Original Paper DOI: https://doi.org/10.5114/biolsport.2021.100362

The effect of breathing technique on sticking region during maximal bench press

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ABSTRACT: The intrathoracic pressure and breathing strategy on bench press (BP) performance is highly discussed in strength competition practice. Therefore, the purpose of this study was to analyze whether different breathing techniques can influence the time and track characteristics of the sticking region (SR) during the 1RM BP exercise. 24 healthy, male adults (age 23 ± 2.4 yrs., body mass 85 ± 9.2 kg, height 181 ± 5.4 cm) performed a 1 repetition BP using the breathing technique of Valsalva maneuver (VM), hold breath, lung packing (PAC), and reverse breathing (REVB), while maximum lifted load and concentric phase kinematics were recorded. The results of ANOVA showed that the REVB breathing decreased absolute ($p < 0.04$) and relative lifted load ($p < 0.01$). The VM showed lower ($p = 0.01$) concentric time of the lift than the other breathing techniques. The VM and PAC showed lower SR time than other breathing techniques, where PAC showed a lower SR time than VM ($p = 0.02$). The PAC techniques resulted in shorter SR and pre-SR track than other breathing techniques and the REVB showed longer SR track than the other considered breathing techniques ($p = 0.04$). Thus, PAC or VM should be used for 1RM BP lifting according to preferences, experiences and lifting comfort of an athlete. The hold breath technique does not seem to excessively decrease the lifting load, but this method will increase the lifting time and the time spend in the sticking region, therefore its use does not provide any lifting benefit. The authors suggest that the REVB should not be used during 1 RM lifts.

CITATION: Blazek D, Kolinger D, Petruzela J et al. The effect of breathing technique on sticking region during maximal bench press. Biol Sport. 2021;38(3):445–450.

Received: 2020-07-01; Reviewed: 2020-07-21; Re-submitted: 2020-08-07; Accepted: 2020-09-25; Published: 2020-11-04.

Key words:
Valsalva maneuver
Lung packing
Holding breath
Intrathoracic pressure
Reverse breathing
Resistance training

INTRODUCTION

The development of upper limb strength is one of the key factors in recreation and competitive sports training, where the bench press (BP) is often used as the training or testing tool [1–4]. Maximum strength development requires exercise stimuli at high intensity such as 1–4 repetition maximum (RM) in a training session [5], while these repetition executions are typically performed with short deceleration in the concentric phase called the sticking region (SR) [6–9]. During a training session, a BP competition or a test trial, athletes and coaches attempt to surpass the SR by movement modifications such as specific breathing techniques to increase performance, training volume or exercise load.

The SR has been found in complex exercises such as the BP, chest press and barbell squat [10, 11] at maximal and submaximal exercise intensity [12, 13], where overpassing this region is crucial for successful lifts [13]. The SR is believed to be caused by mechanical lever arm disadvantage between upper limb body segments [14, 15], but the current research does not provide which anthropometric or other variable can help surpass the SR. Since the thorax plays the role of a mechanical fixation point during the BP, variables such as upper arm to thorax anthropometry [16–19], trunk muscle stabilizers [20], intraabdominal pressure (IAP), intrathoracic pressure (ITP) [21, 22] are possible candidates interacting in surpassing the SR. Specifically, the internal body pressures can be easily modified by breathing techniques and can change the mechanical conditions during maximal and submaximal BP lifts.

The increase of the lifted load during a single workout session and during the whole training cycle is a desired goal of resistance training, where manipulation of breathing may change the mechanical and physiological response to exercise. E.g.: reversed or controlled breathing decreases exercise blood pressure [23] and traditional Valsalva maneuver (VM) can increase the ITP and IAP to support physical performance [22, 24]. In practice, athletes use either the VM, hold breath technique (HB) or lung packing (PAC) to ensure best lifting conditions and optimal performance. This training approach may be justified by the following rationale, which supports the hypotheses that bench press lifting is influenced by breathing technique: The VM is not avoidable during a lift above 80% of 1RM [25], while the HB technique and reverse breathing (REVB) has been reported to decrease blood pressure resulting from exercise without load reduction [26], and PAC has been shown to increases ITP [27]. However, there is currently no evidence whether alternative breathing techniques can increase lifting performance.

Because the SR has not been analyzed during different approaches to breathing techniques, the purpose of this study was to analyze whether different breathing techniques can influence the time and track characteristics of the SR during 1RM and 4RM BP lifts. We hypothesized that methods, such as the breath hold, and breath packing should decrease the time frame and track in the SR compared to the traditional VM and the reverse breath approach.

MATERIALS AND METHODS

Experimental Approach to the Problem

The study was carried out at the Biomechanical Laboratory of Extreme Loading at Charles University, Faculty of Physical Education and Sport between May and August 2018 and consisted of a familiarization period and five main sessions. The familiarization period lasted for 14 days prior to the study, where the participants were familiarized with the experimental procedures, including different breathing techniques and where 1RM was measured for each breathing and lifting technique. The 1RM test was used to assess the impact of the breathing technique, where determination of 1RM values for all five breathing (lifting) techniques (HB, VM, REVB, PAC, FBP) were performed according to the protocol by Van den Tillaar and Saeterbakken [28] during familiarization. The self-reported 1RM was set according to the information given by the participants on maximal lifts performed in the previous six months. When the self-reported 1RM was successful, a trial with an additional load of 2.5–5 kg was performed. When the initial trial was unsuccessful, the weight was decreased by 2.5–5 kg. Rest periods between attempts were at least 5 minutes to avoid the potential effect of fatigue [29]. A total of two to three trials were performed per participant.

Each main session started by a standardized warm-up protocol, including a general warm-up (7–10 min), which consisted of body weight exercises such as pull ups and push-ups at moderate intensity. The specific part of the warm-up consisted of 15–20 BP repetitions with a barbell, five bench press sets with the load adjusted accordingly to 40, 70 and 80% 1RM. The load (kg) of these warm-up sets was estimated according to self-reported 1RM of the participants. One breathing (lifting) technique was selected for each session in a randomized order, where each session consisted of a warm up and successful 1RM lifts. Each successive session was followed by a minimum of 72 hours of recovery.

Subjects

24 healthy, male adults (age 23 ± 2.4 yrs., body mass 85 ± 9.2 kg, height 181 ± 5.4 cm) athletes from various sports disciplines (power lifting, CrossFit, boxing, track and field) participated in the study. Their recruitment consisted of the following inclusion criteria: resistance training experience (a minimum of 3 years), age (≥ 18 years), experienced with VM technique and flat bench press (FBP) technique, injury free for the last three months. The study protocol required the athletes not to perform any resistance exercises engaging upper extremities for 72 hours before the study and for 48 hours during the subsequent study protocols. All participants were familiarized with the protocol and the likely benefits and risks of the study and gave their written consent to participate. They could withdraw from the study at any time. The protocol of the study was approved by the Bioethics Committee at the Faculty of Physical Education and Sport, Charles University no EK143/2015.

Bench press exercise

The bench press 1RMs and the main sessions were performed on an Eleiko Olympic barbell (2.8 cm diameter, length 1.92 m) with maximal 81cm grip width [30]. The participants were instructed to use a constant barbell width of 81cm. All participants performed a bench-press with 2s eccentric lowering, minimal stop in the transition phase and the concentric part performed without time limit with maximum effort [31, 32]. The chest touch was requested, however bouncing the barbell off the chest was forbidden.

Bench press breathing techniques

Each different breathing technique was familiarized for a randomly selected technique before the main measurements and during the warm up. Breathing technique was checked by a sparring investigator who also provided the nose clip, verbal instruction, and tempo of exercise. If the investigator or participant reported disruption of technique, the attempt was repeated. Body position of VM, PAC, REVB and HB was in accordance with IPF rules, where head, shoulders, and buttocks were in contact with the bench surface and feet positioned flat on the floor.

Traditional Valsalva maneuver (VM)

During the eccentric phase of the bench press subjects used the nose and mouth to inhale as much as they could at a defined speed of eccentric contraction. In the bottom part of the eccentric phase, when the bar was close to the chest, the subject's nose was secured by the clip (to avoid air leak by nasal cavity). During the concentric phase, an active exhale was performed against the mouthpiece (close glottis).

Flat bench press with Valsalva maneuver (FBP)

This technique did not modify the VM breathing technique itself but adjusted the body segment position. The breathing technique was the same as during the VM, but the BP was performed with feet contact elevated in the same horizontal line as the participants trunk. Feet were placed on a stable step desks, which were on the same level as the bench. In this position the participants were instructed to have maximal contact of the lumbar spine with the bench cushion. This technique is usually recommended for people with problems in the lumbar spine region, because it activates abdominal muscles and increases production of intraabdominal pressure [21].

Hold breath (HB)

This technique was based on a squat type of breath holding technique often used by athletes competing in power lifting. The athletes used one deep breath before execution of the repetition itself. During the eccentric phase, they held their breath, without putting pressure on the glottis (mouthpiece). After reaching the bottom position at the end of the eccentric phase, the participants performed an intensive exhale against the mouthpiece (simulating closed glottis), until they finished the concentric part of the BP, and then exhaled. This technique causes higher increase of systolic and diastolic pressure, than techniques without breath hold [33], and might increase the amount of muscles participating in exercise stability [34].

Lung packing (PAC)

Packing is a technique which is uses glossopharyngeal breathing [35], and increases the volume of lungs more then 2,59l above the limit of maximum breath capacity [36–38]. From all the techniques that were used in this study, this method has the longest preparation before the attempt. Swallowing muscles during this technique have to force with each breath 30–60 ml of air to the lungs by way of a similar principle as the swallowing of food [39]. During maximal usage of this technique, subjects can reach internal chest pressure of up to 8 kPa [39]. In this study a modified version was used consisting of 3–5 breaths either during the starting, or ending phase of a repetition, followed by a controlled eccentric phase (until bar reached the chest). During the concentric phase, the exhale was performed against a closed glottis (simulated by mouthpiece).

Reverse breathing (REVB)

The reversed breathing technique is based on exhaling during the eccentric phase of exercise and inhaling in the concentric phase of the lift. Prior to the eccentric phase the participants performed a deep inhale, followed by exhalation against the mouthpiece during the eccentric phase of the exercise. In the bottom phase the athletes completely exhaled through the nose. The concentric phase was performed with inhalation through the mouth and nose. This technique was developed to potentially decrease the blood pressure during resistance exercise [34], but generally it resulted in decreased lifted load [23, 40].

Instrumentation

3D kinematics of the bar have been recorded by Qualisys system (Qualisys AB, Göteborg, Sweden), where the bar track and velocity were recorded to describe the concentric phase of movement and SR in details. Eight infrared cameras were placed around the bench press station, and the kinematic data were recorded at 200 Hz in accordance with manufacturers. Reflective markers that were 14 mm in diameter were attached to the subject's skin and barbell over the following positions: manubrium sternum, glabella, center of the bar, as well as the right and left radius of the bar.

Sticking region

The concentric phase of the BP was divided into three regions defined by the occurrence of SR [6, 41, 42]. The pre-SR was defined as the time from lowest barbell point until maximal barbell velocity. The SR as the time from maximal barbell velocity until the first local minimum barbell velocity, and post-SR time from the instant that vertical acceleration of the barbell became positive again until the second maximal barbell peak velocity.

Statistical analysis

All statistical analyses were processed using the STATISTICA software (version 13, Tibco, Palo Alto, CA, USA) where statistical significance was set at $\alpha \le 0.05$. Data normality for each breathing technique was tested with the Shapiro-Wilk test. The one way ANOVA was

TABLE 1. The descriptive characteristics of concentric phases time and track during the bench press exercise.

Breathing technique	Pre-sticking region		Sticking region		Post-sticking region	
	Mean ± SE	95% CI	Mean ± SE	95% CI	Mean ± SE	95% CI
Hold breath time (s)	0.25 ± 0.20	0.21–0.29	1.28 ± 0.11	1.07–1.50	2.5 ± 0.30	1.89–3.09
Flat bench press time (s)	0.25 ± 0.21	0.21–0.29	1.30 ± 0.10	1.09–1.51	2.5 ± 0.30	1.93–3.12
Reverse breathing time (s)	0.28 ± 0.02	0.24–0.33	1.38 ± 0.12	1.14–1.61	2.1 ± 0.33	1.56–2.88
Lung packing time (s)	0.23 ± 0.02	0.19–0.27	1.04 ± 0.11	0.83–1.25	2.5 ± 0.30	1.98–3.17
Valsalva maneuver time (s)	0.27 ± 0.02	0.23–0.31	1.18 ± 0.10	0.97–1.39	1.90 ± 0.30	1.32–2.50
Hold breath track (mm)	47 ± 4	38–55	158 ± 11	135–179	263 ± 18	227–300
Flat bench press track (mm)	49 ± 4	41–58	166 ± 11	144–188	285 ± 18	248–321
Reverse breathing track (mm)	53 ± 5	44–62	191 ± 12	167–214	285 ± 19	247–324
Lung packing track (mm)	41 ± 4	33–49	139 ± 10	118–160	279 ± 17	245–313
Valsalva maneuver track (mm)	46 ± 4	38–54	167 ± 10	147–188	260 ± 17	227–295

CI = confidence interval

used to find differences between breathing techniques (type of breathing x performance value), followed by non-parametric effect size calculation and Tukey post hoc test. The effect size was calculated using non-parametric Hays omega (ω^2 >), where ω^2 0.10–0.29, 0.30–0.49 and > 0.50 were considered as weak, moderate and strong associations, respectively [43].

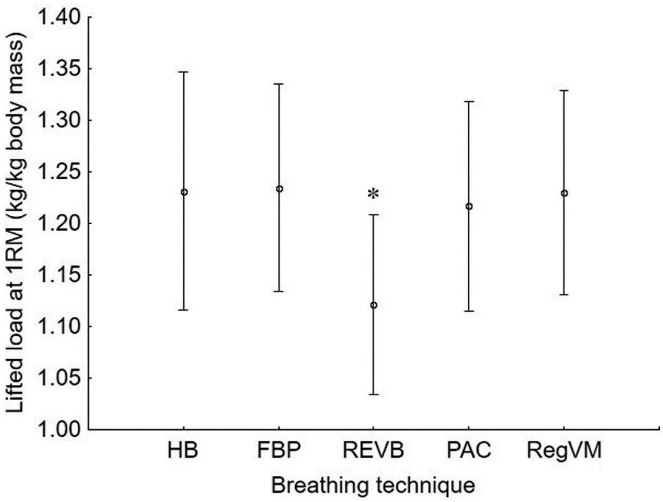

FIG. 1. Relative lifted load in different lifting techniques.
HB = hold breath, FBP = flat bench press, REVB = reverse breathing technique, PAC = lung packing, VM = Valsalva maneuver. The values are expressed as mean and standard deviation. *significantly different than other breathing techniques.

RESULTS

The normality test showed normal data (Table 1) distribution for lifted load (the "W" between 0.89–97), sticking region time (the "W" between 0.91–96) and sticking region track (the "W" between 0.85–94)The ANOVA showed differences in total lifted load ($F_{4, 61}$ = 3.8, p = 0.048, ω^2 = 0.10) and relative lifted load ($F_{4, 69}$ = 3.8, p = 0.007, ω^2 = 0.13) (Figure 1) between breathing techniques, where the REVB showed lower lifted load than all other breathing techniques.

Time of the concentric phase ($F_{4, 67}$ = 3.6, p = 0.010, ω^2 = 0.13) differed between breathing techniques (Figure 2), where the VM showed lower time than other breathing techniques. The sticking region time ($F_{4, 69}$ = 3.25, p = 0.015, ω^2 = 0.10) and track ($F_{4, 69}$ = 3.5, p = 0.044, ω^2 = 0.11) differed between breathing techniques (Figure 3), where the VM and PAC showed lower SR time than other breathing techniques (Figure 2), while the PAC showed lower SR time than the VM (Figure 2). The PAC techniques resulted in shorter SR and pre-SR track than other breathing techniques and the REVB showed longer SR track than other breathing techniques (Figure 3).

DISCUSSION

The main result is that the PAC and VM are methods, which can provide an advantage for overcoming the SR during a 1RM lift. On the other hand, the HB technique does not provide any advantage in 1RM kinematics, and the REVB is an inappropriate method since it decreases 1 RM performance and extends the SR track. Based on the obtained results, it cannot be assessed whether the PAC or VM

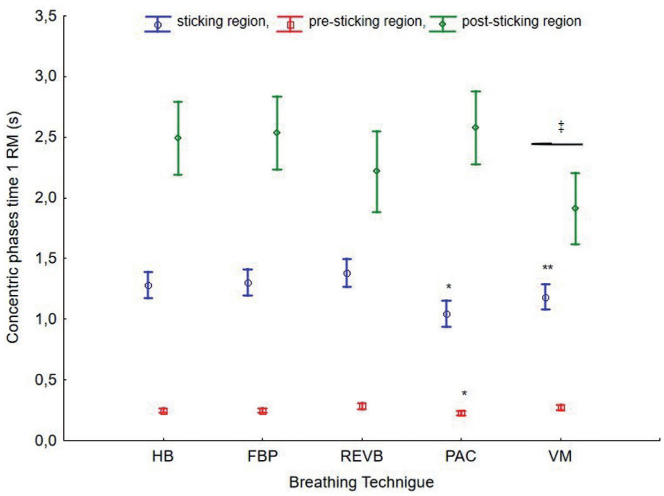

FIG. 2. Time of pre-sticking, sticking and post-sticking region during different breathing strategies.
*significantly different than other breathing techniques. ** longer than PAC technique and shorter than other breathing techniques. ‡significantly different for whole concentric time than other breathing techniques. HB = hold breath, FBP = flat bench press, REVB = reverse breathing technique, PAC = lung packing, VM = Valsalva maneuver. The values are expressed as mean and standard errors.

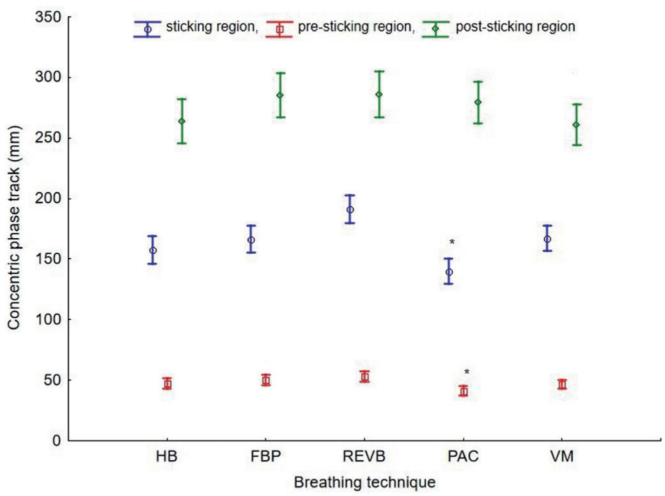

FIG. 3. Sticking region track during different breathing strategies. *significantly different than other breathing techniques. HB = hold breath – FBP = flat bench press – REVB = reverse breathing technique, PAC = lung packing, VM = Valsalva maneuver. The values are expressed as mean and standard errors.

are more advantageous methods than others, because neither resulted in higher lifted 1 RM. The VM had the advantage of the shortest lifting time, and the PAC the advantage of the shortest SR time and track. On the other hand our results are in accordance with findings, that breathing techniques that dramatically increase intrathoracic pressure (PAC) or which are based on a natural reflex [44, 45] provide the best conditions for maximal lifting.

Our reported time values (Table 1) of sticking regions during successful lifts in the BP, were bigger than previously reported results (0.66 ± 0.29s) among competitive athletes lifting above 150kg [8]. On the other hand, the study on non-competitive resistance trained athletes reported similar values as in our study. [10]. This difference can be explained by moderate strength level of our participants and by careful set up of the 1 RM, which extends the lifting time and often causes a cascade waveform of bar kinematics. In terms of total time spent in the concentric phase, the SR took by percentage the following parts of the lift: HB SR time was 36 ± 10.1%, FBP was 35 ± 11,2%, REVB 38 ± 12,5%, PAC 28 ± 9.8% and VM 36 ± 10.1%, which is slightly less than about 40% reported by Lockie [41]. Only the PAC technique resulted in similar values 26 ± 10.9% as Lander [46].

In this study we recorded a relatively long SR track (Table 1), when a previous study reported a SR track of 66 mm in a narrow grip, a 26 mm medium grip and 0.18 mm in a wide grip width [47]. Our SR occurrence started approximately 5 cm above the chest, which corresponds with a previously reported distance [6]. Considering that the SR time of occurrence and SR height above chest does not differ at narrow, medium and wide grip [14], we can state that also those values are consistent across most of the literature.

Previous studies attempted to reveal the cause of the SR, as a mechanically poor position [6] of upper limbs and diminished muscle potentiation [6, 8]. Our study adds to this knowledge that the mechanical support of body pressures elicited by the VM or the PAC might be significant to maintain short duration and track of the sticking region. On the other hand, the other modifications of breathing techniques do not seem to be beneficial for overcoming the SR. Moreover, the VM has an advantage of natural vagal reflex and occurrence of high blood pressure [44, 45, 48], which also supports the learning of this technique and the mechanical support during the BP lift.

Practical implication

The PAC is the most effective breathing technique to overpass the SR during successful 1 RM lifts. The PAC has a shorter SR time and track than other breathing techniques. The VM is the most natural breathing technique, based on vagal reflex which provides the shortest lifting time with a short SR at successful 1 RM lifts. Thus, the PAC or VM should be used for 1RM BP lifting according to preferences, experiences and lifting comfort of an athlete. The FBP and HB techniques do not seem to excessively decrease the lifting load, but those methods will increase the lifting time and the time spent in the sticking region, therefore they do not provide any lifting benefit. The REVB should not be used in 1 RM at all because it decreases lifting performance.

Funding

This research has been supported by Charles University grant UNCE HUM 032 and student support SVV 260466.

Acknowledgments

This reserch has been performed at: Biomechanical Laboratory of Extreme Loading of Charles University in Prague, Faculty of Physical Education and Sport.

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