Muscular tension significantly affects stability in standing posture

Simone Tassani[1*], Josep M. Font-Llagunes[2], Miguel Ángel González Ballester[1,3], Jérôme Noailly[1]

1 Universitat Pompeu Fabra, Barcelona MedTech, Barcelona, Spain.

2 Universitat Politècnica de Catalunya, Department of Mechanical Engineering and Biomedical Engineering Research Centre, Barcelona, Spain

3 ICREA, Barcelona, Spain.

*Corresponding author: simone.tassani@upf.edu

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Abstract

Background:

Muscular co-contraction is a strategy commonly used by elders with the aim to increase stability. However, co-contraction leads to stiffness which in turns reduces stability. Some literature seems to suggest an opposite approach and to point out relaxation as a way to improve stability. Teaching relaxation is therefore becoming the aim of many studies letting unclear whether tension or relaxation are the most effective muscular strategy to improve stability. Relaxation is a misleading concept in our society. It is often confused with rest, while it should be addressed during stressing tasks, where it should aim to reduce energetic costs and increase stability. The inability to relax can be related to sub-optimal neuro-motor control, which can lead to increased stresses.

Research Question:

The objective of the study is to investigate the effect of voluntary muscle contraction and relaxation over the stability of human standing posture, answering two specific research questions:

1. Does the muscular tension have an impact on stability of standing posture?
2. Could this impact be estimated by using a minimally invasive procedure?

Methods:

By using a force plate, we analysed the displacement of the center of pressure of 30 volunteers during state of tension and relaxation in comparison with a control state, and with open and closed eyes.

Results:

We found that tension significantly reduced the stability of subjects (15 out of 16 parameters, $p<0.003$).

Significance:

Our results show that daily situations of stress can lead to decreased stability. Such a loss might actually increase the risk of chronic joint overload or fall. Finally, breathing has direct effect over the management of pain and stress, and the results reported here point out the need to explicitly explore the troubling fact that a large portion of population might not be able to properly breath.

Keywords:

Stability, postural analysis, muscular tension, muscular relaxation

1 Introduction

Muscular tension, or co-contraction, is reported in the literature as a strategy commonly used by elders, or subject at fall risk, to increase stability [1–3]. It is already known that during everyday life, sets of sub-optimal neuro-motor control strategies are used for postural control [4]. It was shown that elders have different stiffness than young adults, and how stiffness tends to increase in elder subject which experienced a fall [3]. However, this strategy leads to increased stresses and higher energy costs [4], and, ironically, can lead to reduced stability [1,2].

Muscular co-contraction can also be related to pathological situations [5] to states of physical or mental stress [6], or simply to the inability to relax [7]. States of psychological stress can lead to prolonged contraction of trapezoid muscles and of the pelvic floor [8–11] and in severe cases, stress can be somatised as continuous states of muscular contraction of the shoulders and of the gluteus and can lead to development of several chronic musculoskeletal pathologies (e.g., lower back pain, shoulder pain, headache) [6,12].

Accordingly, teaching how to relax is becoming the aim of many studies, and several oriental disciplines like Tai Chi, QiGong and Yoga are increasingly used in clinical trials to teach subjects how to breath and relax [13–15]. They are often used for prevention or management of different pathologies [16–19] including, but not limited to, musculoskeletal [20,21], respiratory [22] and cardiovascular [23] problems, or pain [24]. A revision of the literature indexed on Pubmed, looking for the keywords Tai Chi, or TaiChi or Taiji in title or abstract, showed how publications regarding this topic passed from few tens in the 90´s to hundreds in the last 5 years (Figure 1).

While the concept of mechanical stability is quite clear (e.g., ability to stay close to an equilibrium position regardless of external perturbations), the concept of relaxation can be misleading in our society. Relaxation is often associated to a state of mind, or to the possibility to lie down and rest. However, rest and relax are two different concepts. Rest aims to restore our energy after stressing tasks, and it is a fundamental part of our life (e.g. sleeping). In contrast, relaxation stands for what we should do during stressing tasks in order to reduce the energetic cost. In terms of physical activity, the higher the stress, the most important it is to relax, to avoid waste of energy and improve joint mobility, e.g., it is important to relax during weight lifting in order to optimize the direction, magnitude and distribution of stresses and, at the same time, increase stability [25].

From a biomechanical point of view, the idea of relaxation can be seen as a situation of minimum energy necessary to perform a specific task, for instance standing.

Therefore, even if co-contraction seems to be the preferred reaction of subjects under stress to increase stability, literature might suggest an opposite result and actually points relaxation as a way to improve stability.

Accordingly, the objective of the present work is to investigate the effect of voluntary muscle contraction and relaxation over the stability of human standing posture. In order to address this objective, we defined two specific research questions:

1. Does the muscular tension have an impact on stability of standing posture?
2. Could this impact be estimated by using a minimally invasive procedure?

2 Methods

2.1 Subject Recruitment

Thirty subjects between 20 and 45 years of age were recruited, 15 men and 15 women. All subjects were in healthy condition and an informed consent was obtained from all of them. The experimental protocol was approved by the Ethical committee of Hospital Universitari Mútua de Terrassa, Barcelona, Spain.

2.2 Data Collection

The statokinesigram of each subject was acquired according to typical guidelines for stability measurements [26]. Foot-ground contact forces were recorded by using a force plate (AMTI Accugait, Watertown, USA, 100Hz sampling). Subjects were asked to stand on the force plate barefoot for at least one minute and were instructed to keep the feet approximately at the distance of the hips but with no further explicit directive, in order to avoid forced postures at baseline. They performed the exercise, first looking at a target painted on the wall, approximately at the height of the eyes, and secondly with closed eyes. The stability of each subject was analysed under three different states: control, tense and relaxed states and with both open eyes and closed eyes (total 6 measurements).

Control-state aimed to simulate standard daily situation and subjects were simply asked to stand over the force plate according to the aforementioned descriptions, without any additional information. **Tense-state** was simulated through isometric contraction of the body muscles (i.e., without articular movement) with particular attention to the gluteus, perineum and neck/shoulder muscles. Additionally, subjects were asked to keep thoracic breathing. These manoeuvre aimed to produce muscle co-contraction in regions of the body influencing posture and breathing [27,28] and more prone to muscular pain and degenerative musculoskeletal disorders (i.e., shoulder/neck and lumbar area) [8–12]. After the tense analysis, subjects were guided through a few exercises to relax the joints and the perineum:

- Neck: Turn the head left and right, up and down, left right looking forward, make circles clockwise and counter-clockwise, all repeated three times
- Shoulder: Three half circles that consisted in shoulder elevation combined with shoulder abduction followed by sudden shoulder fall. The circles were then repeated by substituting shoulder abduction by shoulder adduction.
- Hips: Six large circles with the hips clockwise and counter-clockwise

- Ankles: Fix the toes on the floor and make three circles clockwise and counter-clockwise per each ankle
- Breathing: Deep diaphragmatic breathing. To help the volunteers understanding deep breathing, the researcher was keeping one hand over the abdomen and one over the back of the subject. This assistance was not given during the actual measurement.
- Perineum: First contract and relax the sphincter of the anus and feel the movements of the perineum. Secondly the subject was instructed to relax the sphincter while deep breathing and feel how the perineum was stretching.

Relaxed-state during the statokinesigram acquisition was then simulated by asking subjects to relax the whole body with particular attention to the gluteus, shoulders and perineum the respective contractions of which influence posture and breathing [27,28]. The volunteers were also asked to perform deep abdominal breathing. The whole procedure was repeated three times in three different days.

Sixteen different parameters were computed per subject and per acquisition to study the displacement of the centre of pressure (COP). They were divided into four main groups:

1) *Time-domain Distance Measures*: parameters associated with either the displacement of the COP from the central point of the statokinesigram, or the velocity of the COP.
2) *Time-Domain Area Measures*: statistically based estimates of the area enclosed by the statokinesigram.
3) *Time-Domain Hybrid Measures*: parameters based on a combination of distance measures.
4) *Frequency Domain Measures*: characterize the frequency distribution of the displacement of the COP.

Full list of the parameters is given in Table 1. Full description of the aforementioned parameters is given in the literature [29]. To avoid transition artefacts, the measurement of the COP started 10 seconds after the subject had adopted the standing position on the force plate. Increased values for time and frequency domain parameters suggest an increased energy cost and a reduced stability [30].

2.3 Statistical Analysis

Due to the effect of multiple testing (16 dependent variables analyzed), management of the statistical error was necessary. Significance level for the multiple testing was computed in order to maintain an overall accuracy of 95%.

$$(1-\alpha)^n = 0.95$$

where 'n' is the number of repeated tests and α is the significance level to compute.

$$\alpha = 1 - \sqrt[16]{0.95} = 0.003$$

Therefore, each statistical test was carried out at a significance level of 0.003 [31]. The distribution of each studied parameter was preliminary evaluated and was deemed to be normal (Kolmogorow-Smirnov $p>0.003$). Therefore, parametric tests were implemented.

The statistical analysis was performed in two consecutive steps:

2.3.1 ANOVA analysis

A three-factors ANOVA for repeated measurements was performed to study the influence of the three analysed factors [32]: **repetition** over time, **eyes** and **state**. The factor repetition had three levels (first, second and third acquisition), the factor eyes had two levels (open and closed) and the factor state had three levels (control, tense and relaxed). Using this analysis, factor influences and interactions were analysed. ANOVA for repeated measurements was used to compare each subject against him/herself in the different repetitions.

For each of the three factors different null hypotheses (H_0) were formulated and tested:

a) **Repetition**: H_0 was to have no learning curve, i.e., subjects' performances would remain statistically not different along the three acquisitions [33]. In case of confirmed H_0, parameter values measured for each subject would be averaged over the three repetitions for the next phase of the analysis. Otherwise, separate analysis should be performed for the different time repetitions.

b) **Eyes:** H_0 was to have no difference between the two levels, i.e., subjects perform equally with open or closed eyes. We expected this hypothesis to be false [34], and should H_0 be rejected, only the measurements taken with closed eyes would be further analysed to achieve an optimal expression of subjects' proprioception. In case of H_0 acceptance, all the measurements would be pooled for the next steps of the analysis.

c) **State:** H_0 was to have no difference among the three different states, control, tension and relaxation. If rejected, the next step of the analysis would focus on the differences among states.

A full factorial analysis was performed to evaluate possible interactions among the factors repetition, eyes, and state; i.e. to evaluate whether the influence of one factor is constant, or changes when other factors vary.

2.3.2 Paired analysis of the levels

The aim of the study is to evaluate the effect of tension and relaxation states over stability. Depending on the results of the three-factors ANOVA, data were arranged as previously described to perform a paired t-test of all the significant parameters and compare the control state against the tense and the relaxed ones.

3 Results

3.1 Descriptive results

Average age of the recruited subjects was 31±6 years. Each of the 30 subjects underwent 6 acquisitions repeated at 3 different time points. None of the subjects was lost during the study and altogether, 540 measurements were collected. All the subjects concluded the 3 acquisitions in 18±10 days, and none had problems to interpret and perform the tense state. In contrast, 8 subjects (7 females and one male) found it impossible or very difficult to perform abdominal breathing during the relaxation state. Other 10 (7 males and 3 females) were able to breath using the abdomen, but only partially or keeping high level of concentration during the task.

3.2 ANOVA Analysis

The ANOVA analysis rejected any influence of the **repetitions** over time: there were no detectable learning curves. Influences were rejected both as single factor and in form of interaction. Results were averaged over the three repetitions for the next steps of the analysis. Conversely, the factor **state** statistically affected all the parameters. The factor **eyes** influenced 7 out of 16 parameters, and two parameters were affected by the interaction between eyes and state**.** All results are reported in Table 2.

Closing eyes increased both time and frequency domain parameters (Table 3). Since open and closed eyes measurements were statistically different, only closed eyes values were considered in the second and third steps of the analysis.

3.3 Interaction interpretation

No interactions were found between the factor **repetitions** and the other two factors. The interaction between the factors **eyes** and **state** influenced two different parameters, MFREQ and FD-CE, and appeared to be quadratic for both parameters (quadratic effect p-value<0.0001 -Figure 2). As already mentioned, closing eyes increased both time and frequency domain parameters, but as showed in Figure 2 Figure 1, this effect was not constant and was reduced in relaxed state.

3.4 Paired analysis of the levels

A paired analysis was performed to compare the *control* **state** to the *tense* and *relaxed* ones. Results showed how tension increases the required energy of standing position in 15 out of 16 parameters (*Table 4*). Both time and frequency parameters increased from control to tense state. Relaxation resulted statistically different from control only for one parameter, i.e. mean frequency.

4 Discussion

The main aim of this study was to measure and evaluate the effects that states of tension and relaxation have over standing posture. Two specific research questions were formulated and answered during the study. In fact, it was verified that states of muscular tension can have an effect on the standing posture, and this impact can actually be estimated by using a minimally invasive procedure. To the authors' knowledge this is the first attempt to focus the study of stability on the influence of tension and relaxation. The major outcomes are discussed in this section.

4.1 ANOVA Analysis

The ANOVA analysis allowed to examine three factors and their interdependences, known as interaction, using only one test.

The effect of **repetitions** over time was confirmed to be negligible as suggested by the literature [33]. Furthermore, the factorial analysis revealed that the influence of repetitions over the other factors was negligible as well, excluding therefore any effect of the repetitions over the whole study. In contrast, **eyes** had effects on stability. The feedback given by sight helps adjusting the posture and provides smoother adjustments compared to the use of proprioception only [34]. Removing this feedback, the stability decreases, as reflected by the increase of 7 out of 16 parameters (Table 2 and Table 3),

However, this effect proved to be non-constant over the different states. A significant parabolic interaction was found for two of the analysed parameters: MFREQ and FD-CE. This result showed that stability of the subjects actually decreased less in relaxed states, suggesting that relaxation improves proprioception and increases stability in absence of sight.

In general, the factorial analysis pointed out the effects of tension and relaxation over the stability of the subjects. All the analysed parameters showed statistical significance of the **state,** confirming an effect of this factor that cannot be confused with noise or chance.

4.2 Paired analysis of the levels

In order to understand the effect of the different states on postural control, we run a paired analysis to compare the control state to relaxed and tense ones. Tension showed statistically increasing effect over the values of 15 out of 16 parameters. Not only had the values increased in a statistically significant way, but also absolute tension values were often twice the control ones. All the parameters used in this study belonged to 4 groups of measurements: Time-domain Distance Measures, Time-Domain Area Measures, Time-Domain Hybrid Measures and Frequency Domain Measures. The obtained results suggest that in situation of tension all the subjects showed longer and faster oscillations over a larger area and involving higher frequencies. The increase that all these parameters showed is a sign of reduced stability related to a situation of tension.

On the other hand, results related to relaxation are less sharp. Only the Mean Frequency (MFREQ), the rotational frequency of the COP if it had travelled the total excursions around a circle with a radius of the mean distance, showed a statistically significant reduction compared to controls. The decrease of this parameter might suggest a slower oscillation of the COP and actually an increased stability in relaxed state. Nonetheless, all the rejected comparisons had a statistical power smaller than 0.8 and often smaller than 0.5, suggesting the possibility of type II errors, i.e. small differences that require larger sample size to be detected. These results could suggest that standing position is already a nearly optimized posture under daily conditions and, therefore, with little differences between control and relaxed states.

However, other two parameters (MDIST and AREA-CE) showed a p-value very close to significance ($p=0.005$ against a significance level of 0.003) and values increased compared to the control ones, suggesting a bigger distance from the COP and a bigger area of the ellipse enclosing the points of the COP. These measurements might signify larger oscillations and thus a decreased stability. These contradictory results might be related to the difficulties that many subjects had with breathing during the relaxation phase. Eighteen out of 30 subjects experienced problems (10) or complete inability (8) to perform abdominal breath. This result was unexpected and motivates further studies with larger sample size and robust quantitative measurements of thoracic and abdominal breath. Confirming the influence of abdominal breath would pave the way to tackle important questions about the effective ability of young subjects to relax [7]. In fact, deep breathing is a very important step in the relaxation procedure [13,35,36], and the inability to perform it correctly can lead to a state of constant tension, with all the related psychological and physical problems.

4.3 Limitations

The main limitation of the study is related to the difficulty to objectively assess relaxation of the subjects. During the study, several subjects showed unexpected difficulties in deep diaphragmatic breathing, which could have affected their ability to relax, and therefore, the results of the analysis control vs. relaxation. Hence, relaxation might have to be analysed through more sophisticated techniques, for instance including a cardiovascular monitoring system [37], or breathing monitoring [38].

A second limitation is related to the number of parameters analysed. Other studies suggest the additional relevance of medio-lateral and anterio-posterior component of the COP in the assessment of stability [34,39–41] that were not analysed in this study due to limits related to statistical power. However, our approach and the use of error correction guaranteed a global error of 5% for the global results of the study, while the majority of the studies in the literature avoid to face this statistical problem [30,34,39,40,42]. This is actually a limitation that makes it difficult to compare our results to the literature. For instance, avoiding correcting the statistical error in the present study would have led to a global accuracy of the study of about 44% instead of 95%, i.e. almost random results. For this reason, ignoring error correction can potentially invalidate many published results [43] while correcting the error of the analysis is a good way to ensure reliability and accuracy of the results.

5 Conclusions

In this work, the influence of neuro-muscular tension over postural stability during standing was proven, suggesting a relation between stability and relaxation. Reasons of tension leading to muscle co-contraction in everyday life are many, including stress and fear. Fear of pain in subjects with osteoarthritis, or fear to fall in old subjects or subjects with a previous experience of fall, can induce an increased state of tension and lead to decreased stability and stiffer movements. In turn, body stiffness, as observed in elders, might increase the chance of fall of the subject. This hypothesis is in line with the literature reporting a postural strategy of muscle co-contration in elder subject, leading to stiffening of the body [2].

Few unclear differences were found between control and relaxed states, suggesting the necessity of a more objective definition of relaxation and probably a larger sample size to explore smaller differences with higher statistical power. Breathing has direct effect over the management of pain and stress [14,35,36], the fact that a large portion of young population might not be able to properly breath is troubling and should be further investigated.

Musculoskeletal somatization of psychological stress is known in the literature for both adolescents [12] and adults [6], and while physical exercise and cognitive behavioural therapy are first line treatment in the management of musculoskeletal pain [44], further studies related to breathing might be necessary. In this sense training based on relaxation, like Tai Chi, can help to manage tension and fear in subjects at risk.

Declarations of interest: none

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Figure Legends

Figure 1 **Number of publications per range of years found on Pubmed**. Keywords Tai Chi, or TaiChi or Taiji were searched in title or abstract.

Figure 2 **Influence of closed eyes over the different states.** The influence of closed eyes plays a different role in the different states. Interaction between eyes (blue closed, green open) and state (Control, Relax and Tense) is shown for MFREQ (a) and FD-CE (b). Interaction is shown in relation to the relaxed state.

Tables

Measure	Unit	Description
Time-domain distance measures		
MDIST	mm	represents the mean distance from the mean COP
RDIST	$mm^{1/2}$	root mean square of the mean distance
TOTEX	mm	the total excursions of the COP path
MVELO	mm/s	Mean Velocity of the COP
Time-Domain “Area” Measures		
AREA-CC	mm^2	models the area of the statokinesigram with a circle that includes approximately 95% of the distances from the mean COP, assuming that the distances are normally distributed
AREA-CE	mm^2	is the area of the 95% bivariate confidence ellipse, which is expected to enclose approximately 95% of the points on the COP path
Time-Domain “Hybrid” Measures		
AREA-SW	mm^2	Sway area estimates the area enclosed by the COP path per unit of time
MFREQ	Hz	Mean Frequency is the rotational frequency of the COP if it had travelled the total excursions around a circle with a radius of the mean distance
FD	AD	fractal dimension is a measure of the degree to which a curve fills the metric space which it encompasses
FD-CC	AD	Fractal dimension CC is based on the 95% confidence circle previously described
FD-CE	AD	Fractal dimension CE models the area of the statokinesigram with the 95% confidence ellipse
Frequency Domain Measures		
PRD	W/Hz	spectral power density
F50	Hz	50% Power frequency is the frequency below which 50% of the total power is found
F95	Hz	95% power frequency is the frequency below which 95% of the total power is found

CFREQ	Hz	centroidal frequency is the frequency at which the spectral mass is concentrated
FREQD	AD	Frequency dispersion measure of the variability in the frequency content of the power spectral density.

Table 1 ***Brief description of the 16 parameters used****. NOTE: mm, millimetres; s, seconds; Hz, Hertz; AD, adimensional; W, Watt.*

Factors	MDIST	RDIST	RANGE	MVELO	AREA-CC	AREA-CE	AREA-SW	MFREQ	FD	FD-CC	FD-CE	PRD	F50	F95	CFREQ	FREQD
Repetition	.988	.904	.706	.141	.776	.774	.585	.098	.070	.080	.131	.322	.090	.109	.084	.063
Eyes	.265	.287	.017	**.000**	.590	.143	.004	**.000**	**.000**	**.000**	**.000**	**.000**	.011	.033	.051	**.003**
State	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**	**.001**	**.000**	**.000**	**.000**	**.002**
Repetition * Eyes	.438	.417	.300	.800	.321	.206	.383	.374	.466	.597	.617	.251	.308	.827	.712	.227
Repetition * State	.943	.971	.988	.409	.793	.514	.745	.055	.030	.061	.042	.413	.099	.011	.008	.315
Eyes * State	.004	.024	.694	.004	.486	.093	.113	**.000**	.125	.007	**.000**	.022	.612	.168	.523	.455
Repetition * Eyes * State	.046	.084	.718	.718	.133	.258	.556	.130	.844	.288	.202	.845	.752	.940	.908	.930

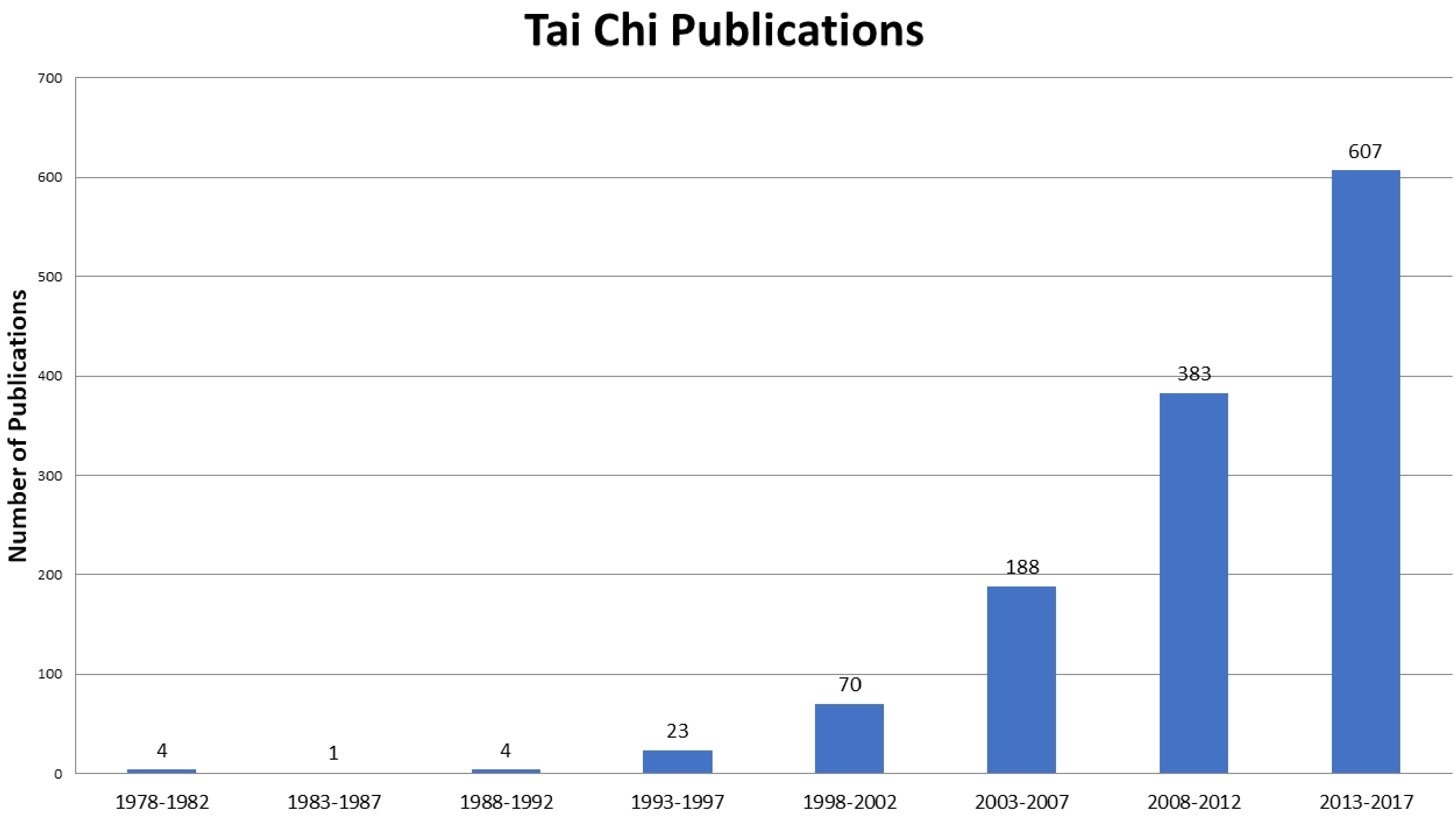
Table 2 ***Results of the three factors ANOVA for repeated measures****. Differences were deemed to be significant for p<0.003. Significant values in* ***bold.***

		Open Eyes		Closed Eyes	
Condition	Parameter	Mean	Std. Deviation	Mean	Std. Deviation
Control	MVELO [mm/s]	6.81	1.81	8.07	2.28
	MFREQ [Hz]	.24	.08	.30	.12
	FD [-]	1.45	.07	1.48	.08
	FD-CC [-]	1.55	.09	1.61	.11
	FD-CE [-]	1.61	.09	1.67	.12
	PRD [W/Hz]	8869	5108	12996	7872
	FREQD	.78	.03	.78	.04
Relax	MVELO [mm/s]	7.01	1.79	8.60	2.23
	MFREQ [Hz]	.24	.08	.26	.09
	FD [-]	1.44	.07	1.46	.07
	FD-CC [-]	1.55	.09	1.57	.10
	FD-CE [-]	1.62	.10	1.63	.10
	PRD [W/Hz]	15178	25826	20507	28389
	FREQD	.79	.02	.78	.03
Tense	MVELO [mm/s]	12.96	5.48	15.74	7.39
	MFREQ [Hz]	.33	.12	.39	.13
	FD [-]	1.51	.08	1.55	.09
	FD-CC [-]	1.64	.12	1.70	.12
	FD-CE [-]	1.68	.11	1.74	.12
	PRD [W/Hz]	20535	15264	29436	21897
	FREQD	.77	.03	.76	.05

Table 3 ***Descriptive statistics.*** *Mean and Standard deviation values for parameters that showed statistical difference between open and closed eyes.*

	Condition									
	Control		Tense		Control-Tense		Relax		Control-Relax	
Parameters	Mean	Std. Deviation	Mean	Std. Deviation	p-value	Power	Mean	Std. Deviation	p-value	Power
MDIST	4.85	1.71	6.66	2.20	**<.003**	.974	6.01	2.19	.005	.745
RDIST	5.69	1.99	7.74	2.55	**<.003**	.977	6.96	2.57	.008	.371
RANGE	30.44	9.61	43.19	13.78	**<.003**	1.000	34.92	13.00	.034	.182
MVELO	8.07	2.10	15.74	6.83	**<.003**	.998	8.60	1.99	.056	.516
AREA-CC	351	278	617	424	**<.003**	.847	515	438	.050	.140
AREA-CE	237	188	493	360	**<.003**	.982	331	249	.005	.521
AREA-SW	11.32	6.58	34.54	26.90	**<.003**	.939	14.45	7.51	.013	.302
MFREQ	.30	.10	.39	.11	**<.003**	.929	.26	.08	**.003**	.527
FD	1.48	.07	1.55	.08	**<.003**	.991	1.46	.06	.088	.775
FD-CC	1.61	.10	1.70	.11	**<.003**	.529	1.57	.09	.009	.500
FD-CE	1.67	.10	1.74	.10	**<.003**	.833	1.63	.09	.017	.529
PRD	12996	6695	29436	18297	**<.003**	.994	20507	21819	.056	.507
F50	.37	.07	.43	.12	**<.003**	.619	.36	.06	.428	.020
F95	1.27	.30	1.58	.40	**<.003**	.975	1.18	.28	.021	.501
CFREQ	.56	.12	.68	.17	**<.003**	.970	.51	.12	.008	.014
FREQD	.78	.33	.76	.04	.025	.622	.78	.02	.766	.766

Table 4. **Paired comparison.** p-values of the comparison among the reference value (control) and the state of tension and relax. Differences were deemed to be significant for p<0.003. Significant values in bold. Power values were calculated using the free-to use software G-Power.


Tai Chi Publications
Number of Publications
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200
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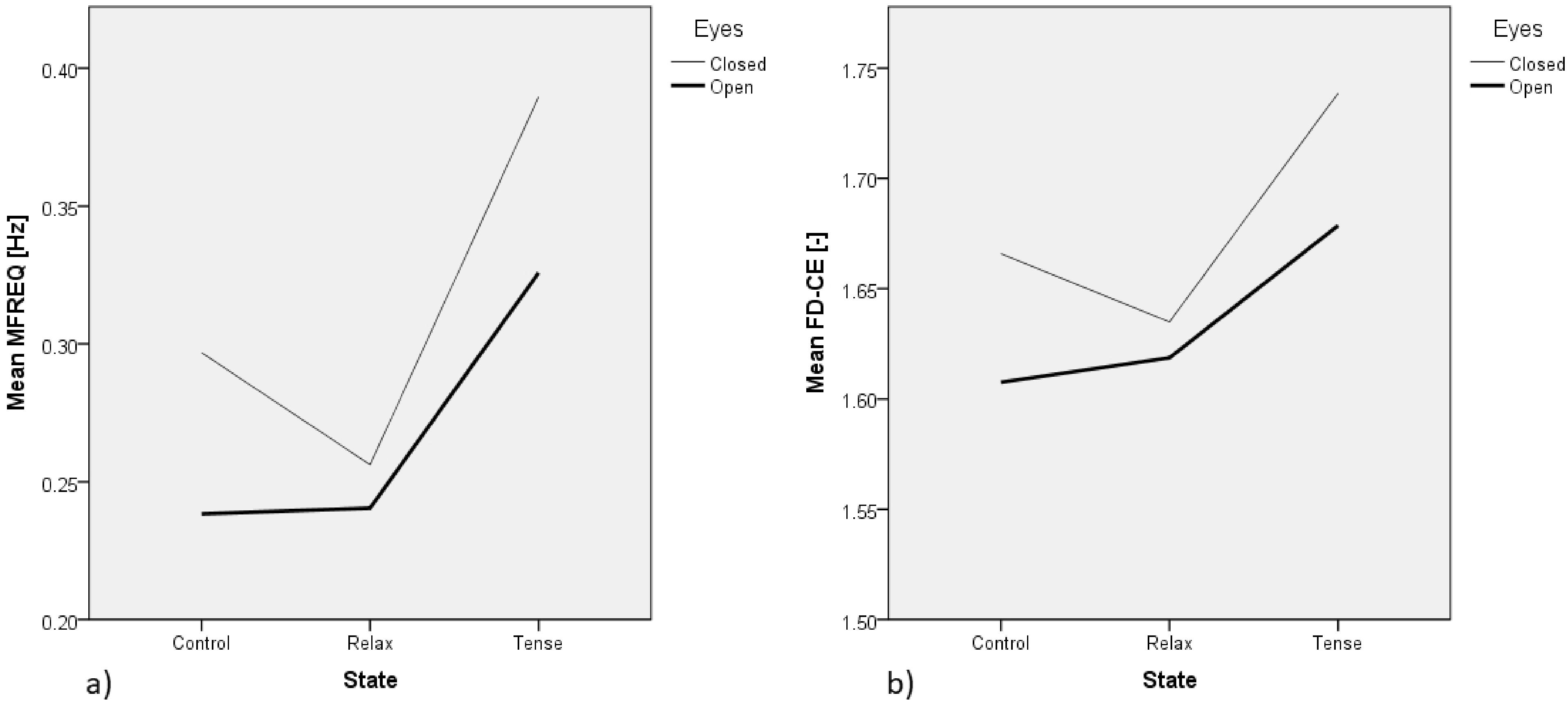
Eyes
Closed
Open
Mean MFREQ [Hz]
0.40
0.35
0.30
0.25
0.20
Control
Relax
Tense
State
a)
Eyes
Closed
Open
Mean FD-CE [-]
1.75
1.70
1.65
1.60
1.55
1.50
Control
Relax
Tense
State
b)

Conflict of interest statement:

The authors declare no competing financial interest nor any personal relationships with other people or organisations that could inappropriately influence (bias) their work.