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Research Article

Efficacy of Rapid Inspiratory Bouts Followed by Sustained Expiration on Maximal Force Generation During Isometric Exercise

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I N F O

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A B S T R A C T

Introduction: Isometric is a static type of exercise in which the strength of muscle is increased due to an increase in tension in the muscle fibres, but many health professionals are against the use of isometrics due to its adverse effect on the cardiovascular system.

Objective: The objective of the current research is to examine the impact of rapid inspiratory bouts followed by sustained expiration on maximal force generation during isometrics.

Methodology: Forty patients with lower limb weakness performed rapid inspiratory bouts followed by sustained expiration while performing isometrics of the quadriceps and hamstrings muscle group. The strength of patients was measured by a hydraulic hand dynamometer. This study assessed pre- and post-isometric results. In the pre-session, participants were asked to do 10 repetitions of isometrics of the quadriceps and hamstring muscle group according to their own method. Then after 10 minutes, they were taught to take several gulps of inspiration and to expire in a controlled way while exerting force on a dynamometer. The mean of all repetitions was calculated.

Results: On comparing the two sessions, the maximal force generation was increased in the quadriceps muscle group ($p < 0.001$) and hamstrings ($p < 0.001$) while doing isometrics with the use of rapid inspiratory bouts followed by sustained expiration while doing isometrics.

Conclusion: Therefore the study concludes that taking rapid inspiratory bouts followed by sustained expiration has a significant effect on the strength of muscles.

Keywords: Rapid Inspiratory Bouts, Isometrics, Maximal Force, Valsalva Manoeuvre, Quadriceps, Hamstrings

Introduction

Isometric exercise is a type of static exercise which is described as a contraction of muscle at a fixed joint angle.[1] In this type of exercise, the joint is at rest which means movement of the limb does not take place. There is no change in the length of muscle fibre. There is only a shortening of

muscle fibres at the initial state. This type of contraction does not produce work because work done is equal to force multiplied by distance. In this type of exercise, muscle tension increases.[2] The level of muscle tension is dictated by the number of cross-bridges established between the thick and thin myofilaments throughout a contraction. These protein filaments collaborate during muscle contraction. Isometric exercises provide extended time at specific joint angles, facilitating the formation of a higher number of cross-bridges, ultimately resulting in maximal tension. The heightened tension in muscle fibres, induced by isometric training, has demonstrated the enhancement of muscle group strength. To achieve this improvement, the training must subject the muscle to tensions equivalent to or surpassing 50% of its maximal capacity.[3–5] Isometric exercises are important for strengthening of muscles. They enhance the stabilisation of the joint. Isometric exercises are preferred in the immobilisation phase of the patient. It results in the atrophy of muscle. Atrophy can cause a decrease in the bone density and size of muscle mass. Thus, as a preventive measure, immobilised patients are advised to do isometrics.[2] It is also helpful for someone who has suffered from injury which could make movement more painful.

However, many health professionals are against the use of isometric exercises because they may have adverse effects on a patient's body.[3] Sometimes patients take a breath before contraction and hold their breath during contraction. It may cause Valsalva manoeuvre. It is a breathing technique in which the patient exhales forcefully against the closed glottis.[2] Yet nevertheless, it imposes adverse haemodynamic effects on the cardiovascular system, such as elevated blood pressure and increased heart rate.[4] Increasing blood pressure can cause vascular complications in future, for example, cerebral haemorrhage. Some patients take breath during contraction and it can reduce the generation of force. Some patients don't have control over their breath during exercise. In this case, the patient may hyperventilate. Major cardiovascular change during isometric is a rise in blood pressure. Two major controlling systems are mainly observed during isometric exercises (peripheral and central). They both work coordinately.[2,5] Chemoreceptors from working muscle stimulate type III & IV fibres and mechanoreceptors detect a change in tension. These fibres travel along the spinothalamic tract to the cardiovascular centre situated in the medulla. The input from these fibres leads to a reduction in vagal activity while stimulating sympathetic non-adrenergic receptors, thereby increasing both heart rate and contractility. Additionally, there is an elevation in sympathetic tone, resulting in vasoconstriction of various intra-abdominal vessels such as the splenic and renal vessels. Baroreceptors detect the heightened pressure and initiate efforts to stabilize blood pressure, though they may not prevent the overall increase. This intricate process constitutes a reflex peripheral-central control mechanism loop.[3]

Inspiratory bout means taking maximum air inside the lungs during the inspiration phase. In sustained expiration, the patient has to breathe out slowly for up to 8–10 sec. Maximal force generation is the maximal contraction done by a particular muscle in 10 sec. To achieve maximal force production, expiration (particularly forced expiration or the Valsalva manoeuvre) should be synchronised with the forceful phase of the movement.[5] In this method, the patient has to take a deep breath before contraction and then has to breathe out slowly while exerting pressure or contraction. This study examines the relationship between breathing patterns and force generation during isometric exercises. Therefore this study aims to find out the effectiveness of rapid inspiratory bouts followed by sustained expiration during isometric exercises.

Method

This study was carried out at the Krishna College of Physiotherapy, Karad. Ethical approval was received from the ethical committee of Krishna Vishwa Vidyapeeth, Karad. All participants were informed about the aim and process of the study and informed consent was obtained. They were free to participate or withdraw from the study. Eligible patients were randomly allocated to an experimental and control group. Exercises were given for 6 days a week for 4 weeks.

Forty subjects exhibiting lower limb weakness were recruited for participation. The inclusion criteria encompassed both male and female individuals within the age range of 18–65 years, specifically selecting subjects with prior experience in isometric training. This deliberate selection aimed to focus on exploring the phenomenon and evaluating the potential influence of ventilation on muscle strength. The patients with cardiovascular risks like hypertension, recent MI–CABG and unhealed fractures were excluded. This study had two sessions. In the first session, the subject had to do 10 repetitions of isometrics of the quadriceps and hamstrings with their own method. The average of all repetitions was calculated.

Then a 10-minute gap was given, after which, the patient was asked to take 3–5 gulps or breathe deeply and expire slowly while exerting force. An average of 10 repetitions was calculated. The force and breathing data were measured

Statistical Analysis

The data from this investigation is presented as mean and standard deviation. Statistical analysis was conducted using Instat, and the strength of each muscle group was compared using a paired t-test.

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Results

The subjects performed rapid inspiratory bouts followed by sustained expiration for isometrics of the quadriceps and hamstrings muscle group. For quadriceps, the muscle group mean of all repetitions in the pre-session was 29.66125 while the standard deviation was 4.527. In the post-session, the mean was 35.104 and the standard deviation was 5.394. The paired t value was 12.523 with 39 degrees of freedom and the p value was < 0.0001 (Table 1).

For the hamstring muscle, the group mean of all repetitions in the pre-session was 25.0783 while the standard deviation was 3.393, and in the post-session, the mean was 29.915 and the standard deviation was 4.568. The paired t value was 12.999 with 39 degrees of freedom and the p value was < 0.0001 (Table 2).

Table 1.Pre- and Post-Test Values for Quadriceps Muscle

Quadriceps Muscle	Mean	Standard Deviation	Paired t Value	p Value
Pre-test	29.66125	4.527	12.523 with 39 degrees of freedom	< 0.0001
Post-test	35.104	5.394	12.523 with 39 degrees of freedom	< 0.0001

Table 2.Pre- and Post-Test Values for Hamstring Muscle

Hamstrings Muscle	Mean	Standard Deviation	Paired t Value	p Value
Pre-test	25.0783	3.393	12.999 with 39 degrees of freedom	< 0.0001
Post-test	29.915	4.568	12.999 with 39 degrees of freedom	< 0.0001

Discussion

Isometric exercise is a type of static exercise which is described as a contraction of the muscle at a fixed joint angle.[1] There is no change in the length of muscle fibre. In this type of exercise, muscle tension increases. Indeed, isometric training has demonstrated effectiveness in enhancing the strength of a targeted muscle group,[1] but many health professionals are against the use of isometric exercises because it may have adverse effects on the patients' bodies.[2] Some patients take breath during contraction and it can reduce the generation of force.[2] Some patients do not have control over their breath during exercise. In this case, the patient may hyperventilate. Some patients expire forcefully against glottis can cause Valsalva manoeuvre. Yet, it imposes adverse haemodynamic effects on the cardiovascular system, exemplified by an increase in blood pressure and an increased heart rate.[4,5] Increasing blood pressure can cause vascular complications in future for example cerebral haemorrhage.[2,3]

Previous studies have been done on different breathing techniques and their efficiency on the strength of larger to smaller muscle groups. They concluded that maximum inspiration can increase the strength of muscles. To minimise the cardiovascular risk related to the Valsalva manoeuvre, the person has to concentrate on exhaling while doing strength training. In this study, 40 samples were taken, of which, 21 were female and 19 were male. The age group of the participants was 15–65 years. This study was divided into two sessions. In the first session, the subject was asked to perform 10 repetitions of isometrics of quadriceps and hamstrings with their prior method. The average of all repetitions was calculated. Then a 5–7-minute gap was given, after which, the patient was asked to take 3–5 gulps or breathe deeply and expire slowly while exerting force. The average of 10 repetitions was calculated and force and breathing data were measured.

Our findings align with previous studies that have highlighted the advantages of incorporating isometric exercise into strength training, corroborating its positive effects.[2] Additionally, in line with prior research, strength training involving isometrics has shown significant pain reduction. Furthermore, voluntary breathing has been identified as a potential modulator for the motor drive to non-respiratory muscles.[2] Earlier studies have indicated that the impact of voluntary breathing on the motor drive to non-respiratory muscles is contingent on the respiratory phase and muscle specificity.[3] Cerebral autoregulatory responses are seen during the Valsalva manoeuvre due to the presence of sympathetic activation during the Valsalva manoeuvre elicited by the baroreflex.[6]

According to a previous study, there is a correlation between higher tension and increased fatigue, for instance, a 20% maximal voluntary contraction (MVC) can be sustained for 10–12 minutes, whereas at 30% MVC, the duration decreases to 5 minutes, and at 50% MVC, it further reduces to 1-2 minutes. This reduction in endurance is attributed

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to the fact that blood flow to the muscle is not in a steady state.[7–9] Notably, blood pressure and heart rate continue to rise until reaching the point of maximum fatigue. Also, for a patient with postural dizziness, the use of appropriate isometric exercises can help to change cardiovascular response by increasing blood pressure or by generalized vasoconstriction with inactive tissues.[1–5,10] Therefore taking rapid inspiratory bouts while exhaling can help to induce generalised relaxation which can be useful to stabilise cardiovascular parameters and minimise fatigue. Valsalva also alters cerebral haemodynamics by both the mechanical effects of changes in intrathoracic pressure and the elicited autonomic neural activity.[6,11,12]

An overall quality of life on the basis of muscle performance and functional independence was found to be better in the patients. The more likely reason for it could be better the treatment of choice, the use of this breathing technique and the early physiotherapeutic approach.

Some limitations must be taken into consideration while interpreting the results of the study. One limitation was that there was no data interpreted before physiotherapy treatment, so comparison was difficult. The present study was carried out at a single institution with a limited sample size and limited conditions therefore generalisation was difficult. For upper limb isometrics, the results may vary. Also, only one outcome measure was taken, therefore the result of this study was limited.

Conclusion

This study demonstrated that rapid inspiratory bouts followed by sustained expiration can influence the muscle strength of large muscles of the body.

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Conflict of Interest: None

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