Baltic Journal of Health and Physical Activity

Volume 12 | Issue 1 Article 1

2020

The reliability and intensity dependence of maximum mouth pressure during bench press exercise in healthy athletes

Dusan Blazek
Faculty of Physical Education, Charles University in Prague, the Czech Republic, DusanMPK@seznam.cz

Anna Pisz
Faculty of Physical Education, Charles University in Prague, the Czech Republic, piszan@gmail.com

Ondrej Pecha
Technology Centre of the Czech Academy of Sciences, Prague, the Czech Republic, DusanMPK@seznam.cz

Petr Kubový
Technology Centre of the Czech Academy of Sciences, Prague, the Czech Republic, DusanMPK@seznam.cz

Recommended Citation
Blazek D, Pisz A, Pecha O, Petr Kubový P. The reliability and intensity dependence of maximum mouth pressure during bench press exercise in healthy athletes. Balt J Health Phys Act. 2020;12(1):1-10. doi: 10.29359/BJHPA.12.1.01

Baltic Journal of Health and Physical Activity 2020; 12 (1): 1-10
Journal of Gdansk University of Physical Education and Sport
e-ISSN 2080-9999

ORIGINAL

doi: 10.29359/BJHPA.12.1.01

The reliability and intensity dependence of maximum mouth pressure during bench press exercise in healthy athletes

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

Dusan Blazek[1] ABCDEF, Anna Pisz[1] BDE, Ondrej Pecha[2] C, Petr Kubový[2] AD

[1] Faculty of Physical Education, Charles University in Prague, the Czech Republic

[2] Technology Centre of the Czech Academy of Sciences, Prague, the Czech Republic

abstract

Background: Respiratory muscle strength is an important indicator of human health and sport condition. The aim of this study was to assess the test/retest reliability of mouth pressure (MP) measured by a created pressure sensor mouthpiece in the sitting position and during bench pressing at various intensities.

Material and methods: 23 healthy athletes were measured in 3 separate sessions for MP in the sitting position and during flat bench press at an intensity of one repetition maximum (1RM), 3 x 90% of 1RM, 8 x 80% of 1RM and 12 x 60% of 1RM.

Results: The measurement device showed acceptable reliability with ICC (Intraclass correlation) ranging from 0.75 to 0.95, where the highest reliability was reached in between repetitions, and slightly decreased when measurements were done in different sessions. The ANOVA showed differences between mouth pressure at different exercise loads ($F_{4, 56}$ = 22.18, p< 0.001),with the highest MP measured in the sitting position, followed by 90% of 1RM, 80% of 1RM and 60% of 1 RM load.

Conclusions: This study shows acceptable reliability of MP measurement by a mouthpiece device with piezo-resistant sensor. The MP depends on the exercise intensity during the bench press and is higher in sitting than in the supine body position.

Key words: bench press, mouth pressure, reliability, resistance training.

article details

Article statistics: **Word count:** 3,469; **Tables:** 4; **Figures:** 2; **References:** 29
Received: December 2019; **Accepted:** February 2020; **Published:** March 2020

Full-text PDF: http://www.balticsportscience.com

Indexation: Celdes, Clarivate Analytics Emerging Sources Citation Index (ESCI), CNKI Scholar (China National Knowledge Infrastructure), CNPIEC, De Gruyter - IBR (International Bibliography of Reviews of Scholarly Literature in the Humanities and Social Sciences), De Gruyter - IBZ (International Bibliography of Periodical Literature in the Humanities and Social Sciences), DOAJ, EBSCO - Central & Eastern European Academic Source, EBSCO - SPORTDiscus, EBSCO Discovery Service, Google Scholar, Index Copernicus, J-Gate, Naviga (Softweco, Primo Central (ExLibris), ProQuest - Family Health, ProQuest - Health & Medical Complete, ProQuest - Illustrata: Health Sciences, ProQuest - Nursing & Allied Health Source, Summon (Serials Solutions/ProQuest, TDOne (TDNet), Ulrich's Periodicals Directory/ulrichsweb, WorldCat (OCLC)

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interests: Authors have declared that no competing interest exists.

Corresponding author: Dusan Blazek, José Martího 269/31, 162 52 Praha 6, the Czech Republic; phone: +420607982741; e-mail: dusanmpk@seznam.cz.

INTRODUCTION

The respiratory muscles of healthy individuals suffer from physiological fatigue following certain types of physical activities; therefore, respiratory muscle strength is an important factor in different sport disciplines [1]. Breathing muscles are used to a high degree during weight lifting with application of the Valsalva maneuver (VM), which has same value as expiratory pressure, or mouth pressure [2–5]. Lack of power of the breathing muscles can lead to sport performance failure, insufficient cough, and possible injuries [6]. The correct assessment of breathing muscles strength is therefore very important. Invasive methods involve esophageal balloons, gastric balloons, bladder catheters, rectal probes, or radio capsules, all having high levels of accuracy. However, these methods cause discomfort to their user [7]. It is well known, that problems connected to their application and removal discourage many volunteers; therefore, they refuse to participate in research or quit it sooner.

Non-invasive methods mostly consist of a mouthpiece that is connected to a reliable manometer. They are usually portable, with good subject tolerance, easy to applicate and maintain. Moreover, measurement can be immediately canceled without further complications. Their disadvantage is that they are rather imprecise, and the results are effort-dependent. Also, the exhale is pressed against the measuring device, not against the glottis, which may be unnatural for some subjects. However, for the benefits listed above, they are widely applied and accepted [8]. Literature also describes unusual mouth pressure (MP) measuring possibility by estimation from systolic blood pressure [5, 9]. However, this method is suitable for static measurements, and hence its usage for sport activity is limited.

Several studies have reported valuable results with reliable manometers with piezo sensitive resistive pressure-sensing technology as the dynamometer used in this study [5, 9–11]. Unfortunately, none of them established reliability during exercises with a high external load (e.g. during bench press). They also do not have unified measuring methods, or use inappropriate or insufficient statistical measurements of questionable reliability [12–15], such as Pearson correlation coefficient, which is difficult for assumption.

There are many parameters connected to breathing muscles, but not all of them are accurate enough for sport. While total lung capacity measurements show some aspects of lung condition, it is mainly used for indication of lung restriction diseases. Also, the relationship between lungs volume and the strength of the respiratory muscle system is not linear [16]. While the lungs volume is easily measured by its capacity, breathing muscle strength can be measured by the maximum inspiratory pressure effort (MIP) and maximum expiratory pressure effort (MEP) [7, 8, 17]. These two values show the ability to generate force of the inspiratory or expiratory muscles during a brief quasi-static contraction. MIP and MEP are commonly measured with a manometer as mouth pressure [18]. Though inspiration muscle strength is important for aerobic performance, resistance exercise with a low number of performed repetitions ($n < 4$) mainly profits from strong expiratory muscles and abdominal muscles. Furthermore, expiratory and abdominal muscles play a crucial role in generating intra-abdominal pressure, which is important in overcoming resistance during strength exercises, such as bench press.

Since the supine position has an effect on generated MP, the purpose of this study is to find out the differences between MP in the sitting position and during bench pressing at various intensities (submaximal and maximal loads) along with the reliability of an ergonomically designed device for mouth pressure measurement, which can be used in the athletic population during high intensity strength exercises. Bench press (BP) has been used because it is an upper body exercise, overcomes high resistance and is easy to alter variables such as the intensity of exercise [19, 20].

MATERIAL AND METHODS

PARTICIPANTS

A sample of 23 healthy athletes (23 males), students of the Faculty of Physical Education in Prague, were recruited. Participants were required to be between 18–30 years old, with at least 1 year strength training and bench pressing experience (Table 1). The exclusion criteria were hypertension, history of respiratory or neuromuscular disease, pulmonary infection, smoking or drug consumption within 2 weeks before the measurements, as they are known to affect the respiratory function. All subjects needed to have undergone a valid sports-doctor exam.

Table 1. Participants' description (N = 23)

	Min	Max	Avg	SD
Age (y)	20	28	23	2.4
Height (m)	1.73	1.92	1.81	0.52
Weight (kg)	66	100	54.53	9.25

PROTOCOL

The familiarization protocol for each participant (or a group of 3 people maximum) was for 2 x 30 minutes on 2 different days. The second session took place 3 days before measurements presented in this study. During the first and the second session, the tempo of movement and tolerance for the measuring device was tested. 1 RM of BP exercise was tested on the 2nd occasion. The protocol itself did not have an exact form, because every subject needed different time for familiarization, but it consisted mainly of BP of light weight (or a wooden stick) in the proper tempo of movement, repetitive breathing exercise while bench-pressing (inhalation in the eccentric phase of movement and exhalation in the concentric phase), fixing minor lacks of BP technique, and measuring the 1 RM.

After prior assessments had been completed, the experimental session was divided into 3 measuring sessions. The first one took place at 10 am ±2 hours, the second 4 hours later, and the third one 3–4 days apart from the first one. At the beginning volunteers were asked to perform dynamic guided warm-up exercises, consisting of pushups, burpees, and isometric pectoral muscle stretches. After that, the volunteers were asked to perform 3 warm-up maximum expiratory efforts in the sitting position that were followed by 3 sharp maximum expiratory effort measurements, lasting at least for one second. Between the attempts there was a 30-second break. Then followed the bench press part, where volunteers were asked to perform expiration against a mouth pressure measuring device during bench pressing, in the concentric phase of movement. The bench press protocol had the following scheme: 1 repetition with 100% 1RM, 3 repetitions with 90% 1RM, 8 repetitions with 80%

1RM and eventually 12 repetitions with 60% 1RM. Between each set, there was a 3–5 minute recovery break. Sets were in a randomized order. After the last recovery break from the bench press part, volunteers were again asked to perform 3 maximum expiratory efforts in the sitting position, with 30-second breaks between each other. The same scheme was repeated 4 hours later, and 3–4 days apart. Measurements for the third part took place at the same time of day as the first measurement for each participant.

This study was approved by the ethics committee of the Charles University of Physical Education in Prague, the Czech Republic, number 143/2015. All measurements were performed at the same place, in the laboratory of biomechanics and extreme loading. All research was performed according to the declaration of Helsinki. All participants gave their written consent.

Measurements

The main measurements included 3 sessions. The first session was 3 hours apart from the second, and the third session was 3-4 days apart from the first one. Each session consisted of measurement of 3 MEP efforts, followed by BP exercise of intensity: 1 repetition with 100% 1RM, 3 repetitions with 90% 1RM, 8 repetitions with 80% 1RM and eventually 12 repetitions with 60% 1RM. Between each set, there was a 3–5 minute recovery break. Sets were in a randomized order. The session finished with another 3 MEP efforts.

Before the measurements, each participant performed a guided dynamic warm-up, which was followed by 3 warm-up maximum expiratory effort attempts, and 3 sharp-measuring attempts. The maximum inspiration was prior to the maximum expiratory effort for each participant. During bench pressing, each subject was instructed to inhale in the eccentric phase and to exhale during the concentric phase, which is globally the most accepted breathing pattern for low, medium and high intensity bench pressing. In both situations, during maximum expiratory effort in the sitting position and the bench press exhalation, volunteers were wearing a nose clip to prevent unintentional nose air leaks.

Bench press exercise

In this study, a variation of an exercise called flat bench press was used, because it is the most common and accepted compromise between power performance and health. During this variation, the subject makes maximally retracts the scapula and pushes the chest anteriorly, while stably lying in the supine position on the bench. The sitting muscles, the upper part of the back and the head are throughout the whole exercise in contact with the bench. The feet are firmly pushed to the floor, and their position does not change during the exercise. The chest is pushed upwards all the time, abdominal muscles stay firm, and the shoulders are pulled down and in the posterior direction. The back, hips, and the pelvis are contracted all the time. The hand is holding the bar with a thumb grip. After taking the barbell from holders, the exercise starts with extended arms, followed by controlled descent, until the bar touches the chest. The point of touch is approximately the inferior part of pectoral muscles. After a brief pause, there is then a strong fluent push, lifting the bar back to the starting position. The elbows are kept facing down throughout and are positioned in line under the barbell. The shoulders should not go to inner rotation. The trajectory of the bar is rarely straight, but mostly follows the reverse J shape.

For every participant the width of the grip was 81 cm, which in this case did not cause any technique changes connected to anthropometric differences between volunteers. The movement tempo used in this study was 3-0-X-1 (3 s for the eccentric phase, 0 s for the bottom phase, the maximum speed for the concentric phase, 1 second between repetitions) for 90% of 1RM (repetition maximum), 80% 1RM, and 60% 1RM. For 1RM, the tempo was volitional. In all, caution was exercised not to squeeze the chest with the bar, or bump the bar up from chest.

The exercise was performed on a professional Eleiko standardized bench, approved by IPF (161 cm length, 20.50 cm wide, 42.5 cm high) using a calibrated Eleiko powerlifting barbell and weight plates.

Mouth piece device

Maximum expiratory pressure was measured by a mouthpiece, manufactured by Kistler 9203, which is a small, portable, lightweight, non-invasive dynamometer that uses piezo resistive pressure sensing technology, and a low volume rubber mouthpiece that was cut from a diving tube. Both parts were firmly sealed together with silicon glue to avoid air leaks and connected by 1 meter resistance-sensitive optic cable to an amplifier with a recounter. Data were stored by acquisition software DEWESoft7 (version 7.1.2) on a hardware disk, and also displayed in real time. Transferring obtained pC to Pascal was manually set in program Dewesoft using the formula 10 000 Pa = -5.647 pC. This pattern was obtained by a calibration process on exact (0, 5000, 10 000, 20 000, 50 000 Pa) values with a calibrated Druck DPI 705 manometer device. Measuring accuracy was reached by connecting Kistlers 9203, DPI 705 sensor parts by a rubber hose, which had a one-sided valve on its end, for easy manipulation and pressure maintenance. DPI 705 is a digital handheld pressure indicator, with a range from 0 to 700 bar (1000 PSI). The guaranteed 0.1% full scale accuracy (0.7 bar) was tested on this device by pneumatic and hydraulic pressure generator according to assurance Standard ISO9000.

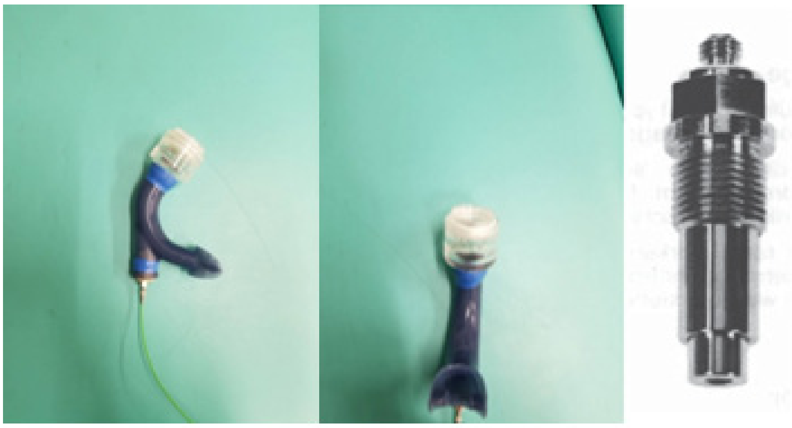

Fig. 1. Assembled mouthpiece presented in this study with pressure sensor detail

Statistical analysis

The data were processed using the Statistica software 13.4 (TIBCO software Inc. 2019, Palo Alto, CA, USA) with possible R software (R Foundation for Statistical Computing, Vienna, Austria) integration with statistical significance set at $p < 0.05$. The basic dataset was presented as mean and standard deviation and standard error (Table 2, 3 and 4). Reliability of the manometer device has been estimated by intraclass correlation coefficient (ICC) and coefficient of variation (CV) across measured repetition in measured trials (during one set of bench press), between different sessions on the same days and between trials 3 to 4 days apart. Although other studies show that for this type of reliability a sample of 11 subjects is enough [11], in this study 23 subjects participated to increase the statistical power of the analyses. For each measuring session, reliability was calculated separately for the maximal sitting expiration, 1RM bench press (BP), 3 x 90% of 1RM BP, 8 x 80% of 1RM BP, 12 x 60% 1RM BP. To assess reliability between repetitions, all successful measurements were taken from session 1, 2 and 3. To assess reliability of intra-session reliability all successful measurements were taken from the first and the second session. To assess intra-day reliability, all successful measurements were taken from the first and the third session.

One way analyses of variance (ANOVA) for repeated measurement were used to compare mouth pressures between sitting VM and BP at different exercise intensities (100%, 90%, 80%, and 60% of 1RM) followed by Dunn's post hoc tests.

RESULTS

The measurement device showed acceptable reliability with ICC ranging from 0.75 to 0.95 (Table 2, 3, 4), where the highest reliability was reached in between repetitions, and slightly decreased when measurements were done at different sessions and days. However, the intra- session and intraday did not differ in reliability values.

The ANOVA showed differences between mouth pressures at different loads ($F_{4, 56}$ = 22.183, $p < 0.001$), where post hoc showed that the highest values were achieved during sitting MEP, and the pressure values during 1 RM and 90% of 1RM were higher than mouth pressure during 80% and 60% of 1RM load.

Table 2. Reliability of peak mouth pressure between repetition during bench press exercise at different exercise intensity

Peak pressure	Mean ±SD (kPa)	ICC	SEM (kPa)	SDD (kPa)	SDD (%)	CV (%)
Sitting expiration	17.23 ±4.3	0.98	0.41	0.86	4.991	24
1 RM	15.1 ±2.2	0.95	0.45	0.44	2.91	15
90% of 1RM	13.3 ±3.42	0.93	0.34	0.684	5.14	25
80% of 1RM	12.5 ±3.6	0.97	0.27	0.72	5.76	29
60% of 1RM	12.6 ±3.3	0.98	0.20	0.66	5.238	26

Legend: RM = repetition maximum, ICC = Intraclass correlation coefficient, SEM = standard error of measurement, CV = coefficient of variation.

Table 3. Intra-session reliability of peak mouth pressure during bench press exercise at different exercise intensity

Peak pressure	Mean ±SD (kPa)	ICC	SEM (kPa)	SDD (kPa)	SDD (%)	CV (%)
Sitting expiration	17.43 +5.02	0.95	0.48	1.004	5.760	29
1 RM	14.80 ±2.7	0.84	0.33	0.54	3.649	19
90% of 1RM	13.3 ±3.42	0.75	0.75	0.684	5.143	25
80% of 1RM	12.71 ±3.31	0.91	0.26	0.662	5.208	26
60% of 1RM	11.7 ±3.43	0.92	0.23	0.686	5.863	29

Legend: RM = repetition maximum, ICC = Intraclass correlation coefficient, SEM = standard error of measurement, CV = coefficient of variation.

Table 4. Intra-day reliability of peak mouth pressure during bench press exercise at different exercise intensity

Peak pressure	Mean ±SD (kPa)	ICC	SEM (kPa)	SDD (kPa)	SDD (%)	CV (%)
Sitting expiration	18.1 ±5.01	0.95	0.54	1.002	5.536	28
1 RM	14.03 ±3.25	0.77	0.29	0.65	4.633	27
90% of 1RM	13.70 ±2.98	0.91	0.19	0.596	4.350	25
80% of 1RM	10.4 ±3.58	0.81	0.28	0.716	6.88	34
60% of 1RM	10.12 ±3.09	0.89	0.19	0.618	6.113	31

Legend: RM = repetition maximum, ICC = Intraclass correlation coefficient, SEM = standard error of measurement, CV = coefficient of variation.

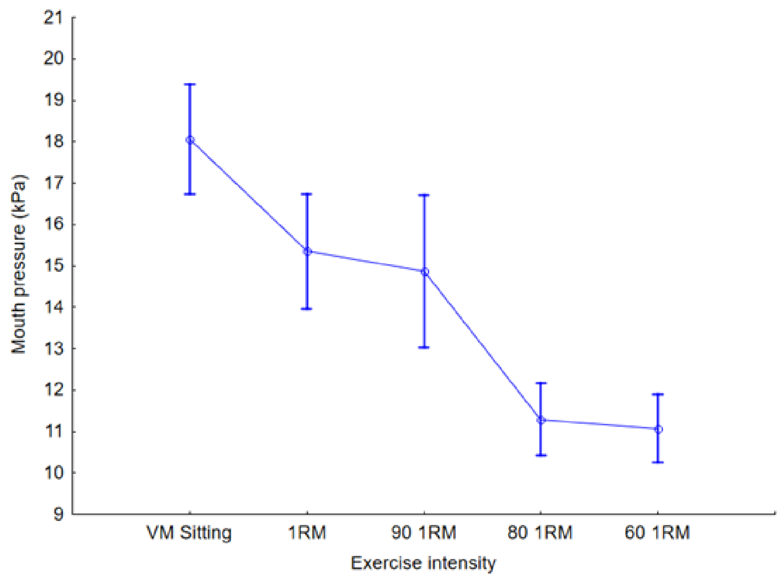

Fig. 2. The differences in mouth pressure during sitting VM and bench press at different lifted load

Legend: RM = repetition maximum, VM Sitting = Valsalva maneuver in the sitting position – maximal expiratory pressure, * significantly higher than all other conditions, ** significantly different from 80% and 60% repetition maximum

DISCUSSION

The measured MP in this study was higher than in other bench press studies [21, 22], results of (18.1 ±5.01 kPa for MEP, 14.03 kPa ±3.25 for 1 100% RM BP, 13.70 ±2.98, for 90% RM BP, 10.4 ±3.58 for 80% RM BP and 10.12 ±3.09 kPa for 60% RM BP) support conclusions of other studies [9, 23] that MP is mainly affected by the body position and then by the intensity of exercise. Higher measured values can be explained by the test sample. This study involves lifting by experienced males who have higher muscle strength and different muscle activation, muscle cooperation and diaphragm activation compared to other groups [24–26].

Since ICC values higher than 0.6 are considered as accepted reliability, and ICC values higher than 0.8 are considered as high reliability measurements [27], this study proves that a well assembled mouthpiece containing Kistler 9203 can be used as a MP measuring tool with high reliability. Our measurements device showed reliability values with ICC ranging from 0.75 to 0.95 (Table 2, 3, 4), where the best results were in between repetition reliability and slightly decreased when measurements were taken on different days. However, the results on two different days did not differ in reliability values.

Several studies [11–13, 15, 17, 28] report reliability of portable MP measuring devices on healthy or breath-connected limitation patients. Hamnegard et al. [13] were comparing simultaneous measurements with a portable manometer versus a laboratory standard machine, with subjects who were healthy or with a respiratory disease, resulting in mean SD difference 0.19 ±0.12 for pImax (average of 1 second in peak of MIP value) and -0.04 ±0.12 kPa for pEmax (average of 1 seconds in MEP peak). However, this study refers more to the accuracy of measurement between 2 devices, rather than reliability. Jalan [29] examined the reliability of a portable manometer in 80 adult subjects. His results were very reliable. The ICC for intra- and inter-rater reliability was 0.96 and 0.92, which is similar to results in our study. Larson [17] measured the reliability once a week for 4 weeks in 91 patients with chronic obstructive pulmonary disease with an aneroid gauge, with test-retest reliability coefficient r = 0.97 for pImax. Maillard et al. [28] also measured MIP in young healthy people with a portable manometer with ICC 0.88–0.92. Moreover, Dimitriadis et al. [11] tested reliability of a piezo-sensitive crafted mouth-piece device on 15 healthy volunteers. Their results for sitting MIP and MEP (ICC 0.86–0.90, SEM 9–10, SDD 18–22) and the standing position (ICC 0.78–0.83, SEM 12–14, SDD 23–26) reached reliability from 2 measured expiratory/inspiratory maneuvers on each from 3 testing occasion with (ICC > 0.90). The ICC for MEP in this study has similar values (0.95–0.98) and decreases as the sport activity (BP) is added. However, the lowest measured ICC during BP was 0.75, which is still very strong reliability. The amount of measured maneuvers during each part of this study is for each participant except for 1 RM every time was higher than or equal to 3, for increasing the power of the test.

Dimitriadis et al. [11] also presents in their study of 15 healthy volunteers grand mean values for MEP in the sitting position and the standing position. The results for both positions were the same (20.3 kPa). Compared to our mean result (17.23 kPa) for healthy athletes, they were significantly higher. In addition, their measured values for standing and sitting position do not correspond with results of other studies, concluding that tights closer to the chest position is more suitable for abdominal muscle force production, resulting in higher sitting MP generation, rather than standing [21].

One of the most complex studies [21] on bench press, leg press, dead lift, slide row and box lift reports measurements of VM at intensity of 50, 75 and 100% of 4 RM. Their peak MP values were 8.7 ±2.4 kPa, 12 ±3.5 kPa, 14 ± 4.4 kPa for dead lift, 9.5 ±3.1 kPa, 11.5 ±2.8 kPa and 14.8 ±2.5 kPa for box lift, 7.6 ±4.4 kPa, 9.9 ±5.2 kPa, 11.7 ± 4.3 kPa for slide row, 6 ±2 kPa, 9.9 ±3.6 kPa, 17.3 ±3.7 kPa for leg press, 7.6 ±2 kPa, 8.9 ±2.8 kPa, 13. ±4.9 kPa for bench press and 22.2 ±6 kPa for MEP. The highest values were reached during MEP, followed by leg press, dead lift, box lift, slide row and bench press. These results support the conclusion that exercise selection plays the main role in generating MP, and is further dependent on the intensity of exercise and the lifted load.

CONCLUSIONS

This study shows acceptable reliability of MP measurement by a mouthpiece device with a piezo-resistant sensor. The MP depends on the exercise intensity during the bench press and is higher when sitting compared with the supine body position.

REFERENCES

[1] Hartz CS, Sindorf MAG, Lopes CR, Batista J, Moreno MA. Effect of inspiratory muscle training on performance of handball athletes. J Hum Kinetics. 2018;63:43-51. https://doi.org/10.2478/hukin-2018-0005

[2] Hemborg B, Moritz U, Lowing H. Intra-abdominal pressure and trunk muscle activity during lifting. IV. The causal factors of the intra-abdominal pressure rise. Scand J Rehab Med. 1985;17(1):25-38.

[3] Sheikh SA, Untoo RA, Lone IA, Shaheen N. Maculopathy: A rare association of the Valsalva manoeuvre (Valsalva maculopathy). BMJ Case Reports. Jan 2010, 2010 bcr0820080760. https://doi.org/10.1136/bcr.08.2008.0760

[4] Haykowsky MJ, Eves ND, DE RW, Findlay MJ. Resistance exercise, the Valsalva maneuver, and cerebrovascular transmural pressure. Med Sci Sport Exerc. 2003;35(1):65-8. https://doi.org/10.1097/00005768-200301000-00011

[5] Niewiadomski W, Pilis W, Laskowska D, Gasiorowska A, Cybulski G, Strasz A. Effects of a brief Valsalva manoeuvre on hemodynamic response to strength exercises. Clin Physiol Funct Imaging. 2012;32(2):145-57. https://doi.org/10.1111/j.1475-097X.2011.01069.x

[6] Compton D, Hill PM, Sinclair JD. Weight-lifters' blackout. Lancet (London, England). 1973;2(7840):1234-7. https://doi.org/10.1016/S0140-6736(73)90974-4

[7] Syabbalo N. Assessment of respiratory muscle function and strength. Postgraduate Med J. 1998;74(870):208-15. https://doi.org/10.1136/pgmj.74.870.208

[8] Polkey MI, Green M, Moxham J. Measurement of respiratory muscle strength. Thorax. 1995;50(11):1131-5. https://doi.org/10.1136/thx.50.11.1131

[9] MacDougall JD, Tuxen D, Sale DG, Moroz JR, Sutton JR. Arterial blood pressure response to heavy resistance exercise. J Appl Physiol. 1985;58(3):785-90. https://doi.org/10.1152/jappl.1985.58.3.785

[10] Niewiadomski W, Pilis A, Strasz A, et al. In aged men, central vessel transmural pressure is reduced by brief Valsalva manoeuvre during strength exercise. Clin Physiol Funct Imaging. 2014;34(3):191-8. https://doi.org/10.1111/cpf.12080

[11] Dimitriadis Z, Kapreli E, Konstantinidou I, Oldham J, Strimpakos N. Test/retest reliability of maximum mouth pressure measurements with the MicroRPM in healthy volunteers. Respir Care. 2011;56(6):776-82. https://doi.org/10.4187/respcare.00783

[12] Romer LM, McConnell AK. Inter-test reliability for non-invasive measures of respiratory muscle function in healthy humans. Eur J Appl Physiol. 2004;91(2-3):167-76. https://doi.org/10.1007/s00421-003-0984-2

[13] Hamnegard CH, Wragg S, Kyroussis D, Aquilina R, Moxham J, Green M. Portable measurement of maximum mouth pressures. Eur Respir J. 1994;7(2):398-401. https://doi.org/10.1183/09031936.94.07020398

[14] Larson JL, Covey MK, Vitalo CA, Alex CG, Patel M, Kim MJ. Maximal inspiratory pressure. Learning effect and test-retest reliability in patients with chronic obstructive pulmonary disease. Chest. 1993;104(2):448-53. https://doi.org/10.1378/chest.104.2.448

[15] McConnell AK, Copestake AJ. Maximum static respiratory pressures in healthy elderly men and women: Issues of reproducibility and interpretation. Respiration. 1999;66(3):251-8. https://doi.org/10.1159/000029386

[16] De Troyer A, Borenstein S, Cordier R. Analysis of lung volume restriction in patients with respiratory muscle weakness. Thorax. 1980;35(8):603-10. https://doi.org/10.1136/thx.35.8.603

[17] Larson JL, Covey MK, Vitalo CA, Alex CG, Patel M, Kim MJ. Maximal inspiratory pressure: Learning effect and test-retest reliability in patients with chronic obstructive pulmonary disease. Chest. 1993;104(2):448-53. https://doi.org/10.1378/chest.104.2.448

[18] Caruso P, Albuquerque AL, Santana PV, et al. Diagnostic methods to assess inspiratory and expiratory muscle strength. Jornal brasileiro de pneumologia : publicacao oficial da Sociedade Brasileira de Pneumologia e Tisilogia. 2015;41(2):110-23. https://doi.org/10.1590/S1806-37132015000004474

[19] Wilk M, Gepfert M, Krzysztofik M, et al. The Influence of Grip Width on Training Volume During the Bench Press with Different Movement Tempos. J Hum Kinetics. 2019;68:49-57. https://doi.org/10.2478/hukin-2019-0055

[20] Wilk M, Golas A, Stastny P, Nawrocka M, Krzysztofik M, Zajac A. Does tempo of resistance exercise impact training volume? J Hum Kinetics. 2018;62:241-50. https://doi.org/10.2478/hukin-2018-0034

[21] Harman EA, Frykman PN, Clagett ER, Kraemer WJ. Intra-abdominal and intra-thoracic pressures during lifting and jumping. Med Sci Sport Exerc. 1988;20(2):195-201. https://doi.org/10.1249/00005768-198820020-00015

[22] Adams J, Schmid J, Parker RD, et al. Comparison of force exerted on the sternum during a sneeze versus during low-, moderate-, and high-intensity bench press resistance exercise with and without the Valsalva manoeuvre in healthy volunteers. Am J Cardiol. 2014;113(6):1045-8. https://doi.org/10.1016/j.amjcard.2013.11.064

[23] Blazek Dusan SP. Systematic review of intra-abdominal and intrathoracic pressures initiated by the Valsalva manoeuvre during high-intensity resistance exercise. Biol Sport. 2019;36(4):373-386. https://doi.org/10.5114/biolsport.2019.88759

[24] Gołaś A, Maszczyk A, Pietraszewski P, et al. Muscular activity patterns of female and male athletes during the flat bench press. Biol Sport. 2018;35:175-9. https://doi.org/10.5114/biolsport.2018.74193

[25] Cresswell AG, Blake PL, Thorstensson A. The effect of an abdominal muscle training program on intra-abdominal pressure. Scand J Rehab Med. 1994;26(2):79-86.

[26] Al-Bilbeisi F, Mc CF. Diaphragm recruitment during nonrespiratory activities. Am J Respir Critical Care Med. 2000;162(2 Pt 1):456-9. https://doi.org/10.1164/ajrccm.162.2.9908059

[27] Richman J ML, Prince B. Research methodology and applied statistics; Part 3: Measurement procedures in research. Physiother Can. 1980;32(4):253-257.

[28] Maillard JO, Burdet L, van Melle G, Fitting JW. Reproducibility of twitch mouth pressure, sniff nasal inspiratory pressure, and maximal inspiratory pressure. Eur Respir J. 1998;11(4):901-5. https://doi.org/10.1183/09031936.98.11040901

[29] Jalan NS, Daftari SS, Retharekar SS, Rairikar SA, Shyam AM, Sancheti PK. Intra- and inter-rater reliability of maximum inspiratory pressure measured using a portable capsule-sensing pressure gauge device in healthy adults. Can J Respir Ther. 2015;51(2):39-42.

Cite this article as:

Blazek D, Pisz A, Pecha O, Petr Kubový P.
The reliability and intensity dependence of maximum mouth pressure during bench press exercise in healthy athletes
Balt J Health Phys Act. 2020;12(1):1-10
doi: 10.29359/BJHPA.12.1.01