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Mind/body techniques for physiological and psychological stress reduction: Stress management via Tai Chi training – a pilot study

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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Summary

Background: Stress can affect health. There is a growing need for the evaluation and application of professional stress management options, i.e, stress reduction. Mind/body medicine serves this goal, e.g, by integrating self-care techniques into medicine and health care. Tai Chi (TC) can be classified as such a mind/body technique, potentially reducing stress and affecting physical as well as mental health parameters, which, however, has to be examined further.

Material/Methods: We conducted a prospective, longitudinal pilot study over 18 weeks for the evaluation of subjective and objective clinical effects of a Yang style TC intervention in young adults (beginners) by measuring physiological (blood pressure, heart rate, saliva cortisol) and psychological (SF-36, perceived stress, significant events) parameters, i.e, direct or indirect indicators of stress and stress reduction, in a non-randomised/-controlled, yet non-selected cohort (n=21) by pre-to-post comparison and in follow-up. SF-36 values were also compared with the age-adjusted norm population, serving as an external control. Additionally, we measured diurnal cortisol profiles in a cross-sectional sub-study (n=2+2, pre-to-post), providing an internal random control sub-sample.

Results: Only nine participants completed all measurements. Even so, we found significant ($p<0.05$) reductions of saliva cortisol (post and follow-up), which seems to be an indicator of general stress reduction. A significant decrease in perceived mental stress (post) proved even highly significant ($p<0.01$) in the follow-up, whereas physical stress perception declined to a much lesser degree. Significant improvements were also detected for the SF-36 dimensions general health perception, social functioning, vitality, and mental health/psychological well-being. Thus, the summarized mental health measures all clearly improved, pointing towards a predominantly psychological impact of TC.

Conclusions: Subjective health increased, stress decreased (objectively and subjectively) during TC practice. Future studies should confirm this observation by rigorous methodology and by further combining physical and psychological measurements with basic research, thereby also gaining knowledge of autoregulation and molecular physiology that possibly underlies mind/body medicine.

key words: **integrative medicine • mind/body medicine • stress • stress management • relaxation • Tai Chi • nitric oxide • cortisol • health**

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BACKGROUND

Stress

The influence of stress on health and well-being, although obvious for some people in our 'stressful' world of these days, seemingly, has long been subject to scientific debate and still is with regard to specific settings and applications [1,2]. Stress is not easy to examine since it depends on the individual's capacities to cope and react in response to challenging external or internal stimuli, i.e., the stressors [3–6]. However, a general impact of stress upon our physiological and psychological health as well as its potentially critical role in disease promotion are now widely accepted and scientifically proven [3,6–8]. In particular, psychosocial stressors seem to be of importance and influential, and here the cardiovascular system appears to be especially sensible to the impact of stress [7,9].

Stress is part of our daily life [3]. Its consideration and integration into modern medical strategies for salutogenesis and prevention has now become urgent and almost indispensable: 60–90% of the medical ailments reported in primary care, i.e., first medical contact, are or may critically be associated with stress and, e.g., about 80% of coronary artery diseases (CAD) are principally avoidable, that is, considered to be preventable solely by life-style change [7,10]. Hence, among the most relevant modifiable risk factors for the heart and the cardiovascular system in general are psychosocial stressors ('mental stress') which account for about 40% of the overall heart attack risk, i.e., risk for myocardial infarction [11,12]. Comparable results for other diseases and medical conditions exist [5,6,8,10]. Thus, various strategies have been developed over the last 20 years to ameliorate the negative 'side effects' of stress, since stress itself is natural and, at times, biologically useful and has, when applied in appropriate situations, e.g., fight or flight, even protective capacities – whereas too much stress or too long periods of it (i.e., overdose) can be detrimental [3,4,13]. It is helpful, therefore, to search for therapies and techniques that help to relief and cope with stress, without necessarily having to avoid or generally eliminate it [13]. These approaches are now termed and characterized as stress management techniques.

Stress management

Stress management approaches consist of various elements that are usually applied in combination with each other and/or in addition to other medical options, i.e, integrative medicine and health promotion [13–15]. Hence, the four regular constituents of professional stress management strategies typically are nutrition ('healthy diet'), exercise, behavior (cognitive behavioral interventions, 'positive psychology') and relaxation, including, for example, meditation, autogenic training, progressive muscle relaxation or mild and 'meditative' movements as part, e.g., of Yoga or Qigong exercises [5,13,15–18]. Additional elements, if not already included in the columns mentioned above, can be social support and spirituality [e.g., 13,15,18–20]. However, a professional stress management clearly relies on scientific evidence and thorough examination, including medical and clinical outcome readings, and therefore each of the columns, as well as their integration into complex stress management approaches, are subject to explicit research and scrutiny which has just recently started to develop in many cases [e.g., 19–21]. A broad array of studies, yet, are weak, show little effects (if any) or contradict other evidence, pointing towards the need of additional studies and further underlining the fact that this area of medical research is still, in parts, at its beginning. However, some areas already exhibit excellent results, including evidence for their clinical efficacy [e.g., 5,22]. Only recently researchers in the field have attempted to integrate and combine scientific evidence from clinical trials with basic research data, thereby substantiating the validity of their results: The combination of physiological and psychological measures, for example, has now boosted scientific interest and effort into this – by nature – predominantly non-pharmacological field.

Mind/body medicine

As it may be a characteristic of a young and growing scientific field, different terms and descriptions of the observed phenomena exist. Thus, not only do we speak of stress management and integrative medicine, as mentioned above, but the related approaches are sometimes also summarized as complementary or mind/body medical therapies [14,18,23]. In fact, this equation makes sense with reference to professional life-style modification and stress management, since these self-care-oriented and 'holistic' strategies involve the whole being, i.e, mind and body (meaning the individual, in whole), and they depend on autoregulatory healing capacities, as they have been described in complementary and classical medicine likewise, also by the use and integration of basic research data [3,23]. Some authors, with regard to stress management and mind/body medicine (MBM), therefore speak of a bio-psycho-socio-molecular model of health [13]. As such, MBM is a holistic approach to health and healing that has recently been shaped by research into stress physiology and stress psychology, including psychoneuroimmunology and -endocrinology, and the salutogenic paradigm described by Antonovsky [24]. MBM seeks to acknowledge physical, psychological as well as social and spiritual aspects of human beings. Considering that a growing number of health issues arises due to maladaptive life-styles, MBM is now identified as a development that supports a shift from increasingly expensive treatments to more cost-effective and preventive approaches [24]. Hence, Tai Chi training, as it lies at the center of this work, is part of the mind/body medical movement, also expressed by the fact that the National Institutes of Health officially name Tai Chi a mind/body technique [13,24]. However, as stated above, evidence is still heterogenous and further studies are needed.

Tai Chi

Tai Chi (also termed Tai Chi Chuan, Taijiquan, or Taiji) is a traditional Chinese martial art that incorporates mild aerobic activity ('exercise'), relaxation, and meditation, all of which are reported to possess positive effects on health, particularly in association with stress-related complaints [5,25–27]. This centuries-old practice is a fusion of Chinese philosophy and arts with healing and traditional Chinese medicine (TCM) [28].

There are five main schools or styles of Tai Chi (TC), each named for the style's founding family: Yang, Chen, Sun, Wu (Jian Qian), and Wu (He Qin) [22]. Though differing in focus on posture and the position of the center of gravity, all styles emphasize relaxation, mental concentration, and

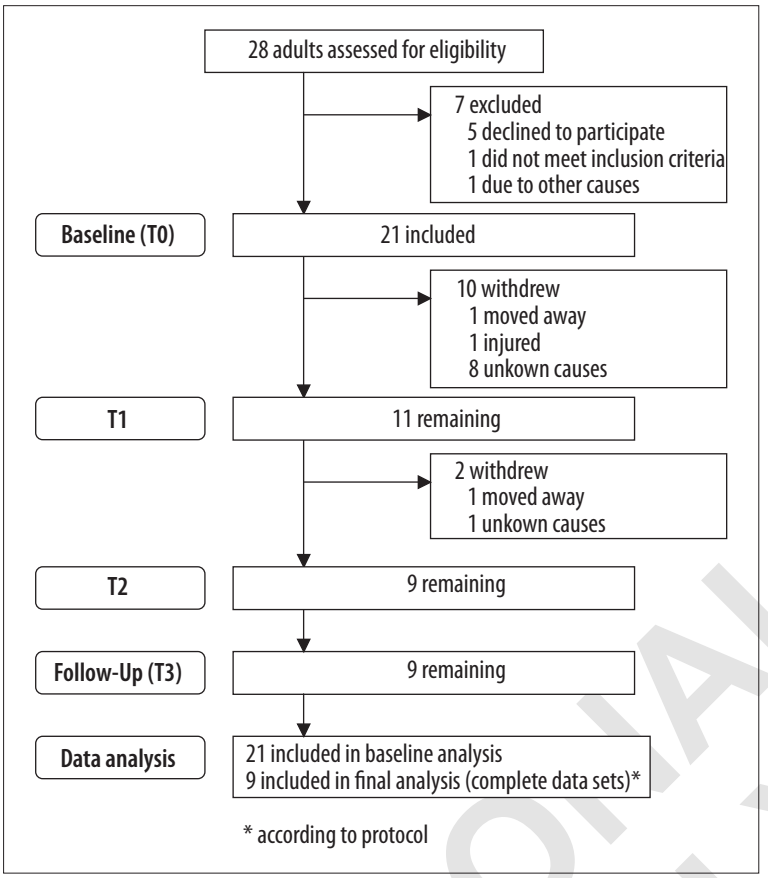


Figure 1. Participant flow. Distribution of subjects in study.

movement coordination, i.e., TC encompasses exercises that promote posture, flexibility, relaxation, well-being, and mental concentration [22,28]. The practice is characterized by slowness of movement, continuity without break or pause, and a focusing of awareness on the moment [22]. Unlike most exercises that focus upon muscular force and exertion, the movements of TC are gentle and light. The active concentration of the mind is instrumental in guiding the flow of the body's movements. Thus, TC is not only a physical exercise, but also involves training the mind, and this has prompted some to consider the practice 'moving meditation' [22]. Although TC follows the principles of other types of martial arts that base on self-defence, its primary objective is to promote health and peace of mind, thereby revealing a close connection with the modern concept of stress management, as illustrated. However, actual medical research examining the assumed health benefits of TC has long separated the field into either physiological or bodily effects on one side and the measurement or description of psychological or mental effects on the other. Moreover, clinical observations were not always correlated with basic research data, leaving a rather scattered picture. This has only recently prompted integrative scientific approaches, combining the different aspects of TC practice and research.

Material and Methods

Study design and participants

This study was a prospective, non-randomized/-controlled pilot trial (longitudinal cohort study) held in Berlin, Germany. In this work, we combined and measured psychological and physiological health parameters in the context of TC practice and their possible association with stress or stress reduction. Thereby, we acknowledged the fact that emotional distress is a growing public health problem and examined the claim that TC may act as a buffer against this distress by inducing sustained stress reduction, i.e., stress management, on a physiological and psychological level: We evaluated potential effects of a Yang style TC program on perceived stress and physiological stress indicators in a beginners program which took place in 2005/06 during one semester/term at the Technische Universität (TU), Berlin. In addition to the longitudinal group design, we had a smaller sample of subjects (random control sample) participating in a cross-sectional analysis/sub-study, i.e., quantitative diurnal cortisol profiles at two time-points, including pre-to-post analysis, to observe more immediate TC effects (e.g., short-term, profile) and also for containment and estimation of proximate effect sizes with regard to stress hormone reduction (cortisol), which may be of help in future study designs.

Approval by the local ethics committee (IRB) at the Charité – Universitätsmedizin Berlin was obtained. Participants enrolled in the program as part and extension of the regular recreation and sports offering at TU. Initial enrolment was an online procedure, thereby generating a random sample (n=28). 21 participants met the inclusion criteria and signed informed consent (Figure 1). None of them had previous experience with TC and all were asked to follow their normal life-styles while the trial was conducted. The participants were physically and mentally healthy, not on regular medi-

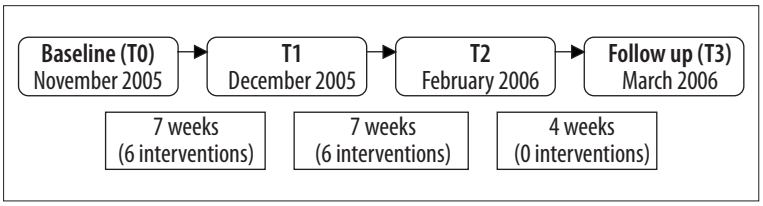


Figure 2. Flowchart. Time course of study.

cation, older than 18 years of age, and screened to exclude those with any pathological condition with the potential of negatively impacting the course of our study.

Intervention

Subjects received TC training once a week, delivered for 90 minutes each by a certified TC teacher from the Yongnian Taijiquan Association Europe (YTAE). In total, 12 sessions/interventions over the course of 14 weeks were offered (Figure 2). YTAE teaches traditional TC under the patronage of Yang Zhen He (5th generation traditional Yang style), meaning Yang style TC according to Yang Cheng Fu and his son Yang Zhen Duo. The teacher chosen for our study had 15 years of experience and was an approved disciple of Yang Zhen He, who himself was educated and trained by Yang Zhen Duo.

The TC training was delivered in a TU-hired sports gymnasium. Each session consisted of a 30 minute warming-up period (breathing and balancing exercises), followed by another 30 minutes of basic TC forms, and finally rounded off by 30 minutes for the teaching and learning of the actual (new) Yang/YTAE forms and figures. In addition, participants were asked to self-train (i.e., practice on their own, meanwhile) selected TC exercises once to twice a day. The attendance as well as the home practice was recorded (not depicted here).

Measurements

Outcome variables were measured four times (T0–T3), as illustrated in Figure 2. TC training was offered over the course of 14 weeks (T0–T2), followed by a four week period without formal guidance (T3, follow-up). Measurements were conducted directly before the start of each TC session (T0–T2), after a 5 minute resting period (sitting position), all at the same point in time (T0–T3) within a minute time frame. There were two categories of variables measured: physiological ('objective') and psychological or self-report ('subjective') markers.

Physiological measures were: Arterial blood pressure, heart rate, and free saliva cortisol. Blood pressure and heart rate are indirect indicators of the sympathetic nervous system (SNS) activity, one of the two major stress axes in the body [6–8,29]. Cortisol is a key player of the second: Free cortisol is an approximate but valid (direct) indicator of a) the general stress/hypothalamus-pituitary-adrenal (HPA) axis activity and b) the momentary physiological stress level [e.g., 25,30]. Due to easy handling and well proven manageability and comparability of data, the free saliva cortisol determination was preferred to the plasma analysis [30–33]. For measurement in our study, the saliva was collected with a 'Salivetten-System' (Sarstedt, Rommelsdorf, Germany), where the subjects chew a cotton wool sponge (dabber) for 30–90 seconds. The dabber was stored in a plastic tube (Sarstedt) and sent to the reference laboratory for analysis (Department of Biological Psychology, Technical University of Dresden, Germany; Prof. Dr. C. Kirschbaum). Note: The diurnal saliva cortisol profile measurements in the sub-study followed a different protocol with five samplings at T0 and T2, respectively: directly after awakening (A), A + 1 hour, A + 4 hours, A + 9 hours, A + 12 hours (reference: John D. and Catherine T. MacArthur Research Network).

Psychological measures/instruments were: The Short Form Health Survey 36 (SF-36), measuring quality of life (QoL) and subjective health status, e.g, physical and mental, postulating QoL being affected by stress or stress perception (i.e., indirect stress indicator) [25,34–36]. Due to international standard procedures, preliminary raw data of this questionnaire were devided into eight dimensions (subscales reaching from 0 to 100, with 0 being the worst and 100 the best state of health, full well-being, accordingly). The eight dimensions were pain (bodily), physical functioning, role-physical, general health perception (these four can be summarized as *physical health measures*), and role-emotional, mental health/psychological well-being, vitality and social functioning (these four can be summarized as *mental health measures*). By transforming the data into dimensional sub-scales, a comparison with a norm/standard, age-adjusted population was possible [34,37,38]. Thus, instead of carrying along an internal control group, we used the German norm population as an external control, i.e., orientation. For this quantitative adjustment (that is, a comparison between our study group and a standard sample), we also calculated the related z-values. Furthermore, for the measurement and quantification of self-reported (i.e., subjective) stress perception, subjects were asked to fill in/check two visual analogue scales (VAS), again ranging from 0 (no stress) to 100 (maximum stress), which consisted each of a line of 10 cm length with marks at both ends ('0' and '100') and no further subdivision [e.g., 39–41]. One scale was used for mental, one for physical perceived stress. Finally, subjects were asked to answer a question regarding significant events in the last 7 days before measurement with yes or no, whereas yes demanded another sub-classification between mild, moderate, and severe. For analysis, intensity was later transformed into numerical values, reaching from 0 (no significant event over the last week) to 3 (severe).

Statistical analysis

We conducted a prospective, longitudinal pilot study for the evaluation of objective and subjective therapeutic/clinical effects and the effectiveness of a TC intervention by measuring physiological and psychological parameters (direct or indirect indicators of stress, stress reduction) in a non-randomized, non-controlled cohort by pre-post comparison and in

Table 1. Characteristics of study participants.

	n/baseline		n/follow-up	
Total	21		9	
Gender				
Male	9		5	
Female	12		4	
Occupation				
Student	16		6	
Working	5		3	
	Mean	**SD**	**Mean**	**SD**
Age in years	27.14	±4.25	27.89 (21–37)	±5.53

SD – standard deviation.

follow-up. Data were acquired from a random sample, i.e., a group of non-selected participants. For statistical analysis of the metric data sets, a two-sided t-test for paired samples (dependent samples) was performed. Before applying the t-test, however, the normal distribution of the data was controlled. In case of a non-normal distribution, the Wilcoxon test (Wilcoxon signed rank test) was used.

The computer-assisted analysis was carried-out with the aid of a professional statistic software program (SPSS). A small sub-group of subjects was additionally tested by cross-sectional analysis (diurnal cortisol measures, pre-to-post) with the objective of providing a random control sample, i.e., these results served as an internal control within the study group. These measures taken at T0 and T2 were compared with each other and processed and diagrammed using MS Excel.

Results

Demographics

Baseline characteristics of the study participants and the finisher group (follow-up subjects who completed all measurements) are depicted in Table 1. Only nine subjects ultimately completed the whole program and the follow-up, i.e., full data recordings, and were thus included in the final data analysis (according to protocol). However, the biggest drop-out already appeared after the initial contact, that is, between baseline (T0) and T1 (Figure 1).

Outcome measures

Summary statistics for the original data are provided in Table 2. The sub-set of diurnal cortisol profiles is depicted in Figure 3, the SF-36 measures are presented in Table 3, Table 4 and Figure 4.

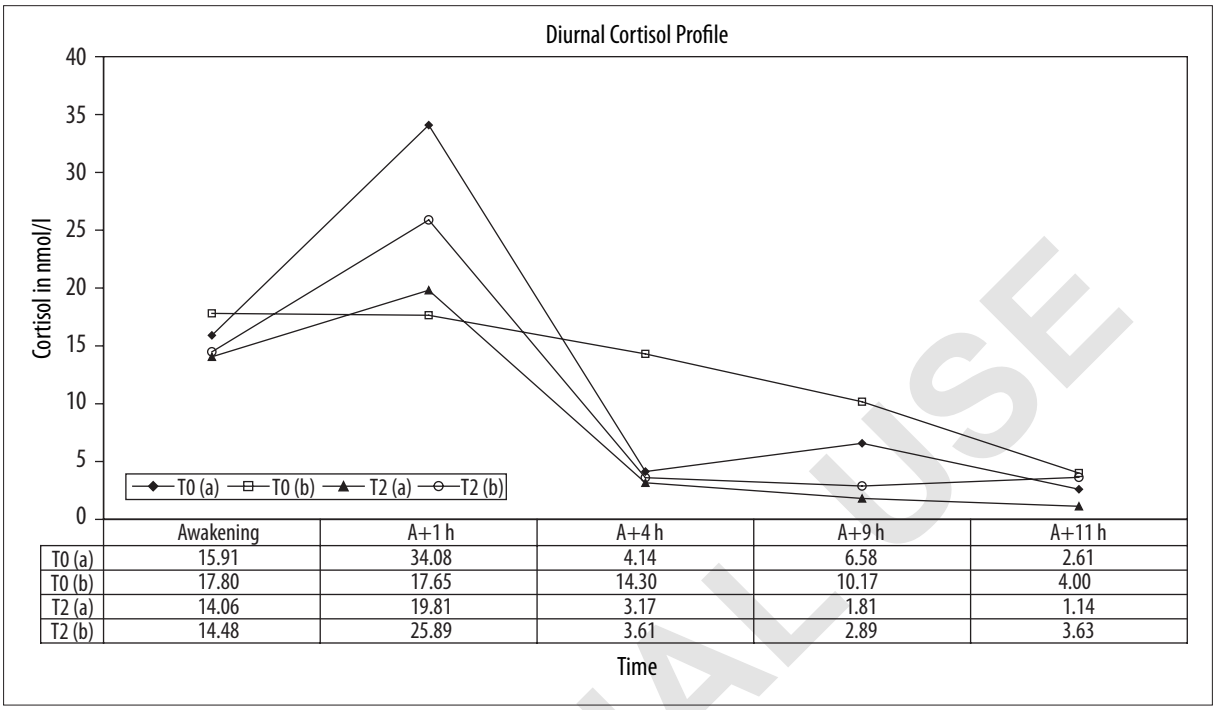
The physiological measurements showed significant ($p<0.05$) reductions of saliva cortisol values in the study group, pre-to-post (T0/T2) and pre-to-follow-up (T0/T3). Other objective or physical markers of stress (blood pressure, heart rate) remained statistically unaltered, i.e., normal. Diurnal stress hormone measures in the sub-sample revealed typical profiles with higher cortisol values in the first hours of the day and a significant drop after four hours, around noon, expectedly. Here, the trend in the post-analysis (T2) is an overall reduction of cortisol values, i.e., down-shifting of the curve, with a putative lowering of peak levels.

The psychological instruments revealed a significant reduction of perceived mental stress, pre-to-post (T0/T2) and pre-to-follow-up (T0/T3), which was even highly significant in the follow-up analysis ($p<0.01$). However, physical stress perception showed no significant changes, although a slight trend towards improvement became apparent (T0–T3). The SF-36 measures showed significant ($p<0.05$) increases in the dimen-

Table 2. Summary statistics of outcome measures (mean values with SD).

	T0	T2	p-value	T2	T3	p-value	T0	T3	p-value
Heart Rate [beats/min] ±SD	69.33 7.21**	70.22 4.52	0.44	70.22 4.52	69.78 6.04	0.88	69.33 7.21	69.77 6.04	0.84
Blood Pressure, systolic [mmHg] ±SD	117.78 9.5	119.44 9.5	0.667	119.44 9.5	117.78 8.70	0.72	117.78 9.5	117.78 8.70	1.0
Blood Pressure, diastolic [mmHg] ±SD	80.56 10.44	80.56 8.82	1.0	80.56 8.82	82.22 4.41	0.667	80.56 10.44	82.22 4.40	0.58
Free Saliva Cortisol [nmol/l] ±SD	5.68 2.84	4.09 3.18	0.046*	4.09 3.18	3.42 2.34**	0.594	5.68 2.84	3.42 2.34**	0.011*
Perceived Stress, mental [0–100] ±SD	64.33 13.35	39.11 28.48	0.026*	39.11 28.48	33.78 21.22	0.668	64.33 13.35	33.78 21.22	0.005*
Perceived Stress, physical [0–100] ±SD	38.22 22.15**	32.89 23.57	0.561	32.89 23.57	24.11 13.89	0.416	38.22 22.15**	24.11 13.89	0.124
Events [0–3] ±SD	1.89 1.08	1.56 1.33	0.563	1.56 1.33	0.67 0.87	0.104	1.89 1.08	0.67 0.87	0.016*

* Significant change (p-value < 0,05); ** non-normal distribution; for SF-36 measures see Table 3 and 4.



	Awakening	A+1 h	A+4 h	A+9 h	A+11 h
T0 (a)	15.91	34.08	4.14	6.58	2.61
T0 (b)	17.80	17.65	14.30	10.17	4.00
T2 (a)	14.06	19.81	3.17	1.81	1.14
T2 (b)	14.48	25.89	3.61	2.89	3.63

Figure 3. Free saliva cortisol. Presented are four diurnal profiles in nmol/l, stemming from two subjects (random sample: a + b), taken at two time-points (T0+T2). Second measure T0/subject b (A+1h) may underestimate real cortisol value due to insufficient (incorrect) soaking of dabber.

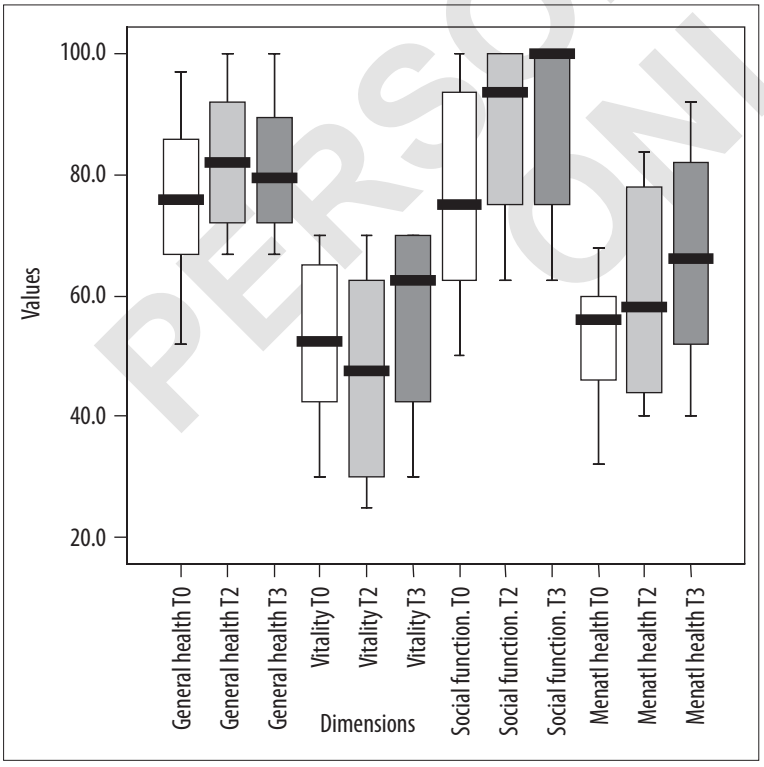


Figure 4. Selected SF-36 dimensions at T0, T2, T3. This figure presents four selected SF-36 dimensional values illustrated in a Box-Whisker-Plot, i.e, boxplot diagram with median and upper/lower quartile (valid n=8). The selection reflects significant changes over the course of the study: general health (p=0.046; T2), vitality (p=0.033; T3), social functioning (p=0.038; T0/T2), and mental health (p=0.017; T0/T3).

sions general health perception (T0/T2), vitality (T2/T3), social functioning (T0/T2, T0/T3), and psychological well-being (T0/T3). Together with a trend to enhancement in role-emotional values, the summarized mental health measures all clearly improved over time. Furthermore, and in face of lack of an internal control group, we consulted external reference data [34] and calculated the SF-36 z-values for the illustration of deviations from the norm, this way using the German age-adjusted norm population as an external control. The initial situation (pre z-values at T0) revealed a statistically normal general

Table 3. SF-36 dimensions in study and norm population.

		Pain	Physical function.	Role-physical	Role-emotion.	Mental health	Vitality	General health	Social function.
	T0								
n	validated*	9	9	9	9	9	9	8	9
Mean		93.33	99.44	86.11	70.37	55.11	52.78	75.88	77.78
Median		100	100	100	66.67	56	55	76	75
	T1								
n	validated*	8	8	8	8	8	8	7	8
Mean		82.25	94.38	84.38	66.67	51.5	45	80.72	73.44
Median		84	100	100	100	58	47.5	82	75
	T2								
n	validated*	8	9	9	9	9	9	9	9
Mean		91.25	99.44	88.89	88.89	63.56	50.56	84	88.89
Median		100	100	100	100	68	55	87	100
	T3								
n	validated*	8	9	9	9	9	9	9	9
Mean		93.88	97.22	83.33	85.18	69.78	58.33	82.89	90.28
Median		100	100	100	100	68	70	87	100
Norm Population (21–30 y, f/m)									
n	valid	483	484	477	478	484	484	482	484
Mean		86.50	95.11	91.86	92.92	74.18	64.93	75.84	91.18
(SD)		(24.56)	(11.79)	(24.55)	(21.21)	(16.93)	(18.55)	(18)	(17.87)

* Adjusted due to missing data in submitted questionnaires; y = years, f/m = female and male.

Table 4. SF-36, z-values.

		Pain	Physical function.	Role-physical	Role-emotion.	Mental health	Vitality	General health	Social function.
T0	z-value*	0.278	0.368	–0.234	–1.063	–1.126	–0.655	0.002	–0.750
T2	z-value*	0.193	0.368	–0.121	–0.190	–0.628	–0.775	0.453	–0.128
T3	z-value*	0.3	0.179	–0.347	–0.364	–0.260	–0.356	0.392	–0.050

* Study population compared with norm population; prefix indicates direction of deflection (quality) and amount specifies value (quantity).

health perception of our cohort, whereas role-emotional and psychological well-being as well as vitality and social functioning scored lower. Over the study, our cohort performed clearly better than the norm population in general health (post and follow-up values), or had increases in role-emotional, psychological/mental well-being, vitality, and social functioning, almost reaching normal levels, eventually. Finally, the monitoring of significant events over the last seven days before each assessment (T0–T3) by means of self-report scales revealed a decrease from T0 to T3. However, mean values (and medians, not depicted here) between T0 and T2 remained relatively stable in the mild to moderate range (1–2), then going down in direction of 'no events' (0–1) in the follow-up measures.

Discussion

TC can be classified as a mind/body technique [18,24,42], and as such it may be of value for stress reduction, i.e., professional stress management [e.g., 5,42]. For estimating the relevance and impact of TC practice on physiological and

psychological markers of stress, we conducted the study on hand, hoping to expand knowledge about TC effects and their sustainability. Hence, we used a four month Yang style TC program for intervention and examined objective and subjective changes over the course of the program, also after a four week 'wash-out' period, i.e, follow-up. In doing so, we found significant improvements in physiological (cortisol reduction) and psychological parameters of stress and health, including subjective stress perception and selected SF-36 measures, all accentuated in the realm of psychological well-being, i.e., mental health.

Strong limitations of this study regard the lack of a regular control group and the high drop-out rate against the background of a restricted sample size of n=28 (initially enrolled) or, more precisely, 21 subjects included in the study group at baseline. However, the unexpected high drop-out already occurred between baseline and T1, indicating an inappropriate or insufficient recruitment (response) of dedicated participants or, more likely, the 'wrong' technique for those people initially enrolled but then dropped-out. This may represent an intrinsic disadvantage of a completely voluntary enrolment, i.e., non-selection of study subjects. Some prospective participants may have come, at first, due to curiosity or a more intellectual interest, and then stayed away because of first practical experiences (T0–T1) or the lack of manifest subjective health/stress problems, e.g., absence of physical and/or psychological strain. We can assume this, although still speculative, by the fact that the group of subjects completing the study and the follow-up measurements remained fairly stable after T1, possibly already experiencing improvements by themselves, which would have been highly motivating. Also, the participants who dropped-out were predominantly students, maybe of good health (i.e., perceived health), or having other priorities and interests. With reference to the missing control group, we tried to make up for this limitation by introducing an external control (i.e., the comparison with an age-adjusted standard population) as well as the additional realisation of a small cross-sectional sub-study, serving as an internal random control sample. Hence, future studies should certainly emphasize regular randomisation and control procedures on the basis of a sample that is large enough for doing so, which has to be achieved by different recruitment strategies. Furthermore, a selection of participants due to characteristics that still need to be specified may be helpful in future, e.g., to enhance adherence/compliance and reduce drop-out rates. This specification itself, i.e., the description of 'TC responders' (by interest and by changes in health parameters), can be an interesting additional approach for future mind/body medical research and care. Finally, TC has been shown to produce positive health effects in the elderly [e.g., 22,26,28], leaving open the question whether the same applies to younger subjects, as in our study.

In spite of their limitations, our data show some interesting results. For example, the initial situation (SF-36 values/z-values at T0) revealed a normal general health perception of our cohort, whereas role-emotional and psychological well-being as well as vitality and social functioning scored lower. Thus, our study population may have been emotionally stressed, i.e., distressed, which is in line with our initial assumption and would be an appropriate setting to test TC for reducing stress. Interestingly, students in the study cohort had their regular exams around T2 (and some T3) with even higher levels of distress, expectedly, therefore making it more likely that the results observed, e.g., with regard to reduced mental stress perception, are real. Mean values, however, for significant/stressful events remained stable pre-to-post, then going down in the follow-up measures. We don't know if these results already reflect a positive effect of TC training or, particularly with regard to the strong decrease at T3, a reduction in obligations (e.g., exams), as mentioned for some students between T2 and T3. A control group, again, would have helped here. Hence, we also found a tendency for normalisation of the SF-36 values (mentioned above), as well as an increase – way above normal – in general health perception. Thus, although being 'normal' at start, our subjects performed explicitly better than the norm population with reference to general health or had remarkable increases when initially inferior to the norm, i.e., lower pre values for role-emotional, psychological well-being, vitality, and social functioning, again pointing towards a predominantly psychological effect of TC training, apparently, or indicating a tendency for regression to the mean/norm. In fact, the physiological (objective) measures only showed significant reductions in saliva cortisol, which occurs to be a sensible marker of the postulated TC effects in young and healthy adults. However, other putative physiological markers of stress (blood pressure, heart rate) remained unaltered, i.e., in the normal range.

With regard to the diurnal cortisol profiles, as determined in the sub-study, the trend here, too, was a general reduction of values, while the typical diurnal shape of the cortisol release curve was maintained. Clearly, these raw and non-significant data are preliminary and should be dealt with great care. However, possible effect sizes of a TC training over a couple of weeks and with reference to physiological stress hormone reductions can be estimated for future studies.

The SF-36 mental health measures as well as the mental stress perception (VAS) all improved, pointing towards a distinct psychological effect of TC training, particularly when the more or less stable physical parameters are taken into account, with the exception of cortisol (as mentioned above), which – more generally – seems to be an appropriate and sensible indicator of the underlying autoregulatory physiology, e.g., stress reduction. This is in consistence with other studies [6–8,25,33]. Thus, the perception and subjective experience of better emotional/psychological health and well-being during TC practice may reflect a reduction in emotional distress, as assumed, whereas approximate markers of objective health status may remain stable. However, the physical parameters (blood pressure, heart rate) already were in the normal range before TC training started, i.e., physically healthy subjects, presumably, thus changes could not necessarily be expected, which has to be considered. Moreover, the perception of physical stress (VAS), which also improved in direction, and the physical health measures of the SF-36 questionnaire (which stayed more or less stable) are still subjective by nature, that is, self-report items, making it necessary for future studies which integrate objective and subjective measures likewise to exactly discriminate the different domains of health (i.e., mental, psychological and physical, physiological, etc.). Furthermore, it appears to be useful, if possible, to precisely examine and specify the objective health status (pre and post) by more

differentiated medical means and sophisticated scores, including indicators of physical stress. Thereby, it will be possible to better classify or estimate objective and subjective changes, in health as well as stress, with the additional benefit of being able to distinguish subjective/perceived physical from mental effects, which is a rather complex undertaking. Certainly, higher numbers of study subjects and a control group would be of help.

Finally, the presented study can not distinguish between specific and non-specific TC effects, since TC was the only intervention examined. However, previous studies suggest that mind/body techniques have a strong non-specific component, i.e., placebo effect [23,42–45]. We surmised before that a crucial component of health effects observable in mind/body medicine and stress management strategies (as well as in various complementary medical procedures) is associated with endogenous autoregulatory signalling mechanisms linked to the brain's innate reward and motivation circuitries, i.e., limbic system [e.g., 14,23,43]. These circuitries get stimulated, for example, when one engages in pleasurable and 'self-paying' activities which enhance feelings of control and self-efficacy, possibly involving positive expectations for a beneficial therapy outcome, i.e., trust and belief [44,45]. Recently, some of the molecular key players for this endogenous health promoting potential, e.g., general autoregulatory self-healing mechanisms possibly also accounting for some of the reported effects in our study, and in others, have been detected: Nitric oxide (NO), endocannabinoids, and endogenous morphine [e.g., 23,43–48]. Future TC and mind/body studies should therefore not only consider the methodological points mentioned above, but further continue to integrate basic research aspects to more precisely specify the underlying physiology, discriminate the effects, and learn better about coupled autoregulatory and molecular phenomena.

CONCLUSIONS

TC appears to be an effective mind/body technique that predominantly works on psychological indicators of stress and health, i.e., mental health. Accordingly, TC is an appropriate candidate for integrative stress management options and related research. TC combines mild exercise with elements of relaxation and meditation, and in this process, with regard to the underlying physiology, autoregulatory signalling pathways may play a significant role. Such pathways are represented in the brain by limbic reward and motivation circuitries. However, since TC was the only intervention examined, we cannot distinguish between specific and non-specific (i.e., placebo, positive expectation) TC effects, the latter of which we expect to be of critical importance due to prior investigations. Modern methods, e.g., for the real-time analysis of stress and signalling molecules like cortisol and nitric oxide, will be of help in the future. The salivary cortisol method that we used in this study already proved to be useful, manageable, and indicative of a general stress reduction. Furthermore, these basic research findings should be related to subjective and objective clinical TC effects, as observed here. In this way, it will be possible to effectively discriminate the various aspects of TC practice, i.e., mental, physical, physiological, psychological, etc. Also needed is a specification of appropriate subjects, indications, settings, types and styles as well as a determination of suitable doses for the practical application of mind/body techniques such as TC. Finally, TC and other medical techniques that claim to base on self-care and innate healing capacities have to scientifically prove their efficacy, i.e, beneficial health outcomes, substantiated by molecular findings, to find their place not only in medical wellness and health promotion, but also in illness and therapy.

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