Differences in Abdominal and Lumbar Muscle Thickness and Contractile Function Between Nulliparous, Primiparous, and Multiparous Women 6 Months Postpartum

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Abstract

Objective. The purpose of this study was to evaluate the differences between primiparous and multiparous women at 6 months postpartum and nulliparous women regarding the thickness (including thickness pattern) and contractile function of the abdominal and lumbar muscles.

Methods. A cross-sectional observational study of 80 women, both primiparous ($n = 29$) and multiparous ($n = 25$), as well as including nulliparous as a comparison group ($n = 26$), was conducted. B-mode ultrasound imaging was used for the measurement of abdominal and lumbar muscle thickness in two conditions (resting and activation). Moreover, the contractile function of these muscles was determined by the thickness ratio.

Results. Significant differences between groups were observed in abdominal muscle thickness. During activation, the obliques showed a lower thickness in both groups of postpartum women compared to nulliparous women, while lower values for the thickness for the transverse abdominis (TrA) were only observed in primiparous women. The thickness pattern observed in nulliparous women both in resting and in activation (internal oblique [IO] > external oblique [EO] > TrA) was also achieved among postpartum women, despite no statistical differences observed between IO and EO in these groups. No significant differences between groups were observed for contractile function, showing the TrA greater values, followed by IO and EO in both nulliparous and postpartum women.

Conclusions. This study suggests that the thickness (and the thickness pattern) of the abdominal muscles in women at 6 months postpartum differs from nulliparous, while for the lumbar muscles, it is comparable to nulliparous. However, despite the obliques being thinner in postpartum women, the abdominal muscles are functionally competent.

Impact. This is believed to be the first study to compare abdominal and lumbar muscles thickness and contractile function specifically between primiparous and multiparous women. Although at 6 months' postpartum abdominal thickness differs from nulliparous women, these muscles are functionally competent. These findings provide valuable insights for use in the development of postpartum interventions.

Key words: Abdominal Muscles; Muscle Thickness; Parity; Postpartum Period; Ultrasound Imaging

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Introduction<< Q11 - Query >>

The postpartum period is commonly referred to as the fourth stage of labor, and it is characterized by three distinct but continuous phases. The first phase relates to the acute period corresponding to the first 6 to 12 hours after delivery and the second phase is the subacute postpartum period, which lasts 2 to 6 weeks. The third phase, known as the delayed postpartum period, can extend up to

6 months. During this time, there is the gradual recovery of the muscles and connective tissues to their pre-pregnant state. Changes in this phase occur gradually and play a critical role in the long-term health outcomes of the mother and child.[1]

The postpartum period has been associated with several physiological, biomechanical, postural, and hormonal changes.[2–5] Furthermore, the characteristics of the delivery, routine life habits of the mother, and emotional health[6] are among several factors that may influence this period. All these aspects are known to contribute to musculoskeletal impairments or incomplete recovery beyond 6 months postpartum. In fact, a recent study showed that at 12 months postpartum following vaginal delivery, the strength and endurance of the pelvic floor muscles are not fully recovered compared with the mid-pregnancy values.[7]

From a muscular perspective, the rectus abdominis, external oblique (EO), internal oblique (IO), transverse abdominis (TrA), and multifidus (MF) are considered to be key components in the optimal functioning of the abdominopelvic region.[8–11] Recent literature has analyzed the natural recovery of the thickness and contractile function of the abdominal muscles during the postpartum period. Several authors have observed that all abdominal muscles remain thinner during the first month after delivery.[12–14] In addition, Fukano et al[15] found that although the TrA thickness recovered spontaneously after 1 month postpartum, its contractile function remained diminished for at least 4 months. Moreover, the recovery time for the IO muscle thickness was found to need more than 6 months. Concerning the lumbar muscles thickness and contractile function, the literature is non-existent in this population.

The findings on the functionality of abdominal muscles in postpartum women are heterogeneous in the literature. Several studies have reported musculoskeletal changes in postpartum women without changes in muscle function.[16–19] However, other authors have confirmed that changes in the thickness of the musculature, the interrectus distance (IRD), the timing or response to perturbation, or the altered direction of action, lead to abdominal functional disturbance in resistance, strength, or muscle fatigue.[12,20,21] All these aspects are important considerations in injury prevention and rehabilitation programs postpartum.[22,23]

Several methods have been employed by clinicians to assess different aspects of the abdominal and lumbar muscles. On the one hand, the use of ultrasound imaging has been increasing in the past decades, given its relative low cost and good reproducibility when it comes to the measurement of thickness and thickness changes (thickness ratio).[24] This measurement not only provides information on the muscle structure but also allows for an understanding to be gained of the behavior of the muscles during functional tasks.[25] Clinical tests for abdominal and lumbar muscles have also been used for the purpose of measuring their functional capability.[26] These two methods may contribute to a more accurate and complete view of the engagement of these muscles regarding function and activation, both at rest and during movement.

Despite the existence of research on changes in the abdominopelvic region among postpartum women, to our knowledge, the status of the abdominal and lumbar muscles 6 months after delivery remains poorly understood in both primiparous and multiparous women. Thus, the aim of this study was to evaluate the differences in the abdominal and lumbar muscles in terms of thickness (including thickness pattern) and contractile function using ultrasound imaging between nulliparous, primiparous, and multiparous women at 6 months postpartum. Our findings could improve the design of individualized physical therapist interventions for postpartum women and provide insights into the development of evidence-based postpartum exercise programs. We hypothesized that the thickness and contractile function of the abdominal and lumbar muscles may be influenced by parity, differing between nulliparous, primiparous, and multiparous women at 6 months postpartum.

Methods

Design

The present study was a cross-sectional observational study conducted by the PTinMotion<< Q12 - Query >> (Physiotherapy in Movement. Research Group on Multi-specialty) research group of the Department of Physiotherapy at the University of Valencia (Valencia, Spain) from November 2018 to January 2021. Data reported in the present study are part of a research project investigating the musculoskeletal changes of the abdominopelvic region and the influence of lifestyle factors in postpartum women. The Strengthening the Reporting of Observational Studies in Epidemiology recommendations were followed.[27] The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the University of Valencia Research Ethics Committee (no. H1542709432243).

Participants

Primiparous and multiparous women were recruited in Valencia (Spain), referred by their gynecologist, midwife, or physical therapist. Women aged ≥18 years old who had had a vaginal delivery 6 months before the study were included. Nulliparous women aged ≥18 years were recruited using convenience sampling from university employees, public buildings around the university, and through word-of-mouth advertising to serve as a comparison group. This group was age-matched to the postpartum women. The exclusion criteria were a history of spinal, abdominal, and urogynecology surgery, including cesarean birth for postpartum women, and any neuromuscular or neurological disease. All women provided written informed consent prior to their participation in the study.

Procedure

Two physical therapists, each with 10 years of experience managing musculoskeletal disorders in women and utilizing rehabilitative ultrasound imaging techniques, conducted all of the assessments. Prior to the assessment session, the entire procedure was thoroughly explained to all participants who attended a single assessment session. The demographic and clinical data, including age, weight gain during pregnancy, perineal damage, profession, exercise before and during pregnancy, and current exercise, were collected. Standardized procedures were employed to measure weight, height, and waist circumference. The participants' professions were classified according to the Daily Physical by Occupational Classification of the National Health and Nutrition Examination Survey.[28] The main characteristics of current exercise/activities, including frequency, intensity, and activity-associated metabolic rate (MET), were collected. Exercise intensity was categorized according to the five categories described by Norton et al (2010).[29] The MET calculation, which represents the rate of energy expenditure during an exercise or activity, was based on the compendium of physical activities.[30] Additionally, the participants were asked to rate the intensity of their abdominal and low back pain during the last 24 hours using a visual analog scale[31] with a range of 0 to 100, anchored by word descriptors at each end ranging from 0 = no pain to 100 = worst pain imaginable.[32] Urinary incontinence (UI) symptom severity and impact on quality of life was also assessed using the Spanish version of the International Consultation on Incontinence Questionnaire–Urinary Incontinence Short Form (ICIQ-UI-SF), which generates a final score ranging from 0 to 21, with a higher score indicating a more severe UI and greater impact.

Afterwards, all participants underwent an ultrasound imaging assessment which included the measurement of the IRD and the thickness measurement of abdominal and lumbar muscles. Lastly, they were tested for abdominopelvic muscle function which, together with the IRD measurement, served to characterize the sample.

Ultrasound Assessment

A Samsung HS30 device (Samsung Medison Co) interfaced with a 2D, high-frequency linear transducer (LN 5–12) was used to collect all of the ultrasound images in B-mode.

IRD images were captured with the transducer placed transversely along the linea alba and at two specific locations: 2 cm above the superior border of the umbilicus (supraumbilical IRD) and 2 cm below the inferior border of the umbilicus (infraumbilical IRD), with the participant resting in a supine position, knees flexed resting on a roller. Good intratester and test–retest reliability of IRD measurement at these locations has been previously demonstrated.[33] IRD was determined by measuring the width of a straight line connecting the medial edges of the bilateral rectus abdominis heads.

To measure the thickness of the abdominal muscles, the transducer was positioned transversely in the lower quadrant of the abdomen, at a point midway between the costal margin and iliac crest along the right axillary line in order to capture the EO, IO, and the distinctive terminus of the TrA into the abdominal fascia, at right and left side, randomly. The thickness was measured under two conditions: at rest and during activation, while the participant was in supine position with knees flexed and resting on a roller. For the measurement during activation, participants were asked to perform the abdominal draw-in maneuver (ADIM) during the expiratory phase, which involved inhaling first and then exhaling while drawing their belly button in, toward the spine. Good intraexaminer and interexaminer reliability for the thickness assessment of the lateral abdominal muscles has been reported.[34]

To measure the thickness of the lumbar muscles, specifically the MF, the transducer was placed longitudinally and immediately lateral to the L4-L5 spinous process, while the participant was in the prone position with a rolled towel positioned below the abdomen to reduce lordosis. The measurement of MF thickness during activation was performed with the participant raising the arm opposite to the location of the transducer, while performing a slight extension of the shoulder.

For the measurement of thickness during activation, each contraction was held for 3 seconds with a 10-second rest period between each contraction. In order to minimize bias, all thickness measurements were determined by consensus among the researchers, taking the thickest point of each muscle as the reference. Image captures of the different thickness measurement conditions are shown in Figure 1. For all ultrasound measurements, three images were recorded at each location and under each condition, and the mean was calculated for further analysis. In this study, the thickness pattern IO > EO > TrA described by Weis et al[13] for nulliparous women was taken as a reference for the comparison within the postpartum groups. The contractile function of each muscle was determined using the thickness ratio, which was estimated by dividing the mean thickness during activation by the mean thickness during rest.[35] A thickness ratio of 2.0, for instance, indicates that the muscle doubled in thickness from its resting position.

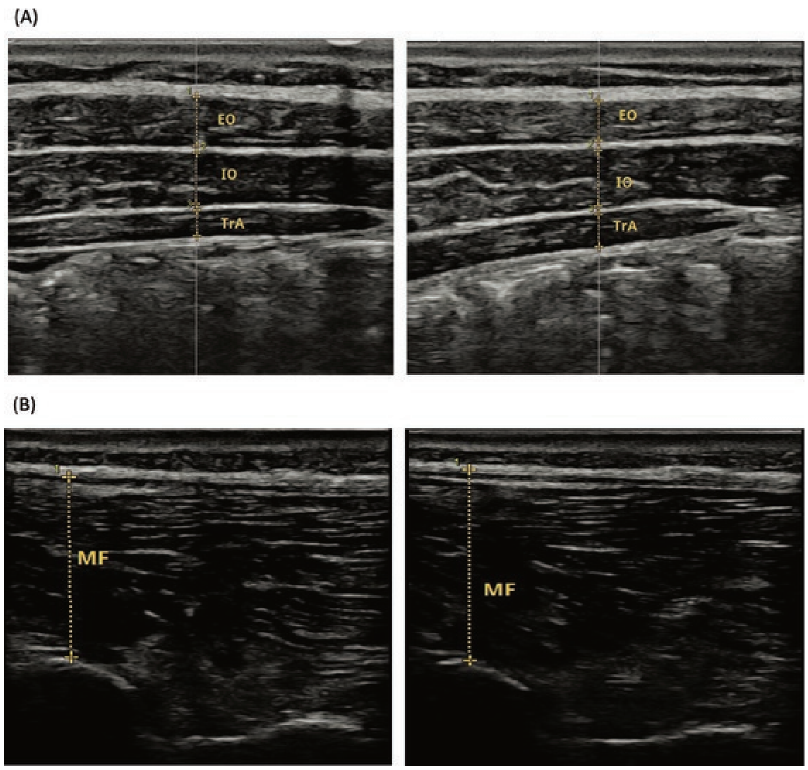

Figure 1 Ultrasound imaging measurement of the thickness changes for the external oblique (EO), internal oblique (IO), and transverse abdominis (TrA) muscles (A) and the multifidus (MF) muscle (B) between the resting (left images) and activation (right images) conditions.

Abdominopelvic Muscle Function

Abdominopelvic muscle function was assessed using the prone and supine bridge test and side bridge test (right and left), with the purpose of characterizing the sample. The procedure for the performance of these tests was previously described in the study of Balasch-Bernat et al.[16] For each test, women were encouraged to maintain the position for as long as possible until general, lumbar, or abdominal fatigue, or until pain prevented the correct position.[36] The time that the participants maintained each posture for was registered and measured in seconds (Suppl. Material).<< Q13 - Query >>

Data Analysis (and Sample Size Calculation)

The normality of the continuous data was checked using the Shapiro–Wilk test. The descriptive results are presented as mean (SD), median (25th–75th percentiles), or number (percentage), as appropriate. The demographic variables were compared using one-factor analysis of variance (ANOVA), Kruskal–Wallis test, or chi square test.

To compare muscle thickness among the groups (nulliparous, primiparous, and multiparous), conditions (rest and ADIM) and muscles (TrA, IO, EO, and MF), a three-factor ANOVA with repeated measures in condition and muscle factors was conducted. Thickness ratio was compared among the groups and muscles using a two-factor ANOVA with repeated measures in muscle factor. When the ANOVA models indicated significant differences in the main effects, Bonferroni's correction was applied to avoid type I errors in the multiple comparisons. The effect size was interpreted as small ($d = 0.2$), medium ($d = 0.5$), and large ($d > 0.8$).

To calculate the sample size, an a priori power analysis was performed using G* Power software (version 3.1.9.4; Heinrich-Heine-Universität). Given the present study design, assuming a medium/large effect size of $f = 0.40$ ($d = 0.80$) to determine the differences between the 3 groups in muscle thickness, $\alpha = 0.05$ and $\beta = 0.15$ meant that a minimum sample size of 72 participants was required.

Results

A total sample of 80 women (26 nulliparous, 29 primiparous, and 25 multiparous) aged between 25 and 42 (mean age = 33.9; SD = 3.8) participated in this study (Fig. 2). All women completed the socio-demographic data collection as well as ultrasound and abdominopelvic muscle assessment The demographic and descriptive data as well as the clinical characteristics of the participants are shown in Tables 1 and 2, respectively.

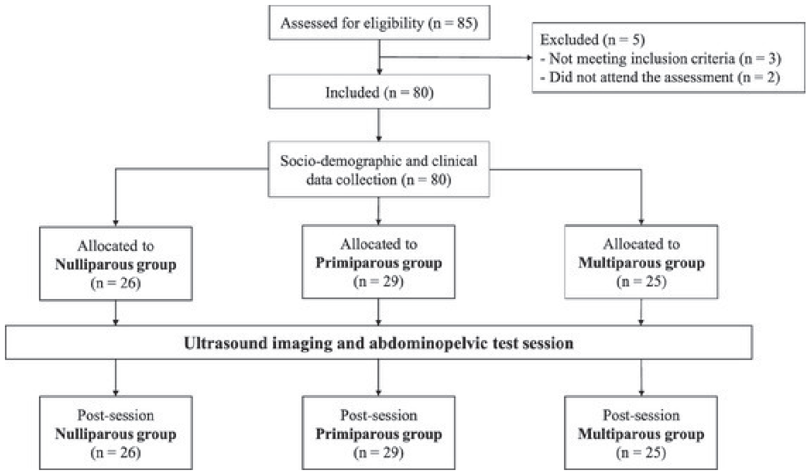

Figure 2 Flow diagram of participants.

Table 1 Demographic and Descriptive Data for Participants

Characteristic	Nulliparous ($n = 26$)[a]	Primiparous ($n = 29$)[a]	Multiparous ($n = 25$)[a]	Differences among groups (P)[b]
Entire sample				
Age, y	33.31 (4.50)	33.24 (2.94)	35.40 (3.52)	$F = 2.87$ (.06)
Weight, kg, median (25th–75th percentiles)	60.00 (55.45–69.50)	60.00 (55.00–67.00)	60.00(53.85–67.50)	H = 0.19 (.91)
Body mass index, kg/m^2, median (25th–75th	22.05 (19.37–24.37)	21.72 (20.39–25.56)	22.66 (20.35–23.89)	H = 0.27 (.88)

Characteristic	Nulliparous ($n = 26$)[a]	Primiparous ($n = 29$)[a]	Multiparous ($n = 25$)[a]	Differences among groups (P)[b]
percentiles)				
Height, cm	167.19 (6.62)	165.24 (5.40)	164.68 (5.64)	$F = 1.30$ (.28)
Waist circumference, cm, median (25th–75th percentiles)	80.50 (76.50–85.33)	81.00 (75.75–89.25)	82.00 (78.25–87.00)	H = 1.22 (.55)
Profession physical activity classification, no. (%) of participants				$\chi^2 = 24.80$ (<.001)[c]
High	14 (54)	2 (7)	3 (13)	
Medium	1 (4)	4 (14)	8 (35)	
Low	11 (42)	23 (79)	12 (52)	
Exercise performance, yes/no, no. (%) of participants	23 (88)/3 (12)	14 (48)/15 (52)	11 (44)/14 (56)	$\chi^2 = 13.10$ (.001)[c]
Exercise frequency, h/wk, median	3.00 (2.00–5.00)	2.00 (1.00–2.13)	2.00 (1.50–3.50)	H = 12.37 (.002)[c]

Characteristic	**Nulliparous ($n = 26$)**[a]	**Primiparous ($n = 29$)**[a]	**Multiparous ($n = 25$)**[a]	**Differences among groups (P)**[b]
(25th–75th percentiles)				
Exercise intensity, no. (%) of participants				$\chi^2 = 20.89$ (.004)[c]
Very vigorous	2 (8)	0 (0)	0 (0)	
Vigorous	8 (31)	3 (10)	1 (4)	
Moderate	7 (27)	6 (21)	3 (12)	
Light	6 (22)	5 (17)	7 (28)	
Sedentary	3 (12)	15 (52)	14 (56)	
Activity-associated metabolic rate, median (25th–75th percentiles)	1755.0 (420.0–2880.0)	510.0 (262.5–960.0)	660.0 (205.5–1657.5)	H = 8.69 (.013)[c]
Postpartum sample				
Perineal damage, no. (%) of				$\chi^2 = 9.22$ (.017)[d]

Characteristic	Nulliparous ($n = 26$)[a]	Primiparous ($n = 29$)[a]	Multiparous ($n = 25$)[a]	Differences among groups (P)[b]
participants				
None		3 (10)	8 (32)	
Episiotomy		16 (55)	5 (20)	
Perineal tearing		9 (31)	12 (48)	
Both		1 (3)	0 (0)	
Exercise before pregnancy, yes/no, no. (%) of participants		22 (76)/7 (24)	15 (60)/10 (40)	$\chi^2 = 1.57$ (.21)
Exercise frequency, h/wk		2.25 (2.00–3.00)	2.00 (1.00–3.00)	$U = 125$ (.20)
Exercise during pregnancy, yes/no, no. (%) of participants		23 (79)/6 (21)	13 (52)/12 (48)	$\chi^2 = 4.51$ (.034)[d]
Exercise frequency, h/wk		2.00 (2.00–3.00)	3.00 (1.50–7.00)	$U = 123$ (.36)

[a] Values are mean (SD) unless otherwise indicated.

[b] Groups were compared using analysis of variance (F), Kruskal–Wallis test (H), χ^2 test, or Mann–Whitney U test (U). Significant differences are shown in bold type.

[c] Differences between nulliparous and multiparous as well as between nulliparous and

primiparous.
[d] Differences between primiparous and multiparous.

Table 2 Clinical Data for Participants[a]

Clinical characteristic	Nulliparous ($n = 26$)[b]	Primiparous ($n = 29$)[b]	Multiparous ($n = 25$)[b]	Differences among groups (P)[c]
IRD				
Supraumbilical, cm	1.21 (0.46)	1.93 (0.56)	2.65 (0.77)	$F = 36.02$ (.001)[d]
Infraumbilical, cm	0.50 (0.33)	1.22 (0.46)	1.42 (0.64)	$F = 25.30$ (.001)[e]
Abdominopelvic muscle function, s, median (25th–75th percentiles)				
Prone	16.24 (9.31–22.65)	12.05 (8.72–14.73)	12.26 (10.44–14.93)	H = 6.51 (.039)[f]
Supine	34.06 (17.63–70.50)	23.11 (16.59–28.39)	24.99 (17.59–36.44)	H = 7.51 (.023)[f]
Lateral	9.19 (4.89–17.95)	9.01 (6.19–11.38)	8.44 (6.79–10.44)	H = 1.02 (.60)
Abdominal pain lasting 24 h, yes/no, no. (%) of participants	4 (15)/22 (85)	2 (7)/27 (93)	1 (4)/24 (96)	$\chi^2 = 2.27$ (.38)

Clinical characteristic	Nulliparous ($n = 26$)[b]	Primiparous ($n = 29$)[b]	Multiparous ($n = 25$)[b]	Differences among groups (P)[c]
VAS, 0–100	49.25 (19.21)	45.00 (21.21)	20.00 (0.00)	
Low back pain lasting 24 h, yes/no, no. (%) of participants	11 (42)/15 (58)	11 (38)/18 (62)	11 (44)/14 (56)	$\chi^2 = 0.22$ (.90)
VAS, 0–100	43.73 (22.92)	50.36 (21.40)	32.73 (21.62)	$F = 1.81$ (.18)
ICIQ-UI-SF, 0/>0 point, no. (%) of participants	15 (58)/11 (42)	12 (48)/15 (52)	11 (44)/14 (56)	$\chi^2 = 1.26$ (.53)
ICIQ-UI-SF, 1–21, median (25th–75th percentiles)	1.00 (1.00–1.00)	4.00 (1.50–4.75)	4.00 (4.00–4.00)	H = 12.68 (.002)[e]

[a] ICIQ-UI-SF = International Consultation on Incontinence Questionnaire–Urinary Incontinence Short Form; IRD = interrectus distance; VAS = visual analog scale.

[b] Values are mean (SD) unless otherwise indicated.

[c] Groups were compared using analysis of variance (F), Kruskal–Wallis test (H), or χ^2 test. Significant differences are shown in bold type.

[d] Differences among all groups.

[e] Differences between nulliparous and multiparous as well as between nulliparous and primiparous.

[f] Differences between nulliparous and primiparous.

Regarding the demographic and descriptive characteristics (Tab. 1), no significant differences ($P > .05$) were observed in age, weight, body mass index, height, or waist circumference. However, several variables presented significant differences between groups. Nulliparous women had professions demanding a greater intensity of physical activity ($P < .01$) than postpartum women. Concerning current exercise, nulliparous women presented with a higher percentage of performance, frequency, intensity ($P < .01$), and MET for exercise ($P < .05$) than primiparous and multiparous. Regarding the postpartum variables, primiparous women had significantly greater ($P < .05$) perineal damage as well as there being a higher number of participants performing exercise during pregnancy ($P < .05$) than multiparous women.

In relation to the clinical characteristics of the sample (Tab. 2), no significant differences ($P > .05$) were observed in abdominal and lower back pain between the study groups. Nevertheless, ICIQ-UI-SF, both supraumbilical and infraumbilical IRD measures, and abdominopelvic muscle function (except side bridge test) showed significant differences between groups. Nulliparous women reported lower ICIQ-UI-SF scores ($P < .01$) compared to both primiparous and multiparous. Regarding IRD measures, both supraumbilical and infraumbilical values were higher ($P < .01$) in postpartum women than in nulliparous. Furthermore, multiparous women showed higher supraumbilical IRD values ($P < .01$) than primiparous. Lastly, in terms of abdominopelvic muscle function, nulliparous women exhibited better time values (higher scores) compared to primiparous ($P < .05$) for prone and supine tests.

The results of the ANOVA for the abdominal and lumbar muscles thickness are summarized in Table 3. Regarding the between-group comparisons for the abdominal muscles, for the TrA, statistically significant differences ($P < .05$) were observed only between nulliparous and primiparous women during ADIM, with a greater thickness in nulliparous women. Considering IO and EO thickness, significant differences ($P < .05$) were observed between nulliparous and postpartum women for both supine rest and ADIM, presenting with a greater thickness in nulliparous. In all cases, the effect size was medium or large. For intragroup abdominal muscle comparisons, nulliparous women had significant differences between all abdominal muscles ($P < .001$), with IO being the thickest, followed by EO and TrA, both in resting and activation. In the case of postpartum women, in the resting condition, both primiparous and multiparous women showed significant differences between TrA and EO and between TrA and IO ($P < .001$), following the same pattern as nulliparous (IO > EO > TrA). However, no statistical differences were observed between IO and EO in these groups. During the muscle activation, primiparous women showed significant differences between all muscles ($P < .05$), with greater thickness values for IO, followed by EO and TrA. For multiparous women, only the comparisons between TrA and IO and between IO and EO were statistically significant ($P < .001$ and $P < .05$, respectively). In relation to lumbar muscles thickness, no significant differences were obtained for MF in any of the comparisons.

Table 3 Results of Multiple Comparisons Analysis for the Thickness of the Abdominal and Lumbar Muscles[a]

Muscle thickness	Muscle or comparison	Nulliparous ($n = 26$)	Primiparous ($n = 29$)	Multiparous ($n = 25$)	Nulliparous vs primiparous		Nulliparous vs multiparous		Primiparous vs multiparous	
					P (95% CI)	*d*	*P* (95% CI)	*d*	*P* (95% CI)	*d*
Resting	TrA	0.35 (0.09)	0.31 (0.06)	0.32 (0.06)	.13 (−0.01 to 0.09)		.65 (−0.02 to 0.07)		1.00 (−0.06 to 0.03)	
	IO	0.74 (0.17)	0.56 (0.11)	0.57 (0.11)	<.001 (0.10 to 0.27)	1.27	<.001 (0.08 to 0.26)	1.18	1.00 (−0.11 to 0.08)	
	EO	0.63 (0.17)	0.54 (0.12)	0.54 (0.08)	.028 (0.01 to 0.18)	0.62	.038 (0.01 to 0.18)	0.67	1.00 (−0.09 to 0.09)	
	MF	2.63 (0.37)	2.67 (0.34)	2.68 (0.37)	1.00 (−0.27 to 0.20)		1.00 (−0.29 to 0.20)		1.00 (−0.25 to 0.23)	
	TrA vs IO									
	P (95% CI)	<.001 (−0.46 to − 0.34)	<.001 (−0.31 to − 0.19)	<.001 (−0.32 to − 0.19)						
	d	4.33	4.17	4.17						
	TrA vs EO									
	P (95% CI)	<.001 (−0.34	<.001 (−0.28	<.001 (−0.27						

Muscle thickness	Muscle or comparison	Nulliparous (*n* = 26)	Primiparous (*n* = 29)	Multiparous (*n* = 25)	Nulliparous vs primiparous		Nulliparous vs multiparous		Primiparous vs multiparous	
					***P* (95% CI)**	***d***	***P* (95% CI)**	***d***	***P* (95% CI)**	***d***
		to − 0.24)	to − 0.19)	to − 0.17)						
	d	3.11	3.83	3.67						
	IO vs EO									
	P (95% CI)	.001 (0.04 to 0.18)	1.00 (−0.05 to 0.09)	1.00 (−0.04 to 0.11)						
	d	0.65								
Active	TrA	0.55 (0.18)	0.43 (0.12)	0.47 (0.09)	.004 (0.03 to 0.21)	0.79	0.10 (−0.01 to 0.18)		0.94 (−0.13 to 0.05)	
	IO	0.89 (0.26)	0.65 (0.13)	0.68 (0.13)	<.001 (0.11 to 0.36)	1.19	.001 (0.08 to 0.34)	1.01	1.00 (−0.15 to 0.10)	
	EO	0.64 (0.16)	0.54 (0.11)	0.54 (0.10)	.008 (0.02 to 0.19)	0.74	.018 (0.01 to 0.19)	0.74	1.00 (−0.09 to 0.08)	
	MF	3.18 (0.40)	3.18 (0.38)	3.24 (0.41)	1.00 (−0.26 to 0.26)		1.00 (−0.33 to 0.22)		1.00 (−0.22 to 0.33)	
	TrA vs IO									

Muscle thickness	Muscle or comparison	Nulliparous ($n = 26$)	Primiparous ($n = 29$)	Multiparous ($n = 25$)	Nulliparous vs primiparous		Nulliparous vs multiparous		Primiparous vs multiparous	
					P (95% CI)	*d*	*P* (95% CI)	*d*	*P* (95% CI)	*d*
	P (95% CI)	<.001 (−0.41 to − 0.26)	<.001 (−0.29 to − 0.15)	<.001 (−0.28 to − 0.13)						
	d	1.89	1.83	2.33						
	TrA vs EO									
	P (95% CI)	.007 (−0.16 to − 0.02)	<.001 (−0.17 to − 0.04)	.07 (−0.15 to 0.01)						
	d	0.50	0.92							
	IO vs EO									
	P (95% CI)	<.001 (0.14 to 0.35)	.013 (0.02 to 0.21)	.005 (0.03 to 0.24)						
	d	0.96	0.85	1.40						

[a] Values are mean (SD) unless otherwise indicated. Comparison results are shown as *P* (95% CI) for the mean difference and effect size (*d*). Significant differences are shown in bold type. EO = external oblique; IO = internal oblique; MF = multifidus; TrA = transverse abdominis.

Figure 3 shows the results of the ANOVA for the contractile function (obtained from the thickness ratio) of the abdominal and lumbar muscles. In relation to intragroup abdominal muscle comparisons, significant ($P < .001$) differences were obtained in all cases (except between IO and MF), showing TrA greater values, followed by IO and EO. No significant intergroup differences were observed.

Discussion

Based on the results of our study, the hypothesis has been partially proven. We observed differences in thickness and thickness pattern when comparing nulliparous versus primiparous and multiparous women, but not between both postpartum women conditions. However, the hypothesis related to contractile function was not confirmed since no differences were observed between nulliparous, primiparous, and multiparous women. As far as we know, this is the first study to compare these three groups and to specifically examine the differences between primiparous and multiparous women.

In relation to the results of the abdominal muscle thickness, while the TrA values in resting were similar for all women, during activation through ADIM, greater thickness was found in nulliparous compared to primiparous women. This finding may have been influenced by the fact that a higher percentage of primiparous women in our sample had less physically demanding professions (79%) compared to the women who were multiparous (52%), which commonly involve static or sitting positions. Moreover, primiparous women reported performing less exercise in terms of MET than multiparous (510 and 660 MET units, respectively). Since the TrA is considered a postural muscle, it is mainly activated in response to external perturbations,[37] which typically occur during dynamic activities or physically demanding professions. When compared with previous research, the thickness of the TrA at rest in our sample (0.31 cm for primiparous and 0.32 cm for multiparous women) is similar to the values reported in the studies of Fukano et al[15] (0.30 cm) and Kim et al (0.31 cm),[38] both of which also included a sample of women measured in resting at 6 months postpartum. Other authors have reported TrA thickness values of 0.40 cm at 1 month postpartum,[13] 0.25 at 2 months,[39] 0.28 at 4 months,[40] and 0.25 at 12 months.[14]

Regarding the IO and EO muscles, they were found to be thinner at 6 months postpartum compared to nulliparous, both at rest and during activation. This finding is consistent with the studies by Fukano et al[15] and Kim et al,[14] who reported a thinner IO in postpartum women at 6 and 12 months, respectively. However, no differences were observed between primiparous and multiparous women in these muscles, suggesting no influence due to the parity on oblique muscles thickness in our sample. The thickness values of these muscles in postpartum women in our study (0.56 cm in primiparous and 0.57 cm in multiparous for IO, and 0.54 cm in both groups for EO) are similar to the values obtained in women at 6 months postpartum in the studies of Fukano et al[15] (0.64 cm for IO and 0.52 for OE) and Kim et al[38] (0.54 cm for IO). However, the value reported by Fukano et al[15] for EO (0.33 cm) differs from our value.

In short, at 6 months postpartum, while the resting thickness of the TrA in both primiparous and multiparous women is comparable to nulliparous women, the IO and EO muscles are thinner. When interpreting these findings, it is important to note that our sample was comprised of relatively active women who engaged in exercise in their daily routine both during pregnancy and after delivery. This may have influenced our results, as it is plausible that women performing exercise have practiced how to contract their abdominal muscles during the draw-in contraction, some of them doing so early after delivery. Despite this consideration regarding our sample, the findings are consistent with those of Fukano et al,[15] who reported that the recovery of the IO takes more than 6 months after delivery, while the contractile function of the TrA remained reduced for at least 4 months postpartum.

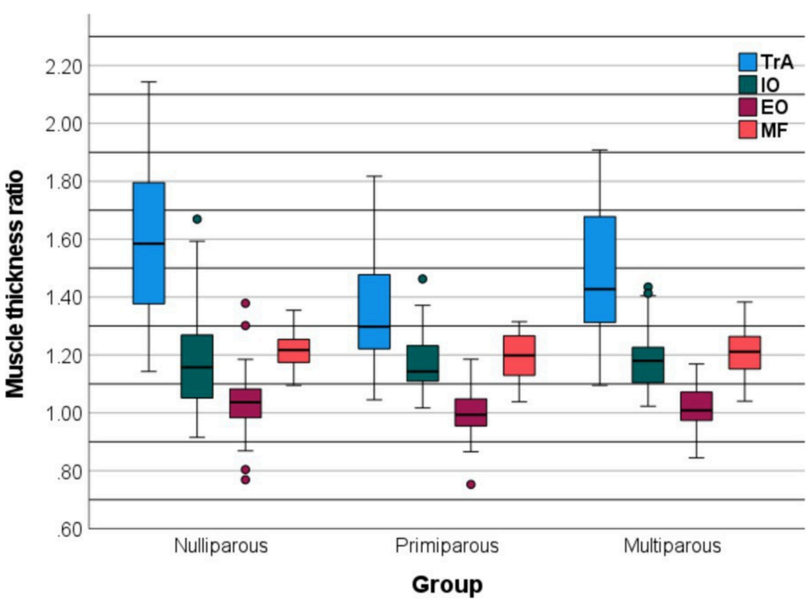

Figure 3 Results of the comparison analysis for the muscle thickness ratio. No between-groups significant differences were found for any muscle. Significant differences ($P < .001$) were found in the muscle comparisons (except for internal oblique [IO] vs multifidus [MF])

for all groups. EO = external oblique; TrA = transverse abdominis.

When comparing the thickness between the different muscles of the abdominal wall, our study found that the pattern of relative thickness for the resting condition in nulliparous women was IO > EO > TrA, which is in accordance with the previous literature.[13,15,41–43] However, among these authors, only Tahan et al[37] conducted a statistical analysis similar to our study, demonstrating there to be statistically significant differences in abdominal muscles thickness. While this pattern was also detected in postpartum women in our study (statistical differences were observed between TrA and both IO and EO muscles, being TrA the thinnest), no statistical differences were detected between the thickness of the IO and EO. These findings suggest that the thickness pattern in postpartum women differs from the normal values observed nulliparous women. Contrarily to our study, Weis et al[13] reported a normalized pattern (IO > EO > TrA) in women at 4-weeks postpartum. However, it is important to note that in this study, no statistical analysis comparing abdominal muscle thickness was performed to confirm this pattern.

Referring to the thickness of the MF, no differences between nulliparous, primiparous and multiparous women were found for this muscle. All women showed a thicker MF than the abdominal muscles, consistent with the previous findings in healthy populations.[43] Several studies have confirmed an association between MF thickness and low back pain in the general population, with people experiencing lower back pain having thinner MF.[44,45] Considering this, our results may be partially explained by the fact that all groups exhibited similar values for low back pain, with no differences between them. Moreover, it is important to highlight that, to the best of our knowledge, this is the first study investigating the thickness of the deep lumbar muscles by ultrasound imaging in postpartum women. Further research is needed to provide more data regarding the behavior of these muscles in this population. In our sample, postpartum women exhibited higher IRD values in rest, both at supraumbilical and infraumbilical levels, compared to nulliparous women. This is in accordance with the previous literature.[16,46] Additionally, multiparous women showed a higher supraumbilical IRD than primiparous. This suggests that when assessing the status of the musculature at a structural level 6 months postpartum, the abdominal distension induced by pregnancy might have influenced the thickness of the abdominal muscles.

In terms of contractile function (thickness ratio), when analyzing the behavior of the abdominal and lumbar muscles during a specific and isolated activation using ultrasound imaging, our study demonstrated that these muscles in postpartum women showed similar values to nulliparous women. Comparable values have been reported in other studies among postpartum women. For instance, for TrA thickness ratio, Fukano et al[15] reported a value of 1.40 and Madokoro et al[39] reported a value of 1.62, while in our study we obtained 1.43 and 1.48 for primiparous and multiparous women, respectively. It is important to highlight that similar values were also observed between primiparous and multiparous women in our study. These findings indicate that at 6 months after delivery, the abdominal and lumbar muscles present a functionally competent status, regardless of parity.

When analyzing the performance of a functional task requiring the participation of the different muscles of the abdominopelvic region, we found that primiparous women showed poorer results compared to nulliparous, while postpartum women presented with similar abdominopelvic function without any differences according to parity. It is plausible that the observed worsened abdominopelvic function in primiparous women may be attributed, once again, to physical deconditioning influenced by their profession and exercise habits.

In accordance with our results, while the structural changes observed in the abdominal muscles at 6 months postpartum (thickness and IRD) in primiparous women seem to be accompanied by altered functional capacity, the structural changes detected in multiparous women at 6 months postpartum did not imply changes in their functional capacity. These findings should be considered to optimize the assessment and treatment approach in postpartum women.

In light of these findings, our study indicates that parity may not influence the abdominal and lumbar muscles' contractile function, at least at 6 months postpartum. Our results also confirm that the contractile response of the abdominal and lumbar muscles in nulliparous and postpartum women is the same. When the participants were asked to activate these muscles during the ADIM, TrA showed the greatest contraction, followed by IO and EO. This is in accordance with the previous studies that analyzed the contractile function or thickness changes percentage in ADIM.[15,47,48] These studies also demonstrated preferential changes in TrA thickness over IO, while EO thickness remained the same, indicating an adequate execution of the ADIM and leading to minimal thickness changes in EO.[15] Lastly, in the case of the MF, postpartum women also showed contractile function values comparable to nulliparous women.

Finally, it is important to note that abdominal and lumbar muscles showed differences in abdominopelvic function in postpartum women compared to nulliparous women but not in contractile function. In this regard, it should be highlighted that the abdominopelvic task (prone and supine bridge tests) constitutes a more demanding task for the abdominal and lumbar muscles, requiring a global participation of the abdominal and lumbar muscles and sustained over time, while when analyzing contractile function (ADIM), these muscles perform more specific work isolated from the muscles involved. This fact may partially explain the differences in the results regarding these two measures.

Limitations

This study has several limitations that should be considered. Firstly, no information regarding other factors such as breastfeeding, diet, or sleep quality was collected. These factors could have influenced muscle recovery and body composition after delivery. Moreover, despite the data regarding exercise having been registered (frequency, intensity, and MET), in this study, the effect of exercise on muscle thickness and contractile function was not considered. It could be interesting to investigate this aspect in future studies by aiming to compare groups performing different types and intensities of exercise. Furthermore, our sample only included normal weight women; therefore, our findings may not generalize to overweight and obese women. Regarding the inclusion/exclusion criteria, it is important to take into account that we excluded women who had undergone a previous cesarean section. Future studies should consider including this population as they are also part of postpartum. It is also important to note that the researchers performing the assessments were not blinded to the parity status of the participants, which could have influenced the results of this study. In addition, although in this study muscle thickness was collected from different muscle conditions (rest and activation), thus allowing for the determining of their thickness ratios, it is important to note that ultrasound imaging is limited in its ability to assess neuromuscular function. Future studies should consider assessing the status of the abdominal and lumbar muscles in terms of neuromuscular function (ie, timing) and evaluating the presence of muscle fat infiltration in order to obtain a more accurate picture of muscle behavior. Regarding ultrasound measures, it should be mentioned that this study was specifically focused on the measurement of the lateral abdominal muscles (TrA, IO, and EO) but not the anterior abdominal wall (rectus abdominis). The only measure of the anterior abdominal wall collected was IRD, although it was only assessed in rest, not during activation. Nevertheless, it could have been of interest to evaluate these aspects of the rectus abdominis in order to obtain a more complete view of the abdominal wall. Lastly, further studies comparing primiparous and multiparous women should examine the natural course of muscle recovery after delivery, analyzing muscle thickness and contractile function throughout postpartum period, including additional follow-up assessments. This would provide additional evidence on the influence of parity, not only at 6 months postpartum, but also in the shorter and longer term.

Finally, our study provides insights into the status of abdominal and lumbar muscles in postpartum women 6 months after delivery. The findings of our work may help clinicians and physical therapists design exercise programs tailored to postpartum women. Based on our results, in order to promote postpartum health and fully restore the thickness and contractile function of the abdominopelvic region muscles, individualized physical therapist interventions and therapeutic exercise may be warranted, not only in the immediate postpartum period but also in the longer term.

Conclusions

This study reveals that the thickness (and the thickness pattern) of the abdominal muscles in our sample of women at 6 months postpartum differs from nulliparous. The lumbar muscle thickness in both primiparous and multiparous women is comparable to that of nulliparous women. Although the oblique muscles are thinner in both primiparous and multiparous women and primiparous women show a poorer abdominopelvic muscle function, in terms of contractile function, the abdominal and lumbar muscles present a functionally competent status.

Author Contributions

Laura Fuentes Aparicio, Sofia Pérez-Alenda, Juan J. Carrasco, Begoña Valls-Donderís, Lirios Dueñas, and Mercè Balasch-Bernat had contributed substantially to the conception and design of the work, acquisition and interpretation of data, and the drafted work.

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All authors have approved the final version to be published and have agreed to be accountable for all aspects of the work.

Laura Fuentes Aparicio (Conceptualization [equal], Data curation [equal], Investigation [equal], Methodology [equal], Supervision [equal], Writing—review & editing [equal]), Sofia Perez-Alenda (Conceptualization [equal], Data curation [equal], Formal analysis [equal], Investigation [equal], Writing—original draft [equal]), Juan J. Carrasco (Data curation [equal], Writing—review & editing [equal]), Begoña Valls-Donderis (Writing—review & editing [equal]), Lirios Dueñas (Investigation [equal], Methodology [equal], Writing—review & editing [equal]), and Mercè Balasch-Bernat (Conceptualization [equal], Data curation [equal], Formal analysis [equal], Methodology [equal], Writing—original draft [equal], Writing—review & editing [equal])

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Ethics Approval

The study was approved by the University of Valencia Research Ethics Committee (no. H1542709432243). The study complies with the Declaration of Helsinki.

Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

Supplementary Data

Supplementary Data for this article are available at *PHYSTH* online.

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