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Bensu Sogut, PT, MSc[1]
Deniz Can Sahin, PT[1]
Damla Arslan, PT[1]
Sercan Yilli, PT[1]
Sumeyya Tarkan, PT, MSc[2]
Gulcan Harput, PT, PhD[1]

1 Hacettepe University, Faculty of Physical Therapy and Rehabilitation, Samanpazarı, Ankara, Turkey.
2 Dokuz Eylul University, School of Physical Therapy and Rehabilitation, Balcova, Izmir, Turkey.

Correspondence (İletişim):

Bensu SOGUT, PT, MSc
Hacettepe University,
Faculty of Physical Therapy and Rehabilitation,
06100 Samanpazarı, Ankara, Turkey
Phone: +90-312 281 42 08
E-mail: bensusogut@gmail.com
ORCID ID: 0000-0001-8897-2848

Deniz Can SAHIN
E-mail: denizcnsahin@gmail.com
ORCID: 0000-0002-7800-7400

Damla ARSLAN
E-mail: damlarslan93@gmail.com
ORCID: 0000-0001-6458-6520

Sercan YILLI
E-mail: sercanyilli@gmail.com
ORCID: 0000-0003-4303-4836

Sumeyya TARKAN
E-mail: sumeyya.yalki@gmail.com
ORCID: 0000-0002-6921-9321

Gülcan HARPUT
E-mail: aktasgulcan@gmail.com
ORCID: 0000-0003-2298-0807

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THE EFFECTS OF ABDOMINAL BRACING MANEUVER ON QUADRICEPS MUSCLE TORQUE, TIME TO PEAK TORQUE AND MUSCLE ACTIVATION LEVELS AT DIFFERENT KNEE FLEXION ANGLES

ORIGINAL ARTICLE

ABSTRACT

Purpose: The aim of the present study was to investigate the effects of abdominal bracing maneuver (ABM) on quadriceps peak torque (PT), time to peak torque (TTPT) and muscle activation levels during maximal strength testing of the quadriceps muscle in healthy individuals.

Methods: Sixteen healthy individuals (Age: 24.63±1.67 years) participated in the present study. Each participant was taught ABM technique by a physical therapist's guidance. Surface electromyography was used to measure internal oblique/transversus abdominis, vastus medialis, vastus lateralis, and rectus femoris activation levels. Isokinetic dynamometry was used to measure quadriceps PT and TTPT during maximum isometric muscle testing at 60° and 90° of knee flexion angles with and without ABM. Repeated measures of ANOVA was performed for statistical analysis.

Results: There was a significant angle by condition interaction for quadriceps PT ($F(1,15)=5.30$, $p=0.04$). PT decreased when ABM was performed, but the decrease was greater at 60° compared to 90° of knee flexion (60°: $p=0.001$, ES=0.68; 90°: $p=0.008$, ES=0.33). Quadriceps activation levels also decreased during ABM ($p=0.04$) regardless of knee flexion angle.

Conclusion: The present study revealed that ABM may decrease muscle activation levels and peak torque during maximal quadriceps strength testing. Researchers should evaluate compensatory movements of the lumbopelvic region in order to prevent the error of force transfer in test results.

Key Words: Electromyography, Knee joint, Maximal Strength

ABDOMINAL BRACING MANEVRASININ FARKLI DİZ FLEKSİYON AÇILARINDA, KUADRİSEPS ZİRVE TORKU, ZİRVE TORKA ULAŞMA SÜRESİ VE KAS AKTİVASYONU ÜZERİNE ETKİSİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Bu çalışmanın amacı sağlıklı bireylerde abdominal bracing manevrasının (ABM) maksimal kuvvet testi sırasında kuadriseps zirve torku (ZT), zirve torka ulaşma süresi ve kas aktivasyonuna etkisini araştırmaktı.

Yöntem: Bu çalışmaya 16 sağlıklı birey (Yaş: 24,63±1,67 yıl) katılım gösterdi. Her bireye fizyoterapist tarafından ABM tekniği öğretildi. Internal oblik/transversus abdominis, vastus medialis, vastus lateralis ve rektus femoris kaslarının aktivasyonu ölçümünde yüzeysel elektromyografi kullanıldı. Maksimal izometrik test sırasında kuadriseps ZT ve zirve torka ulaşma süresi değerleri 60° ve 90° diz fleksiyon açılarında izokinetik dinamometre ile ölçüldü. İstatistiksel analizde tekrarlı ölçümler ANOVA kullanıldı.

Sonuçlar: Kuadriseps ZT değerinde, duruma göre açı etkileşimi anlamlı bulundu ($F(1,15)=5,30$, $p=0,04$). ZT değerleri her iki diz açısında da ABM ile düştü ancak düşüş 60° diz fleksiyon açısında 90°'ye göre daha fazla idi (60°: $p=0,001$; ES=0,68; 90°: $p=0,008$, ES=0,33). Kuadriseps kas aktivasyonunda da ABM ile düşüş olduğu görüldü ($p=0,04$).

Tartışma: Yapılan çalışma sonuçları maksimal kuadriseps kas testi sırasında hem ZT hem kas aktivasyon seviyelerinin düştüğünü göstermektedir. Araştırmacılar test sonuçlarında kuvvet aktarımının sebep olacağı yanılmayı engellemek için lumbopelvik bölgenin kompansatuar hareketlerini değerlendirmelidir.

Anahtar Kelimeler: Elektromyografi, Diz Eklemi, Maksimal kuvvet

INTRODUCTION

Volitional preemptive abdominal contraction (VPAC) techniques aim to increase abdominal muscle activation voluntarily with different strategies. VPAC is commonly preferred to prevent compensatory lumbopelvic motions during functional activities and/or exercises (1, 2). There is a general thought among clinicians that the exercises are more effective if they are performed with VPAC, since VPAC enhances lumbopelvic control via producing lumbar multifidus co-contraction (3). Previous researches support that idea where the activation levels of the targeted muscles increase with VPAC during both lower and upper extremity exercises in healthy individuals (4-6).

VPAC has been applied with different methods such as abdominal draw-in maneuver (ADM) (or abdominal hollowing) and abdominal bracing maneuver (ABM). The ADM emphasizes the activation of abdominal core muscles including the transversus abdominis (TrA) and internal oblique (IO) muscles (7, 8) while ABM involved the global co-contraction of abdominal wall muscles (9, 10). Compared to ADM, ABM has been shown to be more effective for stabilizing the spine as it increases spinal stiffness (2, 11). Moreover, Haddas et al. (12) suggested that ABM might reduce biomechanical factors associated with anterior cruciate ligament injury since it enhanced pelvic stability and improved lower extremity alignment during landing from jump.

Previous studies found that hip muscle activation levels were greater with increased abdominal muscles' co-activation while performing functional lower extremity exercises (13-15). Similarly, Harput et al. (6) reported that quadriceps activation levels increased with ADM during unilateral lower extremity exercises. However, the previous studies investigated the VPAC effects on muscle activation levels during therapeutic exercises which were performed with body weight. Thus, there is limited knowledge about how ABM affects a targeted muscle during maximal strength testing. Tayashiki et al. (16) reported that ABM increased the hip extension torque by increasing intra-abdominal pressure, which radiates the force to weaker muscles in the lower extremities. In another study about intra-abdominal pressure and its relationship with gluteus maximus and hamstring muscle size and hip extension torque showed that only hip extensor torque was related to intra-abdominal pressure (17). Although there is evidence that showed ABM increased hip extensor maximal strength in the prone position in healthy individuals, there is no study to document the effects of ABM on quadriceps maximal torque and activation in the healthy population.

Therefore, the aim of the present study was to investigate the effects of ABM on the quadriceps peak torque and time to peak torque, and quadriceps activation levels during maximum isometric quadriceps strength testing at different knee flexion angles in healthy individuals. It is hypothesized that quadriceps peak torque and activation levels decreased, while time to peak torque would increase with ABM during maximal isometric knee extension muscle testing.

METHODS

Participants

The sample size was calculated according to study by Barbosa et al. (13) by using the G-POWER software (Version 3.1.5, Franz Faul, Universitat Kiel, Germany). To achieve 0.90 power, considering the effect size of 1.12 and significance level <0.05 between two different conditions in terms of quadriceps EMG amplitudes, a sample size of minimum 11 participants were necessary (with and without abdominal bracing).

Sixteen healthy individuals (8 Male, 8 Female; age: 24.6±1.7 years; BMI: 21.8±2.1 kg/m^2), between 18-30 years of age, participated in this study. Participants were excluded if they had any systemic/neurological problems, had a BMI higher than 25 kg/m^2, had a lower extremity injury in the last year, and had experience in core stability training (Table 1).

Table 1. Demographic Characteristics of the Participants

N=16 (8 Male, 8 Female)	Mean±SD
Age (years)	24.63±1.67
Height (cm)	171.63±10.47
Body mass (kg)	65.94±13.65
Body mass index (kg/m^2)	21.80±2.13

This cross-sectional study was conducted at Hacettepe University Faculty of Physical Therapy and Rehabilitation between March-June of 2020. Ethical approval was given by the Uskudar University Institutional Review Board, and the study was performed according to the Declaration of Helsinki. Written informed consent was obtained from each subject prior to the study.

Testing Procedures

The physical characteristics of the participants were recorded and their dominant limbs were identified. The dominant limb was defined as the leg used to kick a ball (6).

Quadriceps peak torque and time to peak torque, and quadriceps muscle activation levels of the dominant limb were measured during quadriceps maximum voluntary isometric contraction (MVIC) at different knee flexion angles with and without ABM. Internal Oblique/Transversus Abdominis (IO/TA) muscle activation levels during muscle strength testing were measured bilaterally.

Electromyography (EMG)

Electromyographic data processing of the IO/TA, Vastus Medialis Obliquus (VMO), Vastus Lateralis (VL), and Rectus Femoris (RF) muscles during the quadriceps isometric muscle strength testing were accomplished using a surface EMG system (TELEmyo DTS; Noraxon USA, Inc, Scottsdale, AZ, USA). The identified locations for surface electrode placement were shaved, were abraded, and were cleaned using 70% isopropyl alcohol before testing. Bipolar Ag/AgCl surface electrodes were placed at an interelectrode distance of 2 cm (1-cm diameter). The common-mode rejection ratio was greater than 80 Db, and the input impedance was greater than 10 mΩ. The sampling rate for EMG data was 1500 Hz. SENIAM's European Recommendations for Surface EMG was used to make the placement of electrodes for each muscle (18). The electrodes were placed bilaterally for the IO/TA muscles and only on the dominant limb for the VMO, RF, and VL muscles.

Prior to quadriceps isometric muscle strength testing, bilateral IO/TA muscle activation levels were measured during 5-second MVIC and it was used to normalize IO/TA muscle activation levels during quadriceps strength testing with and without ABM. The participant was laid in the supine position with hips and knees flexed 90°, feet were supported, and the trunk was maximally flexed and rotated to the right, for the IO/TA MVIC evaluation. The examiner applied manual resistance at the shoulders by pushing the trunk extension and left rotation directions (19, 20). MVIC testing was repeated three times. Two-minute rest was provided between repetitions.

Isometric quadriceps muscle strength testing

An isokinetic dynamometer (IsoMed®2000 D&R GmbH, Germany) was used to measure the isometric quadriceps PT and TTPT at 60° and 90° of knee flexion. We selected two knee flexion angles for quadriceps isometric muscle strength testing since there is no consensus in the literature for the optimal knee flexion angle for PT of the quadriceps muscle. These two angles were mainly preferred for MVIC testing for quadriceps in previous studies (21).

The participants were seated with their hip at approximately 90° of flexion. To prevent compensatory movements, the trunk, hip, waist, and distal femur were stabilized by straps. The dynamometer's laser was used to align the axis of the dynamometer to the lateral femoral epicondyle. The force arm of the dynamometer was secured two centimeters above the lateral malleolus. The Knee flexion angle was set at 60° and 90° in a randomized order.

To familiarize themselves with the testing procedures the participants were allowed three maximal isometric quadriceps contractions. During the testing, the participants performed three MVICs (each 5-sec duration) with 2-min rest intervals. The participants were instructed to push the lever arm of the dynamometer as strongly as possible. They were not allowed to hold the handgrips along the seat to prevent any additional force and were asked to put the hands just above the shoulder straps with crossed forearms on the chest. Standard verbal encouragements were provided for each individual and also visual feedback which is known to improve the real-time force values was provided throughout the test via a computer monitor (22).

Abdominal Bracing Maneuver

After completing quadriceps isometric testing without ABM, the participants rested 15 minutes and then, they were taught the ABM by a physiotherapist (14, 23). The participants were instructed to co-contract their abdominal muscles, without changing in upper body position and hollowing the lower abdomen (16). Real-time EMG feedback (TELEmyo DTS; Noraxon USA, Inc, Scottsdale, AZ, USA) was used to check the level of the IO/TA activations of the participants. Participants practiced till they reached IO/TA muscle activation to 20% MVIC (15) in their ipsilateral (dominant limb side) side and held that contraction for at least 10 seconds. We only checked IO/TA muscles activations since it is harder to contract these deep muscles compared to rectus abdominis and external oblique muscles. Previous studies demonstrated that IO/TA activation levels were higher during ABM (24, 25). The training took approximately 15-20 minutes until the participants were able to contract their IO/TA muscles easily in the sitting position. Then, the quadriceps isometric strength procedure was repeated while performing ABM.

EMG-Signal Processing

Noraxon Myo-Research XP Master Edition software (Noraxon USA, Inc) was used to accomplish EMG data processing. The EMG signals were rectified, were band-pass filtered (20-450 Hz), and were smoothed using a root-mean-square moving-window function with a time constant of 100 milliseconds. During quadriceps isometric muscle strength testing, maximum EMG signals of VMO, RF, and VL were calculated. The sum of the VMO, RF, and VL activation levels was expressed as the quadriceps activation level.

IO/TA muscle activation levels during isometric quadriceps strength testing were normalized to MVIC values and were expressed as MVIC %. For each of the MVIC trials, the maximum value obtained over the 5-second maximum effort was recorded, and the maximum of three MVIC trials was used for normalization of the IO/TA EMG data.

Statistical analysis

The data obtained in the present study were evaluated using the IBM SPSS 21.0 (IBM Corporation, Armonk, NY, USA). Data were expressed as means and standard deviations for descriptive data. The normality of EMG data was tested with the Shapiro-Wilk Test. A repeated-measures analysis of variance was performed to determine the angle (60° and 90° of knee flexion) by condition [Neutral activation (NA) and ABM] interaction for PT, TTPT, and quadriceps activation levels. If a significant interaction was observed, post hoc t-tests were used. A change in muscle activation level with ABM was reported with effect size. Cohen's d-coefficient was used to calculate the magnitude of effect size for all variables. An effect size greater than 0.80 was considered as large; 0.5 to 0.79 as moderate; 0.49 to 0.20 as small; and 0.19 to 0 as negligible (26). Significance levels were set at $p<0.05$.

With 16 participants, 98% power was achieved in quadriceps activation and peak torque.

RESULTS

Abdominal activation

Angle by condition interaction was significant neither for ipsilateral side ($F(1,15)=5.20$, $p=0.04$) nor for contralateral side ($F(1,15)=0.96$, $p=0.35$) IO/TA muscle activation levels. The IO/TA activation levels of the both sides increased with ABM ($p=0.04$, $p=0.02$). There was a 31.6% increase in contralateral and 18.4% increase in ipsilateral IO/TA activation levels with ABM (Table 2).

Peak torque and time to peak torque

There was a significant angle by condition interaction for quadriceps PT ($F(1,15)=5.30$, $p=0.04$). PT values both decreased by performing ABM, but the decrease was greater at 60° compared to 90° of knee flexion (60°: $p=0.001$, ES=0.68; 90°: $p=0.008$, ES=0.33). At both conditions, PT was greater at 60° than 90° (NA: $p<0.001$, ABM: $p=0.02$) (Table 3).

Angle by condition interaction was not significant for TTPT ($F(1,15)=0.07$, $p=0.79$). The condition main effect was also not significant ($F(1,15)=0.42$, $p=0.53$) (Table 3).

Quadriceps activation

There was no significant angle by condition interaction for quadriceps activation level ($F(1,15)=0.96$,

Table 2. Ipsilateral and Contralateral IO/TA Activation Levels with Neutral Activation and with Abdominal Bracing Maneuver During Isometric Knee Extension Strength Testing at Different Knee Flexion Angles.

Side	Angle	NA (MVIC%) Mean±SD (min-max)	ABM (MVIC%) Mean±SD (min-max)	P value	Cohen's d
Ipsilateral	60	54.98±41.67 (6.68-163.57)	70.26±33.38 (14.04-129.23)	0.112	0.40
	90	51.44±37.38 (10.0-161.43)	72.98±31.98 (11.99-124.29)	0.024*	0.62
Contralateral	60	49.79±32.63 (1.71-130.86)	89.98±68.09 (24.70-247.54)	0.007	0.65
	90	65.39±47.68 (10.0-184.30)	91.89±64.70 (22.11-209.38)	0.018*	0.47

Values are mean ± standard deviation. Abbreviations: NA = Neutral Activation, ABM = Abdominal Bracing Maneuver, MVIC = Maximum Voluntary Isometric Contraction. *p<0.05.

Table 3. Quadriceps Peak Torque, Time to Peak Torque, and Quadriceps Activation Levels with and without Abdominal Bracing Maneuver During Isometric Knee Extension Strength Testing at Different Knee Flexion Angles.

	Angle	NA	ABM	P value	Cohen's d
Quadriceps PT (kg/m²)	60	2.83±0.65	2.39±0.61	0.001*	0.68
	90	2.28±0.67	2.07±0.57	0.008*	0.33
TTPT (s)	60	3.01±1.14	2.92±1.48	0.846	0.06
	90	2.27±1.42	2.52±1.67	0.482	0.16
Quadriceps activation level (mV)	60	1.34±0.5	1.10±0.5	0.023*	0.48
	90	1.30±0.4	1.10±0.4	0.002*	0.50

Values are mean ± standard deviation. Abbreviations: NA = Neutral Activation, ABM = Abdominal Bracing Maneuver, MVIC = Maximum Voluntary Isometric Contraction, PT = Peak Torque, TTPT = Time to Peak Torque. *p<0.05.

p=0.34). Condition main effect was determined significant for quadriceps activation level ($F(1,15)=11.88$, $p=0.004$). Quadriceps activation level decreased with ABM (p=0.04) (Table 3).

DISCUSSION

The findings of the present study demonstrated that performing ABM increased IO / TA levels about 18-31 percent during the maximum isometric quadriceps strength test and decreased quadriceps peak torque and activation levels in healthy individuals. The decrease in quadriceps peak torque was greater at 60° knee flexion than 90° knee flexion. On the other hand, time to peak torque of quadriceps did not change with the ABM.

We planned this study since we observed that individuals performed quadriceps isometric tests with compensatory lumbopelvic motions including increased anterior pelvic tilt and trunk rotation even stabilization straps are used for controlling these motions. ABM was shown to be effective for achieving and maintaining lumbopelvic stability during dynamic movements. Despite the previous findings, we postulated that these compensatory movements could increase quadriceps strength due to force transmission from the trunk to the leg and mask the real quadriceps force.

Vera-Garcia et al. reported that during sudden trunk perturbations, ABM causes less trunk displacement than ADM (2). Moreover, ABM provides global abdominal wall contraction, thus performing ABM increases the stability of the lumbopelvic complex along with antagonist co-contraction (16). Previous studies demonstrated that all the muscles of the abdominal wall participate in spinal stability and every part should work harmoniously for maintaining stabilization (27, 28).

During quadriceps muscle strength testing in a sitting position, seat belts are used to prevent trunk compensatory movements. We observed in our clinics that belts were not able to provide a completely stable trunk while performing maximal knee extension muscle strength testing. The individuals demonstrated increased anterior pelvic tilt and trunk rotation during the test, thus, the force transmission via trunk to lower extremity muscles could mislead the results (29, 30). In the present study, our participants were taught how to perform ABM by a physiotherapist prior to actual testing first in the supine position and then in sitting position. In addition, they practiced ABM several times with resistive knee extension at 60° and 90° of knee flexion. The abdominal activation was also checked during the test whether the participants activating related muscles or not. During maximal isometric knee extension muscle strength testing, the participants activated ipsilateral abdominal core muscles between 51 MVIC% and 55 MVIC% without ABM. With ABM, these values increased from 70 MVIC% to 73 MVIC%. On the other hand, contralateral abdominal core activation increased more than the ipsilateral sides. It increased from 59 MVIC% to 96 MVIC% at 60° of knee flexion and increased from 65 MVIC % to 92 MVIC% at 90° of knee flexion. This finding may support that to prevent pelvis and trunk rotation, contralateral abdominal muscles worked more than the ipsilateral side.

We observed a 15.5% decrease in quadriceps peak torque in 60° knee flexion and a 9.2% decrease at 90° knee flexion. The decrease in quadriceps peak torque might occur due to several reasons. The compensatory movements of the trunk and the pelvis might be prevented by performing ABM during the test. This may decrease the transmission of the force from the trunk to the leg and may result a decrease in quadriceps muscle strength. On the other hand, trying to maintain ABM during the testing might be hard and the participants might not exert their maximal knee force while focusing on the ABM. There is no study in the literature investigating quadriceps strength with VPAC techniques in sitting position. Therefore, it is hard to discuss our findings with the available literature. Tayashiki et al. (16) reported greater hip extension muscle strength by performing ABM in the supine position and they suggested that an increase in intraabdominal pressure via ABM radiates the generated force to weaker muscles in the lower extremities. Hwang et al. (31) also found greater concentric hip extension muscle strength in prone standing position in healthy individuals. Hip extension muscle strength is closely related to pelvic tilt movements and intraabdominal pressure. Consistent with the findings of peak torques, quadriceps muscle activation levels decreased by performing ABM. However, the decrease in muscle activation levels was independent from the knee flexion angles. The present study demonstrated quadriceps muscle activation levels decreased 13.7 MVIC% in 60° knee flexion and 19 MVIC% in 90° knee flexion angles. We expected to see an increase in quadriceps time to peak torque by performing ABM. We postulated that while performing ABM, the knee extension force was exerted in a controlled manner so the time passed for reaching peak torque would be longer. However, we found no change in quadriceps time to peak torque.

The findings of the present study might have beneficial clinical points. Since quadriceps torque decreased by performing ABM during maximal quadriceps muscle strength testing, this method may be used in patients in the early phase of anterior cruciate ligament injury rehabilitation for strengthening quadriceps in a controlled manner. Clinicians might seek to prioritize isometric strengthening by performing ABM in the early phase of the rehabilitation for quadriceps muscle strains to improve force development without overloading the quadriceps muscle. Moreover, abdominal core muscles can also be strengthened since the activation levels were greater than 60% MVIC during maximum quadriceps isometric contractions (32, 33). However, the utility of these methods is yet to be investigated in future studies.

The present study had several limitations. First, the findings of the present study reflected the status of healthy individuals. ABM may result in various quadriceps muscle strength and muscle activation levels during muscle strength measurement in different patient populations. Third, the results of the present study reflected the isometric strength testing of the quadriceps muscle. During dynamic contractions such as concentric and eccentric muscle strength testing, the effects of ABM may be different.

In conclusion, the results of the present study showed that an increase in abdominal core activation resulted in a decrease in quadriceps maximal isometric muscle strength and muscle activation levels during quadriceps isometric muscle testing at 60° and 90° knee flexion angles in healthy individuals. The compensatory lumbopelvic motions should be examined during maximal knee extension muscle strength testing.

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Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical Approval: This study was approved by Uskudar University Institutional Review Board (61351342-/2019-101).

Informed Consent: Written informed consent was obtained from each subject.

Peer-Review: Externally peer-reviewed.

Author Contributions: Concept – BS, DCS, DA, GH; Design – BS, SY, ST, GH; Supervision – GH; Resources and Financial Support – BS, DCS, GH; Materials – BS, DCS, DA, SY, ST, GH; Data Collection and or Processing – BS, DCS, DA, SY, ST, GH; Analysis and or Interpretation – BS, DCS, DA, SY, ST, GH; Literature Search – BS, GH; Writing Manuscript – BS, DCS, DA, SY, ST, GH; Critical Review – BS, DCS, DA, SY, ST, GH

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