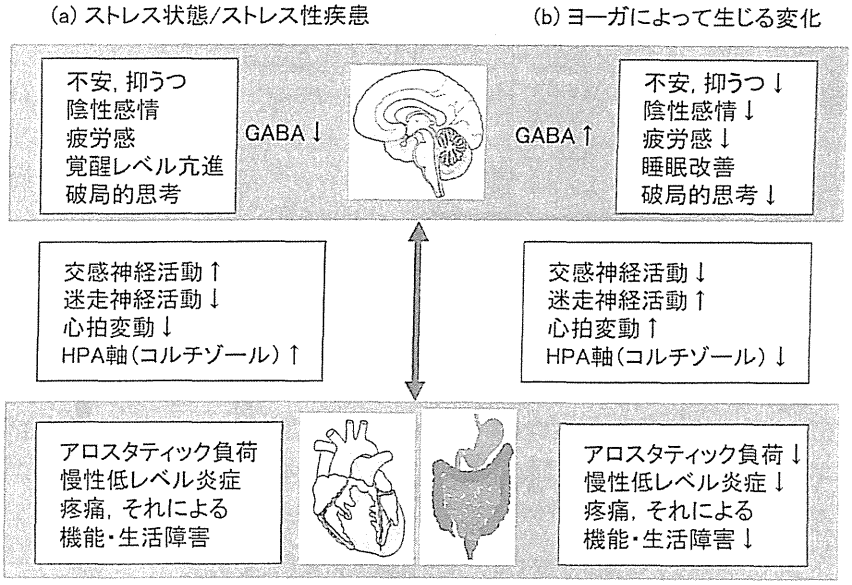

図2：ストレス状態に対してヨーガが有用性を発揮する機序。(a)就労者のストレス状態，もしくはストレス性疾患患者でみられる病態。(b)ヨーガによって生じる変化。ヨーガはストレス状態に対して抑制的に作用することがわかる（文献29より一部改変して引用）。
HPA，視床下部-下垂体-副腎皮質系；GABA，γ-アミノ酪酸。

は抑制され，心拍変動（heart rate variability, HRV）が低下する。この状態が長期間続くと，C反応性タンパク（C-reactive protein, CRP）やインターロイキン-6（interleukin-6, IL-6）などの炎症マーカーが上昇し，動脈硬化などの慢性低レベルの炎症が持続，増悪する結果となる。アロスタティック負荷（ストレスフルな外部環境に適応するためのエネルギーの消耗）の状態となり，様々な身体疾患が増悪する。特に痛みが増強すると，それによる機能障害，生活障害も問題となる。ストレス性慢性高コルチゾール血症はうつ病や記憶障害も引き起こす（図2）。

ヨーガを練習すると，これらの変化に対しておおむね拮抗的な反応が生じる。図3には合蹠前屈のポーズを行なった時の呼吸曲線を示す。まずヨーガのポーズ（アーサナ）を正しく行なうと，自然に呼吸が深く長くなることがわかる[1]。このようなポーズの組み合わせによるヨーガプログラムを行なうと，不安，抑うつ，陰性感情，疲労感は減少し，痛みに対する破局的思考や睡眠障害は改善する。また抑制性神経伝達物質であるγ-アミノ酪酸（γ-aminobutyric acid, GABA）の脳内レベルが増加する[2]。交感神経活動と血中，唾液中コルチゾール値が低下し，HRVは増加する。血中CRPやIL-6などの炎症マーカー値は低下，もしくはストレス性に生じる増加は抑制される[3]。また身体を動かす運動であるにもかかわらず血中乳酸値は低下する[4]。

てんかん，大うつ病，心的外傷後ストレス障害（post-traumatic stress disorder, PTSD），慢性疼痛患者は，脳内GABA系の低下，ストレス性の増悪，HRVの低値という共通点がある。ヨーガはこれらの疾患に対して有効であるが，その共通する機序の一つとして脳内GABAとHRVの増加が示唆されている[5]。心身症患者に対しては，ヨーガによって生じるリラックスした感覚を通して普段の自分がいかに緊張していたかを理解したり，リラックスするとストレス性の身体症状が実際に和らぐことを体験するなど，心身相関の洞察を得やすくなる点が有用である[4][6]。

4．ストレス状態，ストレス関連疾患に対するヨーガの臨床効果

ヨーガの有用性に関するランダム化比較試験（randomized controlled trial, RCT）は2000年から2012年の間に221行なわれ（図4），システマティックレビュー（systematic review, SR），メタアナリシスによる検討も行なわれるようになっている[7][8][9]。ヨーガはストレスを感じている健常人，うつ病，PTSD，てんかん，統合失調症，注意欠陥・多動性障害などの精神

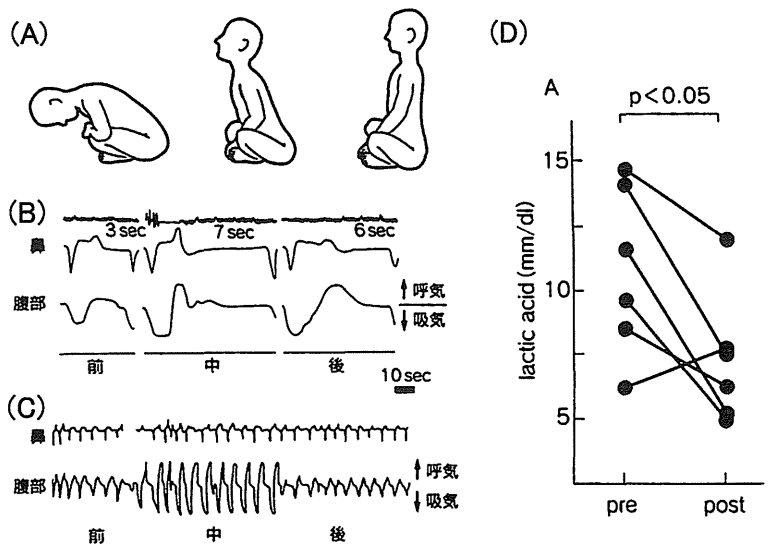

図3：アーサナは呼吸を深くし，血中乳酸値を低下させる。
合蹠前屈のポーズ（A）を行なうと，呼吸は自然に深く，長く，呼気の延長する(B)。また腹式呼吸となり，ポーズ終了後も規則正しい状態が持続する（C）ことがわかる（文献1より一部改変して引用)。気管支喘息患者がヨガアーサナを1時間練習すると血中乳酸値は低下した（D）（文献4より一部改変して引用)。

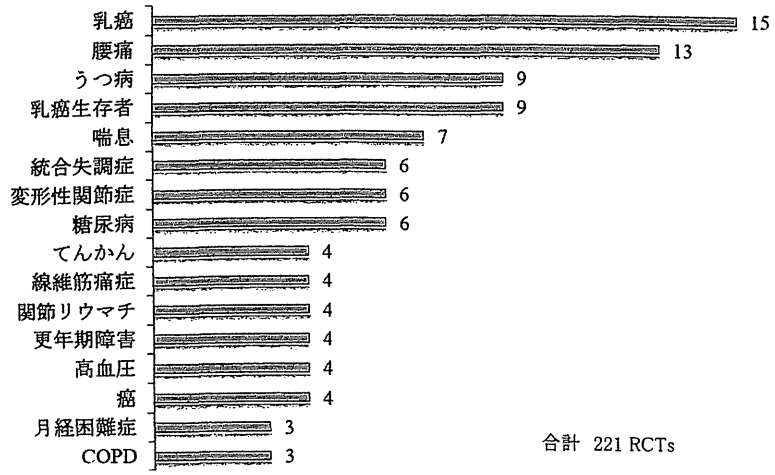

図4：ヨーガを用いたRCT研究(2000年-2012年)。COPD，慢性閉塞性肺疾患。(文献28より一部改変して引用)。

疾患，がん患者，多発性硬化症，線維筋痛症などの身体疾患患者の訴える疲労感や精神的愁訴，筋骨格系疾患（骨関節炎，リウマチ，中等度から重度の腰痛症）の慢性疼痛に対して有効であるとするRCTがある。

健康人のストレスないしプライマリケアレベルのストレス性疾患：ヨーガは健康な成人が日常生活で自覚するストレス（perceived stress）のレベルや症状，不安，抑うつを減少し，全般的な健康感を増進させる(SR)[10]。会社でのストレス軽減プログラムとしてヨーガ(毎週1時間，計12週)の効果を検討した研究では，就労者の自覚されたストレスを軽減するのみならず，睡眠の改善およびHRVの改善が得られた[11]。3ケ月12時間のプログラムであれば日本の企業でも十分実行可能であり，ストレスの多い職場では取り入れる価値があると思われる。同様な効果は，悩みを抱えた女性[12]や，プライマリーケアレベルでのストレス関連疾患患者[13]でも報告されている。つまりヨーガによって自覚するストレスや不安は軽減し，生活の質は向上す

る。

学校カリキュラムにヨーガを導入する試みもある。中学生[14]，高校生[15]に対しては，ストレス軽減，怒りなどの情動コントロールの効果がみられ有用であるが，小学生し対しては，ヨーガよりもバスケットボールなどの運動を希望する者が多く，動機づけが問題である[16]。

精神疾患：うつ病，注意欠陥・多動性障害に対して，また統合失調症に対する薬物療法に付属する治療として，ヨーガの有用性が示唆されている(SR)[8]。その一方で，摂食障害に対する効果は確立されていない。

がん患者：ヨーガはがん患者の自覚的ストレス，不安[17]，抑うつ，落胆などの精神愁訴と疲労感を軽減し，不眠[18]や生活の質を改善する。また放射線治療やがん治療薬による副作用（吐き気，嘔吐，更年期症状，関節痛）を改善する[19][20][21]ことが報告されている。

疼痛性疾患：ヨーガは筋骨格系疾患（リウマチ，変形性関節症，中等度から重度の腰痛症）による疼痛に対して有効である(SR)[9]。しかしながら8-15%の者では，ヨーガによる副作用として腰痛が悪化した点にも注意が必要である。線維筋痛症患者に対しては，破局的思考を改善する効果はあるが，痛みそのものに対する効果は限定的である[22][23]。

慢性疲労症候群 (chronic fatigue syndrome, CFS)：我々は通常の治療では十分な効果が得られなかったCFS患者で30分以上座位が可能な者に対して，アイソメトリックヨーガを併用したところ，通常治療群よりも疲労感と痛みがより改善し，活気が増加することを見いだした[24]。

5．ヨーガの安全性および有害事象

ヨーガがストレス軽減のための治療法として用いられるためには一定の安全性が担保され，起こりうる有害事象の頻度と内容が明らかである必要がある。そこで我々は，ヨーガ教室に通う2532名を対象として，ヨーガによる有害事象の頻度と内容を調査した[25]。ヨーガの練習により何らかのこのましくない症状を報告したのは28%であり，筋肉痛やふらつき，シビレ感，咳がでるといった症状がほとんどであった。このような症状がでても実習に差し支えがなかった者が，その63%であり，実習を中止せざるを得なかった者は1.9%であった。文献的にも有害事象として最も多いのは筋肉痛，筋スパスムであるが，多くは軽度であり[26]，ヨガを行なうベネフィットの方が大きい。

ただし，ストレス関連疾患，精神疾患患者に対してヨーガを導入する場合には，異なる観点からの注意が必要である。ストレス関連疾患／愁訴に対してヨーガの効果を検討した報告では，ヨーガ参加者18名中5名(28%)がヨーガに関連して不快な事象を述べた。その内訳はヨーガプログラムにより，自分の内面的な感情に触れることによって生じる緊張感，自分で自分自身を管理することに負担を感じるというものであった[12]。ヨーガが自らの内面と向き合うセルフコントロール法であることに由来する有害事象であり，治療者は患者の自我強度や病気の性質，治療段階を考慮した上で，ヨーガ導入の適否や時期を検討すべきである。また，ヴァルサルヴァ網膜症の既往をもつ男子学生が倒立のポーズを行なっている時に，一時的に失明したという報告がある[15]。倒立によって眼静脈圧が上昇し，出血したものと考えられる。特殊な病気を持つ患者では，思いもよらない有害事象が生じる危険性があり，ヨーガを行なう前には，十分な問診を行ない，安全にヨーガを行なえるか検討する必要がある。また行なうヨーガプログラムを検討すべきである。

6．ヨーガの医療経済的効果

ヨーガを併用することにより医療費が抑制できる可能性を示唆する報告もある。例えば，化学療法中のリンパ腫患者がヨーガを行なうと睡眠障害が改善し，睡眠薬の必要量が減少した[18]。という報告や，腰痛患者がヨーガを行なうと，通常治療群よりも医療費を抑制できたとする報告がある[27]。

7．ヨーガの用量-反応関連

ヨーガを一つの薬物療法と考えると，ヨーガによってストレス軽減効果を得るためには，どれだけの頻度や時間が必要であるのか，ヨーガによるストレス軽減効果には用量依存性があるのだろうか，という疑問が生じる。この疑問に答えようとする研究もみられる。高いストレスを自覚する女性を対象として，1回90分のアイアンガーヨガのクラスを毎週1回受けた群，毎週2回受けた群と対照群で臨床効果を比較した研究では，ヨーガ群では対照群に比べて不安，抑うつ，自覚ストレス，疲労感が低下し，幸福感が増加したが，こ

れらの効果はヨーガ週1回群と，週2回群との間では差がなかった[12]。この研究では自宅で練習することを勧めており，自宅で練習する限りにおいては，指導者について習う機会（ヨーガクラス参加）は週に1回でもよいと考えられる。

8．疾患に応じたヨーガプログラムの工夫，医療者-ヨーガ指導者連携

現在，ヨーガ教室で行なわれているヨーガは健康な人を対象として作られたプログラムである。したがって，身体疾患，精神疾患患者を対象としてヨーガを行なう場合，当然，疾患に応じてヨーガプログラムを工夫する必要がある。例えばストレス関連疾患患者[13]に対しするヨーガの効果を検討した研究では，伝統的なヨーガよりゆっくりとした動作で行なう様に工夫したプログラム（medical yoga therapy）を用いている。我々がCFSに対して行なうヨーガプログラムは，CFS患者の疲労を増大させないよう，座位で行なうアイソメトリック運動を取り入れたプログラム（isometric breathing exercise）である。

アーサナ（ヨガのポーズ）は，日常動作ではあまり用いない筋肉をストレッチし，目的の姿勢（ポーズの完成形）を一定時間，保持する。したがって筋骨格系疾患患者がヨガを行なう場合，無理なストレッチ，無理な方向の動作を行なうと痛みが増す危険性がある。実際，慢性疼痛に対して有効であるとするRCT研究でも，ヨーガによってかえって痛みが増した者や，ヨーガプログラムをドロップアウトした者が一定の割合で存在する。疼痛性疾患患者にヨーガを導入する場合には，医療者はヨーガ指導者と緊密に連携をとり，痛みを増悪させないよう，ポーズを限定，工夫すべきである。高血圧，動脈硬化の強い患者においては，逆立ちや頸部の強い屈曲，伸展を伴う動作は避ける方がよい。またストレス関連疾患患者では完全癖が強く，それが病態と関連している者がいる。その場合，アーサナを正確に，完全に行なおうとするあまり，かえって緊張状態が強くなる者ある。このような患者の場合，患者がポーズによってリラックスできるように指導を工夫する必要がある。精神疾患患者の中で，過去に精神的外傷体験がある者のなかには，目を閉じてポーズを行なうことに強い恐怖を感じたり，ポーズを直すためにヨーガ指導者が患者の背後に回ったり，身体的に接触する，ヨーガのポーズが外傷定体験を想起させるものである場合，患者は外傷体験を再体験することがある。

したがって医療者はヨーガ指導者に対して，あらかじめ可能な範囲内で患者の病状と，それに基づく注意点を説明しておき，このようなことが起こらないよう配慮すべきである。

9．医療の中でのヨーガの位置づけ

ヨーガによって生じる精神・身体的変化は，おおむね心身症，ストレス関連疾患の予防，治療として好ましいものである。しかしながら，ヨーガによって生じる変化量が臨床効果をもたらすに十分なものかという点については必ずしも明らかではなく，また，ヨーガ単独による治療が薬物療法や心理療法などの現代医学的治療より優れているかどうかを検討した研究は限られている。さらにヨーガの長期効果についても明らかではない。

したがって現時点では，ヨーガをストレス関連疾患，身体疾患の治療法として用いるときには，現代医学的治療のアドオンセラピーとして，現代医学に基づく医療に付け加える形で用いるのが望ましいと考えられる。

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Effect of 12 weeks of yoga training on the somatization, psychological symptoms, and stress-related biomarkers of healthy women

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Abstract

Background: Previous studies have shown that the practice of yoga reduces perceived stress and negative feelings and that it improves psychological symptoms. Our previous study also suggested that long-term yoga training improves stress-related psychological symptoms such as anxiety and anger. However, little is known about the beneficial effects of yoga practice on somatization, the most common stress-related physical symptoms, and stress-related biomarkers. We performed a prospective, single arm study to examine the beneficial effects of 12 weeks of yoga training on somatization, psychological symptoms, and stress-related biomarkers.

Methods: We recruited healthy women who had no experience with yoga. The data of 24 participants who were followed during 12 weeks of yoga training were analyzed. Somatization and psychological symptoms were assessed before and after 12 weeks of yoga training using the Profile of Mood State (POMS) and the Symptom Checklist-90-Revised (SCL-90-R) questionnaires. Urinary 8-hydroxydeoxyguanosine (8-OHdG), biopyrrin, and cortisol levels were measured as stress-related biomarkers. The Wilcoxon signed-rank test was used to compare the stress-related biomarkers and the scores of questionnaires before and after 12 weeks of yoga training.

Results: After 12 weeks of yoga training, all negative subscale scores (tension-anxiety, depression, anger-hostility, fatigue, and confusion) from the POMS and somatization, anxiety, depression, and hostility from the SCL-90-R were significantly decreased compared with those before starting yoga training. Contrary to our expectation, the urinary 8-OHdG concentration after 12 weeks of yoga training showed a significant increase compared with that before starting yoga training. No significant changes were observed in the levels of urinary biopyrrin and cortisol after the 12 weeks of yoga training.

Conclusions: Yoga training has the potential to reduce the somatization score and the scores related to mental health indicators, such as anxiety, depression, anger, and fatigue. The present findings suggest that yoga can improve somatization and mental health status and has implications for the prevention of psychosomatic symptoms in healthy women.

Trial registration: University Hospital Medical Information Network (UMIN CTR) UMIN000007868.

Keywords: Yoga, Somatization, Psychological symptom, Stress, Biomarker, Anxiety, Depression, Anger, Hostility, Fatigue

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Background

Yoga is an ancient technique used for promoting physical and mental health through postures, the regulation of breathing, and meditation. Studies have shown that the practice of yoga reduces perceived stress and negative feelings and that it improves psychological symptoms by lowering the levels of anxiety and anger [1-5]. We also showed that long-term yoga training improves stress-related psychological symptoms, such as anxiety and anger [6].

In addition to these stress-related psychological symptoms, somatization, the most common stress-related physical symptom, is frequently seen in clinical care settings. Somatization is defined as "a tendency to experience and communicate somatic distress in response to psychosocial stress and to seek medical help for it" [7]. Clinically significant somatization leads to excessive health care use. For example, it costs the US health care system an estimated over $100 billion annually [8]. These medically unexplained physical symptoms include headache, dizziness, chest pain, lower back pain, nausea, muscle soreness, breathing problems, hot or cold spells, numbness or tingling in parts of the body, lumps in the throat, a weak feeling in parts of the body, and a heavy feeling in the arms or legs. There are numerous treatments for somatization, and they have varying degrees of effectiveness.

A few studies have demonstrated that somatization symptoms after mindfulness training, which includes meditation, were significantly decreased in comparison with before mindfulness training. Rosenzweig et al. indicated that greater home meditation practice was associated with improvement of somatization symptoms among participants with chronic pain conditions [9]. Franco et al. reported reduced teacher somatization scores on the Symptom Checklist-90-Revised (SCL-90-R) through a mindfulness training program [10]. With regard to yoga, only one study in the English literature has shown the potential effects of yoga practice on somatization symptoms [11]. Although Telles et al. reported that the somatization score was reduced after one week of yoga practice (Before yoga: 10.93 ± 6.05, After yoga: 7.03 ± 5.90) [11], the baseline somatization score on the SCL-90-R in a yoga group of healthy volunteers was higher compared with that of a control group (Yoga group: 10.93 ± 6.05, Control group: 5.69 ± 5.66). There is little evidence about the effects on somatization symptoms of yoga that includes a combination of classical postures, breathing exercises, and meditation.

Because there are no clear biomarkers capable of objectively measuring psychosocial distress, many researchers have examined self-rating symptom scores using questionnaires and various stress-related biomarkers, such as cortisol and catecholamine. Recently, stress-related urinary biomarkers, such as 8-hydroxydeoxyguanosine (8-OHdG) and biopyrrin, have been used to assess psychological distress because blood sampling itself is invasive and has been associated with psychological stress [12-14]. The urinary 8-OHdG level is a putative biomarker of total systemic oxidative stress [15], and psychological distress is associated with oxidative damage [12]. Biopyrrin, an oxidative metabolite of bilirubin, is a stress-related urinary biomarker [13,14,16]. In our previous study, we indicated that the urinary 8-OHdG concentration tended to be lower in a long-term yoga group than in a control group [6]. However, there have been no previous longitudinal studies showing that the practice of yoga simultaneously influences psychosomatic symptoms, urinary 8-OHdG, and biopyrrin levels.

In this study, we performed a prospective, single arm study to examine the beneficial effects for healthy individuals of a 12-week yoga program on indicators of somatization and psychological symptoms using the Profile of Mood States (POMS) and SCL-90-R questionnaires, and on stress-related biomarkers, such as urinary 8-OHdG, biopyrrin, and cortisol before initiation of a randomized control trial (RCT). We did not include patients with somatization symptoms because this is a pilot study. We tested the hypothesis that the indicators of somatization and psychological symptoms would be improved and that the levels of stress-related urinary biomarkers after 12 weeks of yoga training would be decreased compared with those before the start of yoga training.

In this paper, we used the data from a previous study of 38 healthy women with more than two years of experience with yoga (long-term yoga group) and 37 age-matched, healthy women who had no experience with yoga (control group) who were used to obtain reference data [6]. We hypothesized that the data for the psychological symptoms and the stress-related biomarkers of the yoga-training group before yoga training would be almost the same as the data for the control group. In addition, we assumed that there is a dose–response effect of yoga for several weeks and a longer threshold effect. Therefore, we hypothesized that the data on the psychological symptoms and the stress-related biomarkers of the yoga-training group after 12 weeks of yoga training would be almost the same as the data of the long-term yoga group.

Methods

Participants and data collection

A national survey of yoga practitioners reported that the percentage of females attending yoga training was 84.2% in the USA [17]. Because yoga is also far more popular for women than men in Japan, it seemed that it would be difficult to recruit men for a yoga study. Therefore,

we recruited 39 healthy, adult women who had no experience with yoga. The participants were recruited by posters, flyers, and the Internet from ten yoga-training centers and from halls where yoga lessons were only a part of the lesson program. The recruitment sites were in Fukuoka, Kumamoto, and Kagoshima Prefectures of Japan. The following exclusion criteria were applied: (i) age < 20 years and > 50 years; (ii) taking medication including supplements in the month prior to the experiment; (iii) having an illness; and (iv) having a past history of significant physical or mental illness. All participants received detailed information on the purpose of the study and provided written informed consent. The participants who agreed were then handed questionnaires, a paper cup, a tube with a screw cap, and a self-addressed return parcel before and after the 12 weeks of yoga training. Each participant collected urine samples and, at the same time, answered the POMS and SCL-90-R questionnaires at home. The urine, frozen at home by the participant, and the questionnaires were sent as soon as possible via a parcel delivery service, which used a freezer van to keep the samples frozen at −18°C (−0.4°F). Participants who completed the yoga- training program received 2,000 yen (about $20). The study was approved by the Institutional Review Board of Kyushu University.

Yoga intervention

Yoga classes were conducted one day a week for about one hour each session for 12 weeks. All instructors of the yoga classes are certificated. The participants were requested to attend at least 10 of the 12 weekly yoga sessions and to practice on their own at home at least twice a week for over 30 minutes during this 12-week period. If they could not attend 10 of the 12 classes or the requested home practice, they were dropped from the study. The self-reported home practice activity time was confirmed at a classroom session. Some yoga classes were closed classes, for only the participants of our study, and others were not. Of the various types of yoga, we chose cyclic meditation yoga as our yoga intervention because of the availability of scientific studies on this form of yoga (reviewed in [18]). At the beginning of the cyclic meditation yoga training, the instructors emphasized practicing slowly with awareness and relaxation. The cyclic meditation yoga consisted of the following practices;

1. Isometric contraction of the muscles of the body ending with rest in the supine position (Shavasana).
2. Standing at ease (Tadasana) and balancing the weight on both feet (Centering).
3. From the standing position (Tadasna), bending to the right and left (Ardhakati Cakrasana).
4. Forward bending (Pada Hastasana).
5. Backward bending (Ardha Chakrasana).
6. Supine posture for rest (Shavasana).
7. Bending the knees, holding them together while sitting down and adjusting the hips between the heels. While inhaling raise both arms above the head. While exhaling keep the back straight and bend the upper body and arms forward until the arms and forehead touch the floor, without raising the buttocks (Shashankasana).
8. From a kneeling position, coming up onto both knees and placing them hip width apart. Placing the palms of the hands on the sacrum with the fingers pointed down. Inhaling and pressing the knees down while extending the crown of the head up to lengthen the spine. Exhaling and pressing the hips forward, squeezing the buttocks and thighs, and supporting the body weight with the arms while bending backwards (Ardha Ushtrasana).
9. Slowly coming down to a supine posture for rest (Shavasana) with instructions to relax the body in sequence.

Although the participants sometimes practiced breathing exercises (Bhramari Pranayama) or meditation (Om meditation), they mainly practiced cyclic meditation yoga.

Urine sampling

Urine samples were collected from all participants for the quantification of biopyrrin, 8-OHdG, cortisol, and creatinine. The participants were asked to avoid vigorous exercise and heavy psychological stress for 24 hours prior to urine collection. Urine was collected between 6:00 and 9:00 am, and 2 ml of urine from each participant was stored at −80°C (−112°F) until analysis. The urinary biopyrrin, cortisol, and 8-OHdG concentrations were measured by enzyme-linked immunosorbent assay kits (Shino-Test, Tokyo, Japan, Oxford Biomedical Research, Inc. MI, and Nikken Seil Co., Ltd, Shizuoka, Japan, respectively). The urine creatinine concentration was analyzed using the Accuras Auto-Cre diagnosis kit (Shino-Test, Tokyo, Japan) and biopyrrin, 8-OHdG, and cortisol concentrations were corrected based on the urine creatinine concentration. One participant was excluded from the analysis of biopyrrin, 8-OHdG, and cortisol concentrations because her urine was sent to us without having been frozen.

Questionnaires

A questionnaire about demographic characteristics, the POMS questionnaire (Educational and Industrial Testing Service, San Diego, CA), and the SCL-90-R questionnaire were given to each of the participants. The questionnaire about demographic characteristics included questions about age, race, and education. The POMS questionnaire

assesses six mood subscales: tension-anxiety, depression, anger-hostility, vigor, fatigue, and confusion. High vigor scores reflect a good mood or emotion, and low scores on the other subscales reflect a good mood or emotion. Yokoyama et al. previously translated the 65-item scale of the POMS into Japanese and demonstrated the reliability and validity of this Japanese version of the POMS [19]. The Japanese version of the POMS (Kaneko Shobo Co., Tokyo, Japan) was used for the present study. The test taker rates his/her mood over the past seven days on a 5-point scale ranging from "not at all" to "extremely". The SCL-90-R is a validated and reliable questionnaire that is sensitive to changes in psychological distress. The validity and reliability of the Japanese version of SCL-90-R has been confirmed [20]. It is a 90-item self-report symptom inventory and consists of nine symptom dimensions, somatization, obsessive-compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation, and psychoticism. The test taker rates how much each of 90 problems had distressed or bothered them in the past seven days on a 5-point scale ranging from "not at all" to "extremely. Somatization, anxiety, depression, and hostility were chosen for study because it has been demonstrated that the practice of yoga improves the mental state by lowering the levels of anxiety, depression and anger-hostility [4,5,21,22] and because we wanted to ensure that the practice of yoga improves somatic symptoms. These questionnaires were chosen because of their sensitivity to change through therapeutic intervention in about 12 weeks [10,22]. Of the participants, the data of three were excluded from the SCL-90-R data analysis because they did not fill out the back page of the questionnaire.

Statistical analysis and sample size

Statistical analyses were performed using a statistical software package (PASW Statistics 18, version 18.0.0 for Windows; SPSS Inc., Chicago, IL, USA). The Kruskal-Wallis test was used to compare age and education among the yoga-training, control, and long-term yoga groups. Distribution of the subscale scores of POMS and biopyrrin, 8-OHdG, and cortisol concentrations was analyzed using the Kolmogolov-Smirnov test, and we found that the tension-anxiety, depression, anger-hostility, fatigue, and confusion scores of POMS and biopyrrin, 8-OHdG, and cortisol concentrations were not normally distributed. In addition, the anxiety and hostility subscales of SCL-90-R in Japanese community samples had a floor effect (average − 1SD < 0) [20]. Therefore, we chose to run non-parametric statistics. The Wilcoxon signed-rank test was utilized to compare the biopyrrin, 8-OHdG, and cortisol concentrations, which were corrected based on the urine creatinine concentration and the scores of questionnaires before and after 12 weeks of yoga training. The Mann–Whitney U-test was used to compare the biopyrrin, 8-OHdG, and cortisol concentrations and the scores of questionnaires between the control group and the yoga-training group before yoga training and between the long-term yoga group and the yoga-training group after yoga training. Spearman rank correlation was used to test the relationship between the somatization score and the POMS scores or between the changes of subscale scores in POMS and SCL-90-R and the changes of stress-related urinary biomarkers (8-OHdG, biopyrrin, and cortisol). Differences of $p < 0.05$ were considered to be statistically significant.

We estimated that a sample size of 21 would allow us to detect significant differences in the before and after yoga training somatization scores from the SCL-90-R with 80% power ($\alpha = 0.05$) based on the mean and standard deviation of the somatization scores reported in a previous study of mindfulness [10]. The sample size was calculated using the Power and Sample Size Calculation Software version 3.0 for Windows (Vanderbilt University, Nashville, TN, USA).

Results

Follow-up and demographics

The data of 24 of the 39 participants, those who completed at least 10 of the 12 weekly yoga sessions and practiced on their own at home at least twice a week for over 30 minutes during the 12 weeks, were available for analysis (yoga-training group). There were no significant differences in the subscale scores of POMS and SCL-90-R and the stress-related urinary biomarkers before starting yoga training between those who dropped out before the end of the yoga training and those able to

Table 1 Demographic data of the yoga-training group and the reference data of the control and long-term yoga groups

Characteristics	Yoga-training group (n = 24)	Control group (n = 37)	Long-term yoga group (n = 38)
Age[Mean(SD)]	36.79 (6.43)	34.43 (8.16)	33.84 (7.33)
Range	(25–46)	(22–49)	(22–49)
Ethnicity (%)			
Japanese	100 (n = 24)	100 (n = 37)	100 (n = 38)
Education (%)			
Junior H.S. graduate	0.0 (n = 0)	0.0 (n = 0)	2.6 (n = 1)
H.S. graduate	37.5 (n = 9)	24.3 (n = 9)	23.7 (n = 9)
Junior college graduate	41.7 (n = 10)	37.8 (n = 14)	42.1 (n = 16)
College graduate	20.8 (n = 5)	29.7 (n = 11)	31.6 (n = 12)
Blank	0.0 (n = 0)	8.1 (n = 3)	0.0 (n = 0)

SD: standard deviation. H.S.: high school. The Kruskal-Wallis test was used to compare the age and education levels among the yoga training, control, and long-term yoga groups.

complete the 12 weeks of yoga training (data not shown). The demographic data of the yoga-training group, including age, race, and education, are shown in Table 1. As reference data, the demographic data of the long-term yoga group (with more than two years of experience with yoga) and the control group (without experience with yoga) in our previous study [6] are also shown in Table 1. No significant differences were found among the three groups.

Psychological distress from the POMS

The results of the subscale scores of the POMS questionnaire are shown in Figure 1. To add reference for the current results, the subscale scores of the control (without experience with yoga) and long-term yoga (with more than two years of experience with yoga) groups from our previous cross-sectional study are shown on the left and right sides, respectively [6]. All negative subscale scores, tension-anxiety ($p = 0.022$; Figure 1A), depression ($p = 0.010$; Figure 1B), anger-hostility ($p = 0.020$; Figure 1C), fatigue ($p = 0.001$; Figure 1E), and confusion ($p = 0.004$; Figure 1F) of the POMS after the 12 weeks of yoga training were significantly decreased compared with those before starting yoga training. There was a trend toward an increase of the vigor score after the 12 weeks of yoga training ($p = 0.083$; Figure 1D). There were no significant differences in any of the negative subscale scores of the POMS questionnaire between the control group and the yoga-training group before yoga training and between the long-term yoga group and the yoga-training group after yoga training.

Psychosomatic symptoms from the SCL-90-R and the relationship between the change of somatization and the change of mood state

Scores for somatization ($p = 0.006$), depression ($p = 0.002$), anxiety ($p = 0.002$), and hostility ($p = 0.007$) from SCL-90-R were significantly decreased after 12 weeks of yoga training compared with those before starting yoga training (Figure 2A-D).

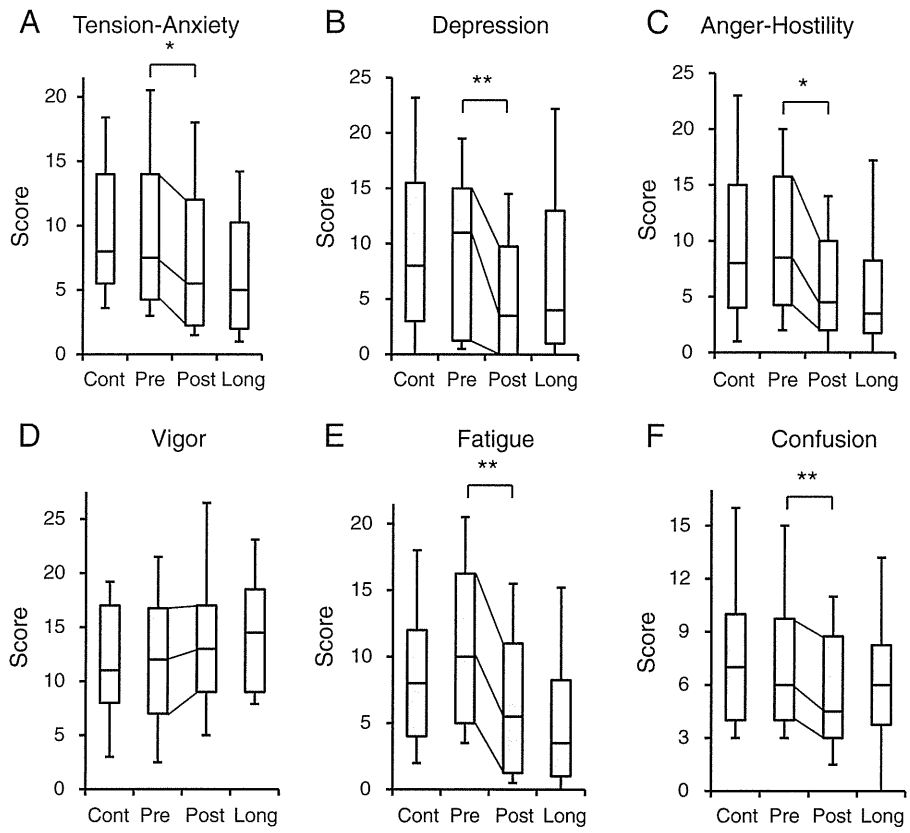

Figure 1 Psychological distresses results from the Profile of Mood State (POMS) related to yoga training. Box plot representing the POMS subscale score of the yoga-training group (n = 24) before (Pre) and after (Post) 12 weeks of yoga training with reference control (Cont) and long-term yoga groups (Long). The 25th and 75th percentiles are represented by the lower and upper borders of the grey box. The dark line within the grey box represents the median. The whisker error bars represent the 10th and 90th percentiles. **(A-C, E, F)** All negative subscale scores, tension-anxiety ($p = 0.022$), depression ($p = 0.010$), anger-hostility ($p = 0.020$), fatigue ($p = 0.001$), and confusion score ($p = 0.004$), from the POMS after the 12 weeks of yoga training were significantly decreased compared with those before starting yoga training. **(D)** There was a trend toward an increased vigor ($p = 0.083$). Statistically significant differences are shown: $^{*}P < 0.05$, $^{**}P < 0.01$.

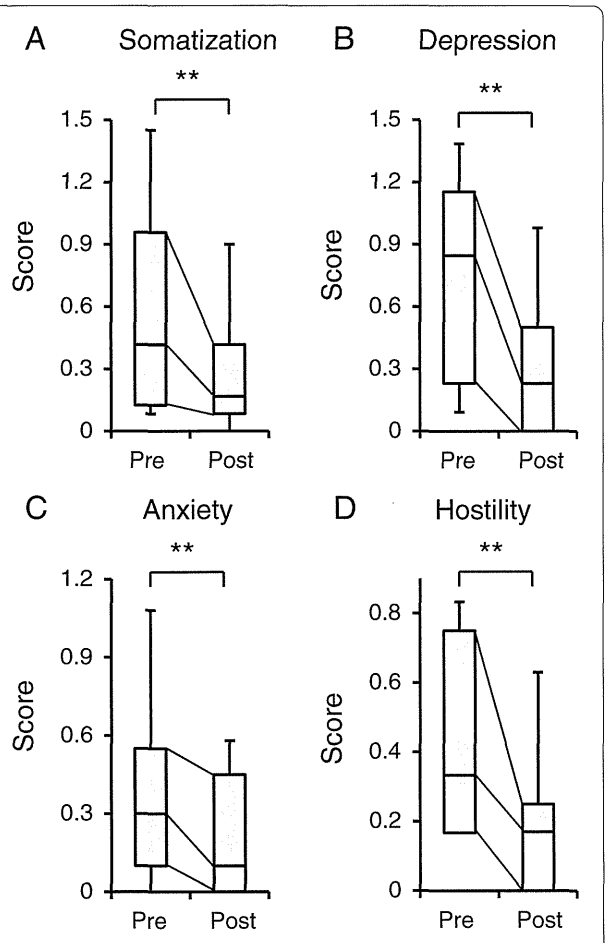

Figure 2 Somatization and psychological symptoms from the Symptom Check List-90-R (SCL-90-R). Box plot representing the SCL-90-R subscale scores of the yoga-training group before (Pre) and after (Post) 12 weeks of yoga training (n = 21). The 25th and 75th percentiles are represented by the lower and upper borders of the grey box. The dark line within the grey box represents the median. The whisker error bars represent the 10th and 90th percentiles. **(A-D)** Scores for somatization ($p = 0.006$), depression ($p = 0.002$), anxiety ($p = 0.002$), and hostility ($p = 0.007$) from SCL-90-R were significantly decreased after 12 weeks of yoga training compared with those before starting yoga training. Statistically significant differences are shown: $^{**}P < 0.01$.

Therefore, we investigated if changes in mood were related to changes in somatization. However, we did not find any significant correlation between the changes in mood (tension-anxiety, depression, anger-hostility, vigor, fatigue, and confusion in POMS) and the changes in somatization (data not shown). These results suggest that the change of somatization does not have a direct relation with the change of mood.

Stress-related urinary biomarkers

The stress-related biomarkers urine concentration of 8-OHdG, biopyrrin, and cortisol are shown in Figure 3. As a reference for the current results, the urine concentration of the control group is shown on the left and that of the long-term yoga group is shown on the right [6]. Contrary to our expectation, the urinary 8-OHdG concentration after 12 weeks of yoga training showed a significant increase compared with that before the start of yoga training (Figure 3A). The urinary 8-OHdG concentration of the yoga-training group before yoga training was significantly lower than that of the control group from our previous study (Figure 3A). No significant changes were observed in the levels of urinary biopyrrin and cortisol after the 12 weeks of yoga training (Figure 3B, C). There were no significant differences in the urinary biopyrrin and cortisol levels between the control group and the yoga-training group before yoga training and between the long-term yoga group and the yoga-training group after yoga training.

Correlations between the changes of the POMS and SCL-90-R subscale scores and the changes of stress-related urinary biomarkers

We investigated if the changes of the subscale scores of the POMS and SCL-90-R are related to the changes of stress-related urinary biomarkers, such as 8-OHdG, biopyrrin, and cortisol; however, we did not find any significant correlations (data not shown).

Discussion

After 12 weeks of yoga training, all negative subscale scores (tension-anxiety, depression, anger-hostility, fatigue, and confusion) from the POMS and somatization, anxiety, depression, and hostility from the SCL-90-R were significantly decreased compared with those before starting yoga training. This is the first study to demonstrate the effect of yoga training on the somatization symptoms of healthy women who had almost normal somatization scores on the SCL-90-R (Before yoga: 6.86 ± 6.69, After yoga: 3.64 ± 4.04 in this study and in a Japanese community sample: 7.56 ± 5.64 in a previous study [20]; these figures were calculated as the somatization scores in this paper and the previous paper multiplied by 12, because the number of questions about somatization in SCL-90-R are 12). Our findings suggest that regular yoga training reduces not only the level of psychological symptoms, but also somatization symptoms.

Somatization symptoms include medically unexplained physical symptoms such as headache, dizziness, chest pain, lower back pain, and nausea. Some of these physical symptoms have been shown to improve with yoga training. For example, it has been reported that the practice of yoga improved the symptoms of patients with clinically diagnosed migraine [23] and chemotherapy-induced nausea [24]. However, these symptoms are not classified as somatization symptoms because they can be explained medically. Additionally, there is evidence of

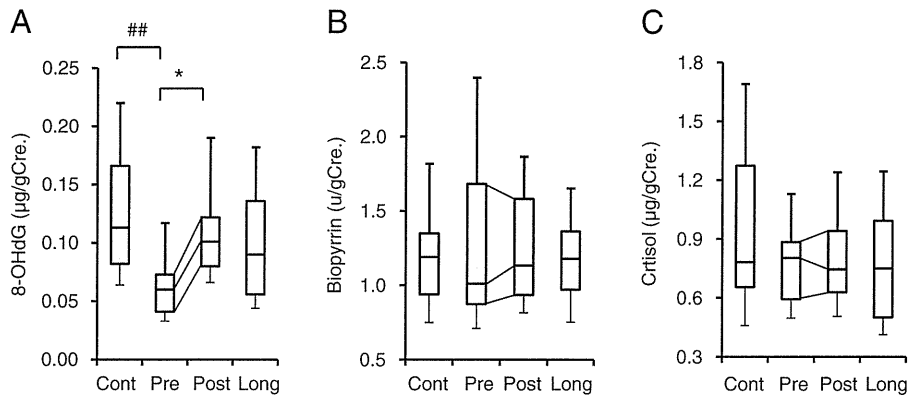

Figure 3 Change of stress-related urinary biomarkers by 12 weeks of yoga training. Box plot representing the stress-related urinary biomarkers of the yoga-training group (n = 23) before (Pre) and after (Post) yoga training with reference control (Cont) and long-term yoga groups (Long). The 25th and 75th percentiles are represented by the lower and upper borders of the grey box. The dark line within the grey box represents the median. The whisker error bars represent the 10th and 90th percentiles. **(A)** The urinary 8-Hydroxydeoxyguanosine (8-OHdG) concentration after 12-weeks of yoga training showed a significant increase compared with that before starting yoga training. The urinary 8-OHdG concentration of the yoga-training group before yoga training was significantly lower than that of the control group from our previous study. **(B, C)** No significant changes were observed in the levels of urinary biopyrrin and cortisol after the 12 weeks of yoga training. Statistically significant differences are shown: $^{*}P < 0.05$ (Wilcoxon signed-rank test), $^{\#\#}P < 0.01$ (Mann-Whitney U-test).

lower back pain improvement with yoga training [25,26]. However, low back pain is only one of the 12 somatization score items on the SCL-90-R. A few studies have demonstrated that mindfulness training improves somatization symptoms [9,10]. Meditation is a major component of mindfulness. However, the participants of our study practiced a combination of classical postures, breathing exercises, and meditation. Therefore, our findings show that this combination of yoga practices also has the potential to improve somatization symptoms.

Yoga has been reported to be effective with respect to negative psychological symptoms, such as anxiety [3,27-29], anger/hostility [29], and depression [29-31]. Our previous study also suggested that long-term yoga training can improve negative psychological symptoms such as anxiety and anger [6]. Our current results using the POMS and SCL-90-R questionnaires confirm these previous findings that negative psychological symptoms, such as anxiety, anger/hostility, depression, and confusion, are improved by yoga.

As for the relation between mood and somatization, previous study showed that only anxiety, not depression nor anger, had a direct effect on the somatic symptoms of anxiety disorder patients, whereas anxiety and depression, not anger, had a direct effect on the somatic symptoms of somatoform disorder patients [32]. However, in healthy people there were no significant correlations between the changes in mood (tension-anxiety, depression, anger-hostility, vigor, fatigue, and confusion in POMS) and the changes in somatization. Our results suggested that anxiety, depression, and anger are not intimately linked to somatic symptoms in healthy people.

Contrary to our expectation, the level of urinary 8-OHdG after 12 weeks of yoga training showed a significant increase compared with that before starting yoga training. In Figure 3A, the urinary 8-OHdG level of the participants before starting yoga was significantly lower than that of the control group from our previous study [6] ($p < 0.01$; Mann–Whitney U-test). Before being corrected based on the urine creatinine concentration, the average urinary 8-OHdG level of the participants before starting yoga (7.0 ng/mL) was lower than the reference value for women (10.3 ng/mL) described in the document for the ELISA kit we used that appears on the manufacturing company's website (http://www.jaica.com/guidance_8ohdg/index.html) Japanese. It is unclear why the urinary 8-OHdG level before starting yoga was lower than that of the control group. It is possible that the yoga-training group had an atypical background in terms of their daily activity. A previous study suggested that a heavy burden of work in addition to daily domestic roles increases urinary excretion levels of 8-OHdG [33]. We speculate that the participants in the yoga-training group, in contrast with the others, had sufficient time to attend and continue the 12 weeks of training sessions. Most of them may have been working-women without daily domestic roles. Viewed in this light, through the practice of yoga, their activity levels may have increased and approached the activity levels of the long-term yoga group. Further studies are needed to elucidate the relationship between urinary 8-OHdG and psychosomatic distress that include the activity level.

The analysis of urinary biopyrrin in our previous cross-sectional study of yoga indicated no significant differences in the level of urinary biopyrrin between the

control and long-term yoga groups [6]. The current results also showed no significant change in urinary biopyrrin levels after 12 weeks of yoga training. This may be because it is difficult for healthy people to reduce their concentration of urinary biopyrrin by yoga training because their urinary excretion of biopyrrins is already stable at a lower concentration. Our results suggest that biopyrrin is suitable for studies of clinical populations, but not suitable for studies of healthy people.

Cortisol is an accepted, objective stress-related biomarker, because dysregulation of the level of cortisol is related to pathologies associated with stress-related symptoms, such as anxiety, depression, and negative affect [34-36]. However, a previous cross-sectional study of meditation and our previous cross-sectional study of yoga demonstrated that the baseline cortisol level of long-term practitioners was almost the same as that of a control group [6,37]. Our present results also showed no significant change in urinary cortisol level by 12 weeks of yoga training. Although it has been reported that chronic stress causes a high basal cortisol level, the basal cortisol level of most healthy participants may be stable at a lower concentration. Another possibility is that we did not get the accurate peak cortisol level of all participants because we did not take into consideration differences in the participant's sleep/wake schedules, although urine was collected between 6:00 and 9:00 am. Circadian rhythm should be tracked leading up to the urine collection to more accurately measure the cortisol level.

This study has some limitations. The first is the small sample size. However, we were able to demonstrate significant differences in somatization and psychological scores because there were more participants than the calculated sample size necessary to insure significance. The second limitation is that there is a lack of a comparison group. By using the previous data as a reference, we were able to show that the data of the yoga-training group before yoga training were almost the same as the data of the control group, except for the level of 8-OHdG. Also, the data of the yoga-training group after yoga training were almost the same as the data in the long-term yoga group. These data indicate that the changes of somatization and psychological symptoms in the yoga-training group compared with the "true" control group would have remained significant if an RCT has been used. Despite these limitations, the present findings suggest that yoga training can reduce the somatization score and scores related to mental health indicators, such as anxiety, depression, anger, and fatigue. Yoga training may affect both physical and mental well-being and be useful for preventing somatization and mental disorders. Further studies that measure psychosomatic symptoms and stress-related biomarkers of patients with somatization using yoga intervention compared with controls without yoga intervention, taking into consideration differences in their sleep/wake schedules using methods such as 24 hr urine collection, and/or sleep/wake logs, are needed to verify the effect of yoga.

Conclusions

Yoga training has the potential to reduce the somatization score and scores related to mental health indicators, such as anxiety, depression, anger, and fatigue. The present findings suggest that yoga can improve somatization and mental health status and has implications for the prevention of psychosomatic symptoms in healthy women.

Abbreviations

POMS: Profile of mood state; SCL-90-R: Symptom Checklist-90-Revised; 8-OHdG: 8-hydroxydeoxyguanosine; RCT: Randomized control trial; SD: Standard deviation; H.S.: High school.

Competing interests

The authors declare that they have no competing interests.
Our interpretation of the data and presentation of the information was not influenced by the Japan Yoga Therapy Society, which funded our study.

Authors' contributions

K.Y. conceived the study, participated in the design of the study, carried out data collection, performed the statistical analysis and drafted the manuscript. T.H. participated in the design of the study and carried out data collection. T.O. and N.S. evaluated the results of the study and reviewed the manuscript. C.K. participated in the design and coordination of the study and reviewed the manuscript. All authors read and approved the final manuscript.

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