Ultrasonography features of abdominal perimuscular connective tissue in elite and amateur basketball players: an observational study

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SUMMARY
The purpose of this study was to assess and compare with rehabilitative ultrasound imaging (RUSI) the perimuscular connective tissue (PMCT) and interrecti distance (IRD) between elite and amateur basketball players. A sample of 22 healthy basketball players was included and divided into two groups: elite basketball players from Spanish 1st division (n = 11) and amateur basketball players from an entertainment Spanish division (n = 11). Ultrasound images of the external oblique (EO), internal oblique (IO), transversus abdominis (TrAb), rectus anterior (RA) and IRD PMCT were measured and analysed by the ImageJ software. Measurements of abdominal wall muscles PMCT present statistically differences (P < .05) for an increase of perimuscular connective tissue of external oblique (PMC-TEO), perimuscular connective tissue of transversus abdominis (PMCTTA) of the left side and an increase of PMCTEO on the right side in favor of the elite group. Rather, the study showed statistically differences (P < .05) for a decrease of perimuscular connective tissue between the internal oblique and transversus abdominis (PMCTIO-TA), and a decrease in PMCT total summation of the left side with elite group in respect to amateur group. This study reported an increase of left PMCTEO, left PMCTTAA, right PMCTEO as well as a decrease of left PMCTIO-TA and in PMCT total summation on the left side.

KEYWORDS: connective tissue, oblique abdominis, rectus abdominis, transversus abdominis, ultrasonography, basketball.

INTRODUCTION
Muscles and perimuscular connective tissue (PMCT) of the abdominal wall develop an important role stabilizing and supporting the spine.¹ The spine is surrounded in the midline by rectus abdominis (RA), laterally 3 overlapping layers conformed by the external oblique (EO), internal oblique (IO) and transversus abdominis (TrAb).² Moreover, these muscles and PMCT have an important role transferring loads from lower limbs to upper limbs and balancing abdominal pressures.³ In subjects with lumbopelvic pain (LPP), Whittaker et al.² found a thicker abdominal PMCT.
Many methods exist to assess the morphology and characteristics of the abdominal wall muscles, including magnetic resonance, electromyography, and rehabilitative ultrasound imaging (RUSI). These assessment tools have been used to evaluate the thickness, cross-sectional area (CSA) and PMCT related to musculoskeletal conditions that may influence the physical therapy approach. Considering the lower limbs, a recent study found a reduced CSA of the peroneus longus and a negative correlation for the circular perimeter of connective tissue in patients with ankle sprains. Additionally, Taniguchi et al. reported a decreased thickness in vastus medialis muscles in subjects with knee osteoarthritis. CSA and thickness of the flexor hallucis brevis and abductor hallucis were reduced in subjects with hallux valgus. Regarding the upper limb supraspinatus muscle, thickness have been related with subacromial impingement syndrome. Furthermore, CSA of intrinsic hand muscles can be evaluate with RUSI and could be reliable to predict muscle strength in subjects with nerve injury. With respect to cervical muscles, Javanshir et al. observed that deep cervical flexor muscles may be evaluated during programs for individuals with neck pain. Temporomandibular joint disorders have showed an altered function of the masseter, temporalis and sternocleidomastoid muscles. Additionally, ultrasonography examinations can be appropriate to assess muscles and PMCT changes in individuals with pathology. Whittacker et al. found a thicker PMCT and a wider interrecti distance (IRD) in patients with LPP compared with a healthy group. Moreover, multifidus and abdominal wall muscles have been linked with a decreased CSA in patients with LPP.

RUSI may consider a non-invasive, relatively affordable and portable tool, which provides information of morphology, and size of muscles and PMCT. Following Whittacker et al. criteria, ultrasonography assessments were carried out at rest for muscular tissue, PMCT and IRD of the abdominal wall. Moreover, RUSI evaluation of the trunk and abdominal wall may predict risk of injuries in professional football players. To date, RUSI comparison of abdominal wall PMCT of elite and amateur players has not been carried out. Therefore, the purpose of this study was to assess and compare with RUSI the PMCT and IRD between elite and amateur basketball players.

METHODS
Study design
An observational study was developed following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Sample size calculation
A sample size was calculated using the difference between two independent groups with G*Power 3.1.9.2 software and based on the IR distance (cm) of a pilot study with 2 groups (mean ± SD), 10 elite basketball players (1.35 ± 1.01 cm) and 10 amateur basketball players (0.78 ± 0.28 cm). Indeed, 1-tailed hypothesis, effect size of 0.99, α error probability of 0.05, power (1-β error probability) of 0.90 and allocation ratio (N2/N1) of 1 was carried out for the sample size calculation. Therefore, a total sample size of 20 subjects, 10 for each group, was calculated.

PARTICIPANTS
A sample of 22 healthy basketball players (age: 21.0 ± 6.0 y; height: 1.88 ± 0.30 m; weight: 85.9 ± 13.5 kg; body mass index, BMI: 22.6 ± 2.6 kg/m²) was included and divided into two groups: professional elite basketball players from Spanish 1ª Division league club (n =11) and amateur basketball players from an entertainment Spanish division (n = 11). Inclusion criteria for the present study consisted of individuals aged 18 to 35 years old; male; players with right-handed dominance, right-handed throw, and left-foot jump dominance; the professional group had to meet at least three of the following requirements: a) at least three years as a professional player; b) playing at least one year in the national team; c) professional players in youth categories; d) having won an international championship with his team or in a national team.

Exclusion criteria were any musculoskeletal disease in the lumbopelvic region, skin disease, hypopcapnia, neurological signs, lower limb pathology (i.e.; fracture, osteoarthritis) and a body mass index (BMI) greater than 31kg/m². Furthermore, hypopcapnia was considered when Nijmegen questionnaire values were higher than 24.

Ethical considerations
The study was approved by A Coruña University Ethics Committee, Spain, and participants signed the
informed consent form. The study also adhered to the ethical standards of the Declaration of Helsinki.20

Sociodemographic and respiratory distress data

Before the ultrasonography procedure, age (y), height (m), weight (kg) and BMI (kg/m²) were recorded. Moreover, respiratory distress values were registered with the Nijmegen questionnaire.2,19

Ultrasound of the abdominal wall

All imaging procedures were carried out by 1 operator (J.A.P), who was a physiotherapist with 3 years of BUSI experience. Following Whittacker et al.2 procedure, the operator was not blinded during the ultrasonography examination. A diagnostic ultrasound device (Toshiba Apio 500 Platinum, Toshiba American Medical Systems; CA, USA) with a 7 to 14-MHz-range linear transducer (18L7 PLT-1204BT type; 40-mm footprint) was used for B mode ultrasound imaging. All images were performed in supine position. For PMCT of the EO, IO and TrAb, the operator was situated in mid-axillary line, using the reference point located between inferior border of subcostal line and iliac crest. PMCT of RA muscle the transducer was placed aligned with the umbilicus; and IRD was evaluated just under the umbilicus (Figure 1).2 Measurements were collected at right and left sides at the end of expiration with the transducer in the same place. For the statistical analysis, the mean of 3 repeated values for each measure was used. PMCT was defined as the distance between the inside borders of each connective tissue layer. IRD was defined as the distance between the inside borders of both RA.2 ImageJ software (version 2.0; US National Institutes of Health, Bethesda, Maryland, USA) was utilized for measuring all images offline.21

Statistical analysis

SPSS 22.0 software (IBM SPSS Statistics for Windows; NY: IBM Corp.) was employed for the data analysis. An α error of 0.05 (95% confidence interval) and desired power of 80% (β error of 0.2) were used. First, the Shapiro-Wilk test was utilized to assess normality. Second, a descriptive analysis was performed for the total sample together, as well as in both groups separately. Finally, a comparative analysis between both groups was performed. For the parametric data, mean ± standard deviation (SD) and Student’s t-test for independent samples were applied. For the non-parametric data, the median ± interquartile range (IR) and Mann-Whitney U test were used.

FIGURE 1. DESCRIPTIONS
1. Transducer places during ultrasound evaluation of the abdominal wall.
2. PMCT thickness and IRD measurements of the abdominal wall. 1=PMCTO; 2=PMCTEO-I0; 3=PMCTIO-TA; 4=PMCTTA; 5=PMCTSUPRA; 6=PMCTDEERA; 7=IRD. Abbreviations: IRD, interrecti distance; PMCTEO, perimuscular connective tissue external oblique; PMCTEIO-I0, perimuscular connective tissue external oblique- internal oblique; PMCTIO-TA, perimuscular connective tissue internal oblique- transversus abdominis; PMCTTA, perimuscular connective tissue transversus abdominis; PMCTRA, perimuscular connective tissue rectus anterior; PMCTSUPRA, perimuscular connective tissue superficial rectus anterior; PMCTDEERA, perimuscular connective tissue deep rectus anterior.
RESULTS
Regarding the Table 1, sociodemographic data did not show statistically significant differences ($P > .05$) for age between both groups. Instead, statistically significant differences ($P < .05$) were observed in Nijmegen scores in favor of the elite basketball players.

Considering Table 2, measurements of abdominal wall muscles PMCT present statistically differences ($P < .05$) for an increase of perimuscular connective tissue of external oblique (PMCTEO), perimuscular connective tissue of the transversus abdominis (PMCTTA) of the left side and an increase of PMCTEO on the right side in favor of elite group. Rather, the study showed statistically differences ($P < .05$) for a decrease of perimuscular connective tissue between the internal oblique and transversus abdominis (PMCTIO-TA), and a decrease in PMCT total summation of the left side with elite group compared to amateur group.

DISCUSSION
To date, this new study may be considered as the first study to make a comparison of the abdominal wall PMCT between elite and amateur basketball players. To our knowledge, the only study of RUSI examination of PMCT abdominal wall muscles at rest was carried out in subjects with and without LPP.² Langevin and Sherman²² have hypothesized that PMCT plays an important role in subjects with LPP. Additionally, greater thickness (22%) of PMCT was found in patients with LPP.²³ A dominant patterns like left-foot jump dominance may predispose an extra mechanical stress as well

**TABLE 1. SOCIODEMOGRAPHIC DATA AND RESPIRATORY DISTRESS SCORES OF THE BASKETBALL PLAYERS ‡**

<table>
<thead>
<tr>
<th>Data</th>
<th>Amateur (n = 16)</th>
<th>Elite (n= 16)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>21.0 ± 3.0 †</td>
<td>23.0 ± 9.0 †</td>
<td>.748 †</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>79.63 ± 10.29 *</td>
<td>92.18 ± 13.94 *</td>
<td>.026**</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.84 ± 0.07 *</td>
<td>1.92 ± 0.10 *</td>
<td>.035**</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>21.55 ± 2.28 *</td>
<td>23.72 ± 2.67 *</td>
<td>.054**</td>
</tr>
<tr>
<td>Nijmegen test *</td>
<td>3.72 ± 3.13 *</td>
<td>12.54 ± 3.77 *</td>
<td>&lt; .001 **</td>
</tr>
</tbody>
</table>

* Mean ± standard deviation (SD) was applied. ** Student’s t-test for independent samples was performed. † Median ± interquartile range (IR) was used: ‡ Mann-Whitney U test was utilized

**TABLE 2. ULTRASOUND IMAGING OF THE INTERRECTI DISTANCE AND PERIMUSCULAR CONNECTIVE TISSUE.**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Amateur (n=16) †</th>
<th>Elite (n=16) †</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRD</td>
<td>1.04 ± 0.51 (0.64–1.96) †</td>
<td>1.28 ± 0.69 (0.54–3.64) †</td>
<td>0.001†</td>
</tr>
<tr>
<td>Thickness (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right PMCTEO</td>
<td>2.00 ± 4.00 (0.01–11.00) †</td>
<td>0.45 ± 0.18 (1.15–0.81) †</td>
<td>0.001†</td>
</tr>
<tr>
<td>Right PMCTEO-IO</td>
<td>0.11 ± 0.05 (0.07–0.33) †</td>
<td>0.10 ± 0.07 (0.19–0.11) †</td>
<td>0.847†</td>
</tr>
<tr>
<td>Right PMCTIO-TA</td>
<td>0.12 ± 0.04 (0.07–0.24) †</td>
<td>0.04 ± 0.04 (0.09–0.25) †</td>
<td>0.371†</td>
</tr>
<tr>
<td>Right PMCTTA</td>
<td>0.09 ± 0.09 (0.06–0.29) †</td>
<td>0.13 ± 0.04 (0.09–0.22) †</td>
<td>0.193†</td>
</tr>
<tr>
<td>Right PMCTRA</td>
<td>0.16 ± 0.03 (0.11–0.24) †</td>
<td>0.14 ± 0.02 (0.11–0.18) †</td>
<td>0.334†</td>
</tr>
<tr>
<td>Right PMCTSUPRA</td>
<td>0.09 ± 0.02 (0.06–0.14) †</td>
<td>0.08 ± 0.02 (0.05–0.12) †</td>
<td>0.446†</td>
</tr>
<tr>
<td>Right PMCTDEERA</td>
<td>0.06 ± 0.03 (0.04–0.10) †</td>
<td>0.06 ± 0.01 (0.04–0.07) †</td>
<td>0.898†</td>
</tr>
<tr>
<td>Total Right PMCT</td>
<td>0.09 ± 0.04 (0.06–0.22) †</td>
<td>0.11 ± 0.03 (0.08–0.17) †</td>
<td>0.438†</td>
</tr>
</tbody>
</table>

| Left PMCTEO                   | 0.11 ± 0.05 (0.06–0.23) † | 0.47 ± 0.12 (0.36–0.65) † | 0.001† |
| Left PMCTEO-IO                | 0.11 ± 0.29 (0.07–0.17) † | 0.11 ± 0.28 (0.08–0.16) † | 0.520‖ |
| Left PMCTIO-TA                | 0.90 ± 0.01 (0.06–0.13) † | 0.13 ± 0.06 (0.10–0.28) † | 0.001† |
| Left PMCTTA                   | 0.09 ± 0.03 (0.08–0.15) † | 0.13 ± 0.03 (0.10–0.21) † | 0.001† |
| Left PMCTRA                   | 0.16 ± 0.05 (0.12–0.28) † | 0.14 ± 0.04 (0.08–0.20) † | 0.256|
| Left PMCTSUPRA                | 0.09 ± 0.07 (0.20–0.34) † | 0.08 ± 0.05 (0.05–0.13) † | 0.401† |
| Left PMCTDEERA                | 0.06 ± 0.02 (0.04–0.12) † | 0.05 ± 0.01 (0.03–0.09) † | 0.369† |
| Total Left PMCT               | 0.41 ± 0.15 (0.31–0.61) † | 0.10 ± 0.03 (0.08–0.14) † | 0.001† |

Abbreviations: IRD, interrecti distance; PMCTEO, perimuscular connective tissue external oblique; PMCTEO-IO, perimuscular connective tissue external oblique-internal oblique; PMCTIO-TA, perimuscular connective tissue internal oblique-transversus abdominis; PMCTTA, perimuscular connective tissue transversus abdominis; PMCTRA, perimuscular connective tissue rectus anterior; PMCTSUPRA, perimuscular connective tissue superficial rectus anterior; PMCTDEERA, perimuscular connective tissue deep rectus anterior.

* Mean ± standard deviation (SD) (minimum–maximum) was applied. ** Student’s t-test for independent samples was performed. † Median ± interquartile range (IR) (minimum–maximum) was used. ‡ Mann-Whitney U test was utilized.
as physiological changes in these tissues. Fibrosis of the connective tissues is known to occurs as a result of repeated trauma and inflammation. Based on these findings, it is possible to hypothesize the relation between too many training sessions, high intensity, high loads, abnormal movement patterns and adaptive connective tissue changes. In addition, right-handed dominance, right-handed throw, and left-foot jump dominance may be related with the abdominal wall connective tissue morphology. Further studies may be necessary in order to correlate these player’s characteristics with the connective tissue morphology.

Regarding the studies performed by Hides et al. and Leung et al., a motor control RUSI examination of the abdominal wall muscles could be considered as an important index to predict the risk of injuries in soccer players. Likewise, studies developed by Hides et al. showed that a motor control program improves the ability to draw-in abdominal wall in soccer players and normalize excessive tension of abdominal muscles in response to a low load task.

Our sample was composed of healthy subjects and showed a higher IRD for the elite group contrary to LPP subjects. Nijmegen test registered fourfold higher score of respiratory distress in favor elite basketball players. Moreover, the scores are coinciding with the Nijmegen values between patients with and without LPP.

LIMITATIONS AND FUTURES STUDIES

Several limitations should be contemplated in this study. First, the sample was composed of healthy players, so it would be interesting in future investigations to study players with pathology, such as LPP. Second, muscle contraction changes were not studied and the ultrasound exploration during abdominal hollowing, functional tasks, dynamic movements, straight leg raise test or Valsalva manoeuvre might be interesting. At last, ultrasonography M-Mode and power Doppler mode may be useful for the study of PMCT characteristics providing functional thickness examinations and a direct visualization of inflammation within the layers and tissues.

Further research is recommended to determine characteristics of the abdominal wall structures like muscle and PMCT in elite athletes different from basketball. Moreover, it would be very interesting to examine other sports and populations with RUSI.

CONCLUSIONS

This study reported an increase of left PMCTEO, left PMCTTAA, right PMCTEO, as well as a decrease of left PMCTIO-TA and in PMCT total summation on the left side.

Conflicts of Interest and Source of Funding

There are no conflicts of interest or Source of Funding.

RESUMO

O objetivo deste estudo foi avaliar e comparar ultrassonografia de reabilitação (IUR) o tecido conjuntivo perimuscular da parede abdominal (PMPA) e interecti distância (IRD) entre elite e jogadores de basquete amadores. Uma amostra de 22 jogadores de basquete saudáveis foi incluída e dividida em dois grupos: jogadores de basquete de elite e jogadores de basquete amadores de uma divisão de entretenimento espanhol (n=11) e jogadores de basquete amadores de uma divisão de entretenimento espanhol (n=11). As imagens de ultrassom do oblíquo externo (OE), oblíquo interno (OI), transverso abdominal (TrAb), recto anterior (RA) e IRD PMPA foram medidas e analisadas pelo software ImageJ. Medidas dos músculos da parede abdominal O PMPA apresentam diferenças estatisticamente (P<0,05) para o aumento do tecido conjuntivo perimuscular de oblíquo externo (PMOE), tecido conjuntivo perimuscular de transverso abdominal (PMTA) do lado esquerdo e aumento do PMOE do lado direito a favor das elite. Em vez disso, o estudo mostrou diferenças estatisticamente (P<0,05) para uma diminuição do tecido conjuntivo perimuscular entre o oblíquo interno e transverso abdominal (PMOI-TA) e uma diminuição no somatório total de PMTA do lado esquerdo do grupo de elite em relação ao amador grupo. Este estudo relatou um aumento do PMTOE esquerdo, PMTOE direito, bem como uma diminuição do PMCTO-TA esquerdo e no somatório total do PMTO-TA no lado esquerdo.


REFERENCES


