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Difference in muscle activation patterns during high-speed versus standard-speed yoga: A randomized sequence crossover study

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ABSTRACT

Objectives: To compare the difference in muscle activation between high-speed yoga and standard-speed yoga and to compare muscle activation of the transitions between poses and the held phases of a yoga pose.
Design: Randomized sequence crossover trial
Setting: A laboratory of neuromuscular research and active aging Interventions: Eight minutes of continuous Sun Salutation B was performed, at a high speed versus a standard-speed, separately. Electromyography was used to quantify normalized muscle activation patterns of eight upper and lower body muscles (pectoralis major, medial deltoids, lateral head of the triceps, middle fibers of the trapezius, vastus medialis, medial gastrocnemius, thoracic extensor spinae, and external obliques) during the high-speed and standard-speed yoga protocols. Main Outcome Measures: Difference in normalized muscle activation between high-speed yoga and standard-speed yoga.
Results: Normalized muscle activity signals were significantly higher in all eight muscles during the transition phases of poses compared to the held phases ($p < 0.01$). There was no significant interaction between speed × phase; however, greater normalized muscle activity was seen for highspeed yoga across the entire session.
Conclusions: Our results show that transitions from one held phase of a pose to another produces higher normalized muscle activity than the held phases of the poses and that overall activity is greater during highspeed yoga than standard-speed yoga. Therefore, the transition speed and associated number of poses should be considered when targeting specific improvements in performance.

1. Introduction

Yoga has become an increasingly popular and effective exercise modality. It challenges a person's physical, emotional, and spiritual dimensions using different poses (asanas), breathing exercises (pranayama), and meditation techniques.[1] The National Center for Health Statistics show that participation in yoga by adults aged 18y and over linearly increased from 5.1% in 2002 to 6.1% in 2007, and subsequently to 9.5% in 2012.[2]

The most commonly practiced and studied type of yoga is hatha or standard-speed yoga (SSY). Hatha yoga is considered the foundation of all subsequent yoga styles and is regularly used as an alternative source of physical activity. SSY has been shown to improve flexibility,[3] balance and coordination,[4] and muscle strength and power[4] and to attenuate pain.[5] Additionally, yoga has been shown to help with arthritis,[6] weight control,[7] hypertension,[8] diabetes,[9] and cardiovascular disease risk.[10,11]

Power Vinyasa yoga, also known as high-speed yoga (HSY), has emerged as a popular variation of SSY. HSY poses are characterized by shorter held phases and faster transition phases.[12] HSY has been shown to be beneficial in improving balance.[13] and alleviating motor symptoms in patients with Parkinson's disease[14]

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Busko et al.[15] investigated maximal muscle torque and power in the elbow, shoulder, knee, hip, and trunk flexors and extensors in 12 untrained women using power yoga. They found that after a six-month power yoga training program, there were significant increases in maximal muscle torque in the shoulder flexors, and shoulder and elbow extensors. Additionally, they reported that total muscle torque of the arm, leg, and all ten muscle groups significantly improved over the six-month program.

Despite the known benefits of yoga, there are, to our knowledge, no studies that have examined the differences in muscle activation patterns between HSY and SSY. Ni et al.[16] did show that there are variations in muscle activity during specific poses due to practitioners' skill and experience levels. Given that muscle activation patterns are clearly changed with practice, yoga constitutes a neuromuscular training intervention and should therefore follow established training principles. Among the most prominent of these is the principle of exercise specificity. Additionally, EMG activity has been shown to increase in a relatively linear fashion with the rate of force development.[17] and speed of movement[18,19] Therefore, it may be assumed that muscle activity will vary as the movement velocity and pose duration are altered. Identifying differences in muscle activity between HSY and SSY will allow instructors, practitioners, researchers, and healthcare providers to better prescribe yoga practices to target the needs of specific populations.

The purpose of this study was to compare the difference in muscle activation resulting from HSY and SSY. We hypothesized that HSY would produce greater overall activation than SSY. We also hypothesized that HSY would exhibit greater muscle activation during transition phases of the poses, while SSY would exhibit greater muscle activation during the held phases of the poses. Concurrently, we evaluated the difference in energy expenditure and oxygen consumption during HSY versus SSY. Given the unique information offered by each analysis and the volume of data, we will present differences in muscle activation between HSY and SSY in the current article, while the energy expenditure and oxygen consumption results can be found in a separate article.

2. Methods

2.1. Study design

This study used a randomized-sequence crossover trial design that examined the differential impact of high-speed (HSY) and standard-speed yoga (SSY) on the electrical activity of selected muscles. Testing was conducted at the Laboratory of Neuromuscular Research and Active Aging. Subjects were recruited from the University's Wellness Center and local yoga studios. Subjects attended three testing sessions. On day one documents were completed, anthropometric measures taken and maximal oxygen consumption assessed. On days two and three muscle activations patterns were evaluated using EMG during HSY or SSY. The order was randomized, using a random numbers generator (Microsoft Excel), to reduce any carryover effect. To further reduce bias, a designated research assistant performed the randomization of conditions prior to subjects coming to the laboratory; while a separate research assistant scheduled subjects based on their availability. This avoided the influence of knowledge of testing order on subject scheduling. Subjects were informed of their testing condition by the research assistant in charge of randomization upon arriving at the laboratory. All testing sessions lasted approximately one-hour and were completed within a two week period. This study was approved by the University's Subcommittee for the Use and Protection of Human Subjects and is registered on ClinicalTrials.gov (NCT02818881).

2.2. Participants

Twenty-two adults (16 Women, 29.9 ± 5.9 years, 6 Men, 33.2 ± 16.3 years) with at least one year of yoga experience, currently practicing a minimum of two hours a week, and demonstrating good form in the Sun-Salutation poses (asanas), were included in this study. Exclusion criteria included: uncontrolled neuromuscular, orthopedic, or cardiovascular disease or advisement from their physician to abstain from exercise. All procedures were approved by the University's Human Subjects' Subcommittee and participants were informed of the potential risks and benefits associated with the study and provided written consent.

2.3. Conditions and test sessions

2.3.1. Yoga sequences

The Surya Namaskar (sun salutation) B used in this study consisted of 15 poses in the order listed: mountain pose with arms down ($Mnt_{DWN;}$ Tadasana$_{)}$, chair (Chr; Utkaasana), forward fold (FFold; Uttanasana), halfway lift (HLift; Urdhva Mukha Uttanasana), high plank ($Plnk_{HI}$; Dandasana), low plank ($Plnk_{LOW}$; Chaturanga Dandasana), upward facing dog (Dog_{UP}; Urdhva Mukha Svanasana), downward facing dog (Dog_{DWN}; Adho Mukha Svanasana), right side warrior 1 pose (War_{RT}; Virab-hadrasana I), high plank ($Plnk_{HI}$; Uttihita Chaturanga Dandasana); low plank ($Plnk_{LOW}$; Chaturanga Dandasana), upward facing dog (Dog_{UP}; Urdhva Mukha Svanasana), downward facing dog (Dog_{DWN}; Adho Mukha Svanasana), left side warrior 1 pose (War_{LFT}; Virab-hadrasana I), mountain pose with arms down ($Mnt_{DWN;}$ Tadasana).

The transition and held phases of each pose of the Sun Salutation B sequence was set to a metronome. The pose times, including the held and transition phases, were 3 s and 12 s for the HSY and the SSY, respectively. Subjects were given the opportunity to familiarize themselves with the sequence set to the pace of the metronome before each testing session. They were then instructed to repeat the sequence with good form continuously throughout the eight-minute testing session.

2.3.2. Day 1

On the first day of testing, subjects completed an informed consent, a standard American College of Sports Medicine health status questionnaire, and a yoga self-assessment questionnaire designed by our laboratory that asked the subject's number of years practicing yoga, current physical activity level, and the average time spent practicing yoga per week. Height and weight were recorded using a standard medical scale (Detecto 439 Beam Scale, Detecto Corp., Webb City, MO). Subjects completed a maximal oxygen consumption test (VO_{2max}) on a motorized Cybex 790T treadmill (Cybex International, Inc., Medway, MA. USA) and expired gas was continuously collected and analyzed with a portable breath-by-breath gas analyzer (Oxycon Mobile, Hoechberg, Germany). The testing protocol used was a modified version of the Astrand Treadmill Test.[20] Subjects completed a two-minute warm-up at a grade of 0% and at a self-selected speed. The subject was then directed to select the fastest speed during which he or she could maintain a conversation. This selected speed was kept constant throughout the remainder of the test. The incline increased to 2.5% and was increased by 2.5% every two minutes until test completion. Perceived exertion was measured using the 15 point Borg Rating of Perceived Exertion (RPE) Scale.[21] Heart rate was monitored using a Polar T31 Coded Transmitter (Polar Inc., Lake Success, NY, USA). Test termination was determined using the criteria established criteria from the American College of Sports Medicine.[22] Results of cardiovascular testing are reported elsewhere.

2.3.3. Days 2 and 3

Subjects reported to the laboratory for an additional two visits to complete either the HSY or SSY sequence, the order of which was randomly assigned. They practiced the Sun-Salutation B sequence set to the appropriate metronome pace (30 beats per minute for SSY and 40 beats per minute for HSY) to ensure accuracy of movement and timing. Subjects were first fitted with a portable ergospirometery unit to collect volume of oxygen consumed and carbon dioxide produced to calculate energy expenditure. The protocol and results for this analysis can be found in a separate article. Subjects were then fitted with EMG electrodes and instructed to lie in a supine position in a dark, quiet room, on a padded treatment table for 10 min. Following this resting phase, the subject performed either the HSY or SSY sequence for eight minutes. Pulsatile markers were actively placed in the recording of the EMG signal to indicate the start and end of the transition and held phases of each pose. Immediately following the yoga sequence, the subject again repeated the resting condition for 15 min. Cardiorespiratory and EMG data were collected simultaneously throughout the yoga sequence.

2.3.4. Electromyographic collection protocols

Electromyography was used to assess activity levels of eight selected muscles on participants' right sides including: the pectoralis major (Pecs), medial deltoids (DeltMED), lateral head of the triceps (TriLAT), middle fibers of the trapezius (TrapMID), vastus medialis (VM), medial gastrocnemius (GastrocMED), thoracic extensor spinae (ThorES) and external obliques (Obl). A bipolar surface electrode configuration was employed to control the potential for crosstalk among the muscles and reduce noise. Surface electrodes have been specifically recommended for this application.[23] The location of each electrode set was determined according to Cram's Introduction to Surface Electromyography.[24] After electrode locations were determined, the skin surface at each site was shaved, rubbed with light abrasive paper, and cleansed with alcohol to remove dead surface tissues and oil that might reduce conductivity, and disposable Ag/AgCl bipolar electrodes (Noraxon USA, Scottsdale, AZ, USA) were positioned parallel to the pennations of the muscles. Five-second maximal voluntary contractions (MVIC) were then performed targeting all eight muscles while EMG data were collected. Data were also collected throughout the eight-minute testing session and separated into the held and transition stages of each pose using the superimposed pulses. Data collected during each phase were normalized using the rmsEMG values collected during the middle 3 s of each 5 s MVIC (NrmsEMG).

2.3.5. Electromyographic collection methodology

A Noraxon TeleMyo 900 telemetry system (Noraxon USA, Inc., Scottsdale, AZ) was used for data collection. Gain was set at 2000, band width at 3–500 Hz, and sampling speed at 1024 Hz. Data were digitized using a 16-bit A/D convertor (Noraxon USA Inc., Scottsdale, AZ), and stored on a personal computer. Electromyographical signals were stored using MyoResearch XP Version 1/07 Software (Noraxon USA Inc., Scottsdale, AZ) and analyzed using a custom-built LabView program (National Instruments, Austin, TX). The root mean square of the electromyographic signal (rmsEMG) was used to assess signal amplitude.

2.4. Statistical analyses

Power calculations (G-Power, Universitat Dusseldorf, Germany) using differences in NrmsEMG between conditions as the main outcome,[25] indicated that a minimum sample size of 34 participants was required to detect an effect size of 0.25, α of 5% and power of 80%. Data were assessed using 2 (speed) × 2 (phase) repeated-measures ANOVA with NrmsEMG as the outcome variable. Significance was set a priori at $p < 0.05$.

Table 1
Participant Characteristics.

	Sample (n = 22)	Women (n = 16)	Men (n = 6)
Age (years)	29.5 ± 6.0	29.9 ± 5.85	33.17 ± 16.30
Height (m)	1.67 ± 0.10	1.63 ± 0.06	1.79 ± 0.08
Weight (kg)	64.71 ± 14.17	58.51 ± 1.82	81.26 ± 15.27
BMI (kg m^2)	22.90 ± 2.83	22.09 ± 2.46	25.08 ± 2.76
Yoga Experience (years)	5.07 ± 3.82	5.94 ± 4.09	2.75 ± 1.48

Values are Mean ± SD.

3. Results

3.1. Participants

Participants' characteristics are presented in Table 1. No significant group difference was observed in age, sex, height, weight, or yoga experience. Sixteen women (29.9 ± 5.8 years) and six men (33.2 ± 16.3 years) for a total of 22 participants (29.5 ± 6.0 years) completed all three testing sessions. Reasons cited for not participating included musculoskeletal pain not caused by the study conditions, inability to report to the laboratory three times, and unresponsive to study communication. Fig. 1 illustrates the study design and flow of participants through the study.

3.2. Normalized EMG

There were no significant speed × time interactions for NrmsEMG in any of the eight muscles tested. Table 2 displays EMG data between speeds. When examining speed, there were no significant differences between genders (MD = 0.018, SE = 0.037, p=0.627); however, there was a significant difference in NrmsEMG with HSY significantly higher than SSY (MD = 0.035, SE = 0.009, $p < 0.01$). When examining the main effect for phase, once again there were no significant differences between genders ($p = 0.74$). There were, however, significant differences for all eight muscles between the held and transition phases. The transitions phase consistently exhibited significantly greater muscle activity than the held phase for all eight muscles (Fig. 2).

4. Discussion

To compare the effect of movement speed on muscle activation, we tested two different protocols, HSY and SSY, on both men and women using a Sun-Salutation B sequence. Eight minutes of continuous Sun-Salutation B sequences were performed with the total number of sequences being determined by the speeds of movement during HSY and SSY. We chose to keep the time consistent between protocols since this replicates the patterns that would exist during actual yoga practice in the majority of yoga studios.

To our knowledge, this is the first study to evaluate the differences in muscle utilization considering two important components of a yoga practice, speed and pose phase. Most studies evaluating the effect of yoga on muscle activity have utilized SSY poses or yogic breathing techniques, and concentrated on muscle activity during the poses, rather than during a sequence of poses as dictated by most yoga practices.[16,26–28] Although there were no significant differences in activation for any muscle between HSY and SSY for either phase, there was a significant difference in NrmsEMG when comparing phases and across the entire pose sequence between speed conditions. Muscle activation for all muscles exhibited a significant increase during the pose transition compared to the held phases. We expected to see a difference in NrmsEMG

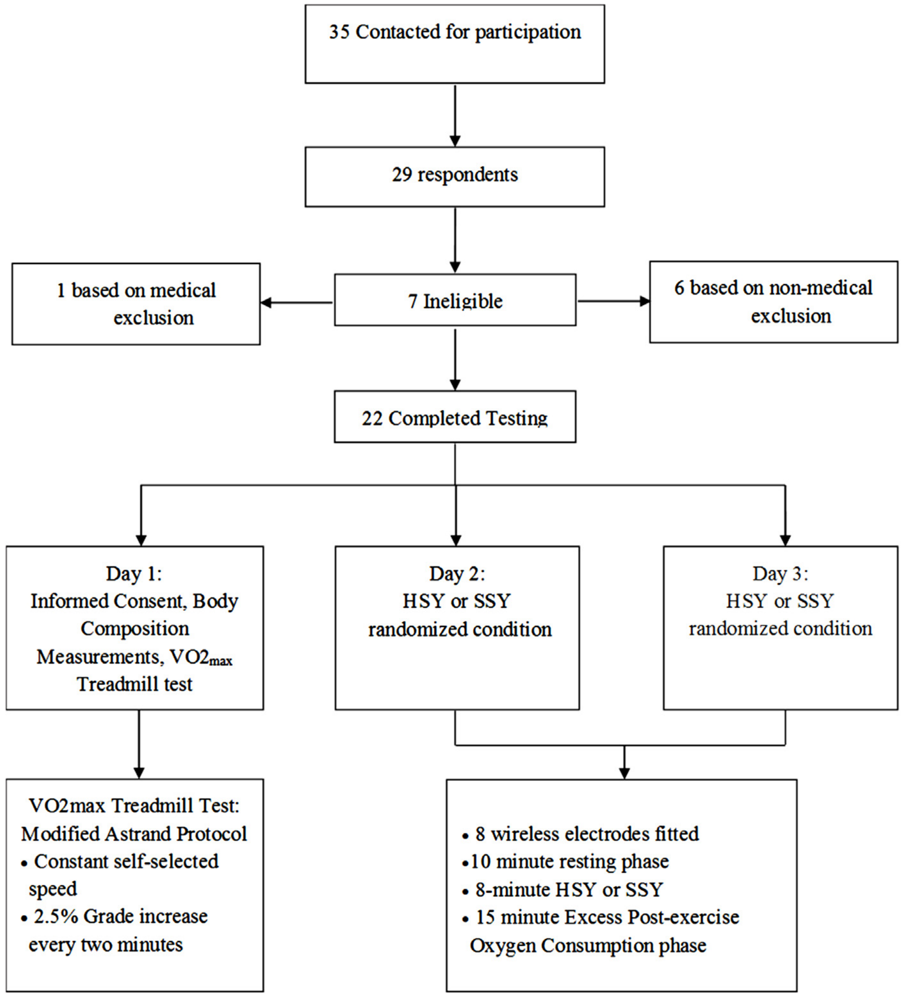

Fig. 1. Study design and participant flow through study.

Table 2
EMG data between speeds.

	Mean ± SE.		MD ± SE	p	η_p^2	95% CI	
	HSY	SSY				LB	UB
Pecs	0.190 ± 0.035	0.160 ± 0.033	0.030 ± 0.017	0.10	0.144	−0.006	0.065
DeltMED	0.065 ± 0.007	0.060 ± 0.005	0.006 ± 0.007	0.423	0.036	−0.009	0.020
TriLAT	0.068 ± 0.006	0.071 ± 0.009	−0.002 ± 0.008	0.75	0.006	−0.018	0.013
TrapMID	0.160 ± 0.024	0.140 ± 0.026	0.020 ± 0.011	0.08	0.161	−0.003	0.043
VM	0.137 ± 0.019	.118 ± 0.012	0.019 ± 0.013	0.17	0.102	−0.009	0.047
GastrocMED	0.137 ± 0.026	0.120 ± 0.027	0.017 ± 0.019	0.37	0.046	−0.022	0.056
ThorES	.111 ± 0.010	0.083 ± 0.008	0.028 ± 0.006	0.17	0.104	−0.010	0.052
Obl	0.223 ± 0.049	0.175 ± 0.042	0.049 ± 0.049	0.34	0.051	−0.152	0.055

Pecs: Pectoralis major; DeltMED: medial deltoids; TriLAT: lateral head of the triceps; TrapMID: middle fibers of the trapezius; VM: vastus medialis; GastrocMED: medial gastrocnemius; ThorES: thoracic extensor spinae; Obl: external obliques; HSY: high-speed yoga; SSY: standard-speed yoga.

between the transition and held phases because of the difference in time that transitions and poses are held in HSY and SSY. Participants of HSY were instructed to move through each pose as quickly as possible (total of 3 s for held and transition phases); while SSY performed each pose (both phases) over a 12 s time period.

Our findings challenge the pre-conceived notion that a pose and transition should be examined as a collective unit. Rather, for the purpose of analysis, the transition and held phases of a pose should be considered separately. The held phase of the pose can be considered an isometric component of varying durations depending on the yoga method being practiced, while the transition is one dynamic movement that can also vary in movement speed depending on the practice. Masuda et al.[29] found that relative EMG amplitude during a maximal isometric contraction of the vastus lateralis (joint angle = 1.57 rad; 50% MVC) was significantly lower than during a dynamic contraction (ROM = 1.57–3.14 rad; 50%MVC; 10 reps min^{-1}) when both exercises were performed to exhaustion. They also noted that muscle fiber conduction velocity during the dynamic contraction did not significantly change throughout the exercise; however, during the isometric contraction muscle fiber conduction velocity exhibited a significant decline over the duration of the test. Masuda et al. explained that during static contractions, there is reduction of blood flow, resulting in accu-

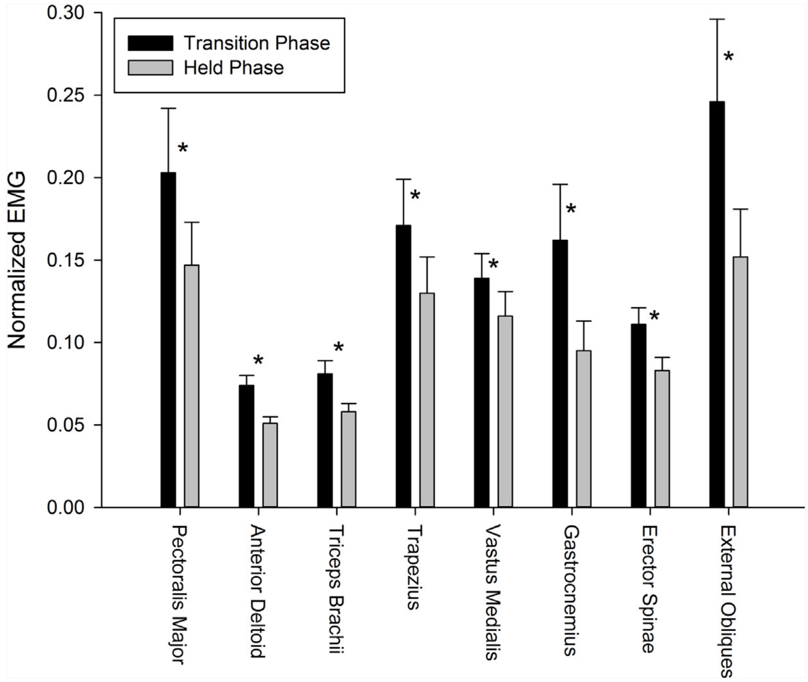

Fig. 2. Differences in NrmsEMG across muscles between the transition and held phases. *Indicates $p < 0.05$.

mulation of metabolic byproducts, which can acutely affect EMG amplitude. Conversely, with dynamic contractions, the lengthening and shortening of the muscle facilitates venous return, thus removing metabolic byproducts, allowing greater EMG amplitude.

Our results also support the notion that HSY may be considered a challenging exercise modality, similar to interval training. During a yoga practice the "rest period" and "active period" can be considered the held phase and transition phase, respectively. Therefore, in HSY, the higher muscle activation overall is likely due the more dynamic nature of the exercise. We argue that the HSY used in this study constitutes a high-intensity interval training program, and therefore provides a neuromuscular overload similar to that seen during typical high-intensity interval workouts. The high-speed movements and short recovery times influence the intensity of the practice; since transitions and poses are held for approximately the same short duration producing a work-recovery duty cycle can be modified to target specific goals.

Even though there was no significant interaction between speed * phase, there was a significant difference in overall NrmsEMG. When transitions and poses were considered across the entire training period, HSY elicited significantly greater muscle activity than SSY. This finding helps support our assertion that the speed of the dynamic movements are of greater importance that the static poses in effecting increases in muscle activity.

4.1. Study limitations

Even though our study demonstrated that HSY yielded a significantly higher muscle activity than SSY, there were a few limitations to our study. Our collection period was only eight minutes, rather than the standard 45 min to one hour session. Also, our subject pool consisted of young, active yoga practitioners, making our results generalizable to populations with adverse medical conditions more difficult. Our yoga protocol also does not account for warm-up or cool-down poses, which may have altered NrmsEMG.

5. Conclusion

Despite the limitations on our study, we demonstrated that HSY produces significantly greater muscle activity during the transition phase, rather than during the actual yoga poses, which challenges the current school of thought. Yoga has many cardiometabolic[8–10] and musculoskeletal[30,31] benefits, yet, unlike other exercise modalities like aerobic and resistance training, there is a paucity of literature evaluating the different variations of yogic methods. Our study demonstrated that with the proper modifications and considerations to the participants, HSY can be an effective alternative to traditional aerobic and strength training, with the ultimal goal of maximizing muscle activity.

Conflict of interest

The authors confirm that there are no known conflicts of interest.

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