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CLINICAL AND SONOGRAPHIC FINDINGS IN HORSES AFFECTED WITH CHRONIC FLEXOR TENDINOPATHIES AND ASSOCIATED SOFT TISSUE INJURIES OF VARIOUS JOINTS

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ABSTRACT

Flexor tendinopathies and injuries to ligaments along with arthropathies are common in athletic horses. In this study, forty-eight client-owned healthy and injured horses, suffering from chronic tendinitis, fetlock arthritis and pain/swelling in other joints, were selected and divided into three equal groups (n=16) i.e. Group A (Race), Group B (Polo) and Group C (Draft horses); each group comprised of two equal sub-groups i.e. sound (n=8) and unsound (n=8). Chronic superficial and deep digital flexor (SDFT and DDFT) tendinopathies, as well as ligament injuries from various joints (elbow, carpus, fetlock, stifle and hock) were assessed. Thorough clinical and sonographic assessments were performed. Percentage prevalence of injuries depicted fetlock collateral ligament injuries to be of highest in occurrence (50%) in the Race Horse Group A, while flexor tendinopathies (50%) were greatest in the Polo horse Group B. Contrastingly, the Draft Horse Group C manifested greater prevalence of carpus, fetlock, stifle and hock injuries (25%). All unsound horses manifested with statistically significant clinical parameters of swelling, pain, lameness and reduced range of motion. Sonographically, unsound Race and Polo horses presented with lesion hyperechogenicity ($P \leq 0.014$), fiber pattern disruption ($P \leq 0.002$ and $P \leq 0.007$, respectively), and heterogeneity ($P \leq 0.002$). Severity of injury was highly significant ($P \leq 0.003$) in Groups A (Race) and C (Draft). Race and Polo horses manifested greater unsoundness ($P \leq 0.002$), with a poorer prognosis ($P \leq 0.001$), as compared to Draft horses (unsoundness: $P \leq 0.012$; prognosis: $P \leq 0.006$). Conclusively, injuries were more pronounced in Race horses, followed by Polo and Draft horses, respectively.

Key words: ultrasonography; tendons; ligaments; joints; horses; soundness.

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INTRODUCTION

Flexor tendinopathy and ligament injury, occurring either alone or sometimes also involving a joint, are the most important causes of lameness and career termination in Polo, Race and Event horses (Alzola *et al.*, 2018; Bertoni *et al.*, 2020). Tendinopathy refers to an overstrained, swollen, painful tendon (usually the superficial digital flexor tendon) causing impaired performance and manifesting sonographic abnormalities (Smith and McIlwraith, 2012). Superficial Digital Flexor Tendon (SDFT) injuries especially in forelimbs, are most frequently encountered (Zuffova *et al.*, 2013; Alzola *et al.*, 2018), with a high incidence of re-injury (Rinnovati *et al.*, 2020). Tendon injuries are termed "chronic" when they prevail for more than 3 months (Fredberg and Stengaard-Pederson, 2008). The SDFT holds high elasticity; for high-speed movement, it acts like a spring, in storing elastic energy (O'Sullivan, 2007) and transferring it to the high-motion fetlock joint (Hauspie, 2011). Together with the rotatory action of the fetlock, the SDFT thus augments high speed movement in the athletic horse, whilst simultaneously absorbing the impact of the energy generated (Zuffova *et al.*, 2013). This also explains the high incidence of traumatic or degenerative fetlock joint injuries especially in the forelimbs of athletic horses, such as Polo and Race horses (Vanderperren and Saunders, 2009). Contrarily, draft horses are subjected to excessive loads over long distances, thus making their carpus, fetlock and hock joints more vulnerable to degenerative changes, as compared with the rest of the musculoskeletal structures (Goble, 2011; Mustefa, 2019).

Clinical assessment of the lame horse begins with an invaluable thorough clinical examination, including local nerve blocks to localize the site of lameness. Radiography is primarily used for assessment of bone tissue derangements; however, it lacks the ability to differentiate soft tissue structures (Vanderperren and Saunders, 2009). This makes ultrasonography as a vital auxiliary diagnostic aid. Ultrasound, being a simple, non-invasive, portable modality, adds value to clinical scenarios and outshines radiography by enabling direct visualization and precise diagnosis of soft tissue injuries (Vanderperren and Saunders, 2009; Docking *et al.*, 2012). These features additionally, also promise close

monitoring of the healing process during treatment of injured soft tissues in equines (Reis and Baccarin, 2010).

Most athletic horses in Pakistan, present with palmarly "bowed tendons", ligament strains, sprains and arthropathies of various joints. Likewise, draft horses are observed to present with complaints of arthropathies. This study was thus conducted to investigate the prevalence, and assess the clinical and sonographic findings in cases presented with chronic tendinopathies of the superficial and deep digital flexor tendons (SDFT and DDFT), as well as injuries to ligaments associated with various joints (elbow, carpus, fetlock, stifle and hock), which commonly occur in Race, Polo and Draft horses in Lahore, Pakistan.

MATERIALS AND METHODS

Study Design: This study was conducted to assess superficial and deep digital flexor (SDFT, DDFT) tendinopathies, and desmopathies (occurring concurrently with various arthropathies), through collaboration with the Lahore Race Club, Lahore Polo Club and UVAS Outdoor Clinic, Lahore. Approval from the Animal Ethical Committee [No.: DAS 1621, dated 23.12.2014], and owner consent was obtained prior to clinical and sonographic assessment of each case. Forty-eight (n=48) client-owned healthy, as well as injured horses of either sex and with a mean age range of 4-15 years, suffering from chronic tendinitis, fetlock arthritis and pain/swelling in other joints (elbow, carpus, fetlock, stifle, hock) were included in the study. The horses were divided into three equal groups (n=16) i.e., Group A (Race), Group B (Polo) and Group C (Draft-purpose); each group was further subdivided into two equal sub-groups, i.e. sound (n=8) and unsound (n=8).

Chronic flexor tendinopathies associated with superficial (SDFT) and deep digital flexor (DDFT) tendons, as well as injuries occurring to ligaments (desmopathies) associated with various joints (elbow, carpus, fetlock, stifle and hock), were taken into consideration (**Table 1**).

Table 1. Soft Tissue Structures Scanned During Joint Examination.

Joints		Soft Tissue Structures Scanned		
Elbow		**Triceps tendon**	**Lateral Collateral Ligament**	
Carpus		**External Carpi Radialis tendon (ECR)**	**Tendon sheath**	**Carpal Joint Capsule**
Stifle		**Middle Patellar Ligament**		
Hock		**Long Digital Extensor tendon;**	**Peroneus Tertius tendon**	
Fetlock	**Forelimb**	**Common Digital Extensor tendon (CDET)**	**Joint Capsule**	**Collateral Ligaments**
	Hindlimb	**Long Digital Extensor tendon (LDET)**	**Joint capsule**	**Collateral Ligaments**

***Clinical Examination*:** Each client-owned horse was thoroughly examined and palpatory clinical findings over the affected site were recorded for the presence or absence of warmth and swelling, pain scores, lameness grades (Schramme *et al.*, 2010; Zielińska *et al*., 2020), and range of motion (on flexion and extension) of the joints, respectively (**Table 2**).

Table 2. Score-Charts for Evaluation of Various Clinical Parameters.

Parameter Assessed	Grades	Scoring
	Grade	**Severity of Pain**
Severity of Pain (Simple Descriptive Scale)[a]	0	No pain (sound horse)
	1	Mild pain
	2	Moderate pain
	3	Severe pain
	Degree of Lameness	**Clinical Findings**
Degree of Lameness (AAEP Lameness Scale)[b]	0	Lameness not perceptible under any circumstances
	1	Lameness difficult to observe and not consistently apparent
	2	Lameness difficult to observe at walk, or when trotting in a straight line; Apparent under certain circumstances (under saddle, circling, inclines, hard surface, etc.)
	3	Lameness consistently observable at a trot under all circumstances (Nodding/ Hitching/ Shortened Stride/Toe dragging)
	4	Lameness obvious at a walk

	5	Minimal Weight-bearing in motion and/or at rest; a complete inability to move
	Grade	**Range of motion**
Range of Motion in Joints[c]	0	Normal / sound joint with 100 % normal flexion and extension
	1	50% decrease in flexion and extension
	2	75% decrease in flexion and extension
	3	100% decrease in flexion and extension

Adapted from: [a]*de Grauw and van Loon, 2016.* [b]*Kester WO 1991.* [c]Nganvongpanit *et al.*, 2009.

Most unsound horses presented with a history of chronic tendinitis, fetlock joint effusion and poor performance. Cases with ankylosis (post-fracture) were infrequent (n=2) in the athletic horse groups (Race and Polo). Most cases in the Draft horse Group C presented with ankylosis of the carpus or hock.

For each unsound horse, the degree of lameness was assessed at walk and trot, and local nerve blocks were used for site location. Radiographs were taken as a primary diagnostic tool for identification of effusive or degenerative changes, especially for swollen and painful fetlock joints. The score charts for assessment of pain, degree of lameness and range of motion, are given in **Table 2** (above).

Sonographic Examination

Preparation of the Patient: Ultrasound scans were performed with Honda 1500V ultrasound unit, using a high frequency (7.5 to 10 MHz) linear transducer (30 mm), and AquaFlex® (Parker Laboratories, Inc. USA) gel stand-off pads, as required.

Prior to ultrasound scanning, the affected site on each patient was shaved and scrubbed, along with a final coating of methylated spirit for asepsis, and to optimize clear image acquisition. In case of owner reluctance to shave their animals, only a scrub and methylated spirit were used to clean the area, and coupling gel applied thereafter (Masoudifard, 2008). All horses were scanned in standing position with equal weight bearing on each limb (Reis and Baccarin, 2010), in order to avoid any undue alteration in the sonographic presentation of any soft tissue structure being examined (Masoudifard, 2008).

Sonographic Technique: The flexor tendons were scanned on the palmar aspect of the metacarpus in seven zones starting 4 cm distal to the accessory carpal bone (Schramme *et al.*, 2010; Kidd *et al.*, 2014). Respective ligaments associated with various joints (Table 1) were scanned as per standard techniques (Kidd *et al*., 2014), as per case requirements.

Sonographic Parameters Assessed: The sonographic findings (in healthy and injured tendons and ligaments) were assessed on the basis of parameters including lesion echogenicity, fiber pattern, homogeneity, severity of injury, soundness via ultrasound and the degree of prognosis, respectively (Zuffova *et al.*, 2013). Lesion echogenicity was scored from 0 to 3, i.e. near-normal echogenicity grade 0, to mostly anechoic grade 3 (Reef, 2001). Fiber pattern was assessed as being either regular or irregular; sonographic features regarding homogeneity were assessed as being either homogenous or heterogenous (Zuffova *et al.*, 2013). Severity of the injury was graded as 0 (sound), 1 (mild tear), 2 (moderate tear), 3 (severe injury with fibrosis) and 4 (severe injury with subsequent fibrosis and synovitis), respectively. Consequently, soundness via ultrasound was categorized as being either sound or unsound, while prognosis was drawn as either being good (0), fair (1), poor (2) or guarded (3), respectively.

Statistical Analysis: Using SPSS 17 version of the statistical software, chi square analysis was applied to the results, in order to test for variance in the normal distributions of values obtained. Significance of all tests was set at <0.05 (Schramme *et al.*, 2010).

RESULTS

Clinical Findings: The data for clinical findings has been summarized in **Chart 1** (given below), and presented as follows:

Warmth: The Race Horse Group A showed significant warmth at the site of injury (P<0.021). In the other two groups, viz., Polo Horses (Group B) and Draft Horses (Group C), values were insignificant (Chart 1).

Swelling: Presence of swelling in response to injury was highly significant in all three groups, viz., Polo Horse Group B (P<0.000), followed by the Race Horse Group A and Draft Horse Group C (P<0.002), respectively (Chart 1).

Pain Scores: All groups showed marked degrees of pain, evidenced by the highly significant values of pain in relation to the presence of pain with injury. The value of P was 0.001 for all three groups, i.e. Race, Polo and Draft horses (Chart 1).

Degree of Lameness: The degree of lameness is also a cardinal sign for the presence of injury in the vicinity. Degree of lameness was highly significant in all three groups (P<0.003), Chart 1.

Range of Motion: Range of joint motion is inevitably affected with injury. In this study, ankylosis was our

chief finding in most of the chronic cases which were presented with chronic collateral ligament injuries and associated fetlock osteoarthritis (in Race horses), **Figures 1 to 6**.

Hence, a very highly significant decrease in the range of motion (P<0.001) was found in the Race Horse Group A, followed by the Draft Horse Group C (P<0.022) and Polo Horse Group B (P<0.034), respectively (Chart 1).

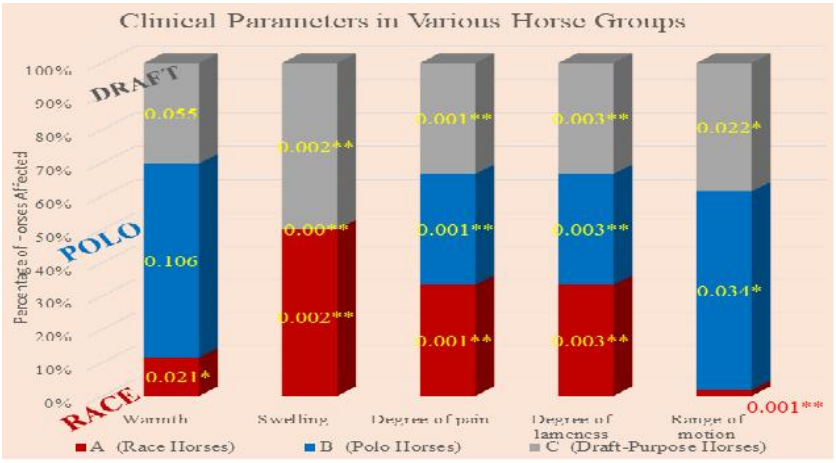

Chart 1. Clinical Parameters in Various Horse Groups

Key: This chart summarizes findings of clinical parameters in the three groups of horses. The parameters of **Warmth, Swelling, Degree of Pain, Degree of Lameness** and **Range of Motion of Joints**, are shown. The three colors on each bar (red, blue, grey) show the values for the three different groups (Race, Polo and Draft), respectively. Significant *P values* have been shown with asterisks.

Warmth: was significant in the Race Horse Group A (P<0.021*).

Swelling: was more pronounced in the Polo Horses, followed by Race and Draft Horses: Polo>Race>Draft Horse, P<0.000** > 0.002** > 0.002**

Degree of Pain: was highly significant in all three groups, P<0.001**.

Degree of Lameness: was highly significant in all three groups, P<0.003**.

Range of Motion: Significant decrease in range of motion of joints was seen as follows:

Race< Draft < Polo Horse, P<0.001** < 0.022* > 0.034*, i.e. Race horses showed the greatest decrease in range of motion, followed by the Draft and Polo horses, respectively.

Sonographic Findings: The sonographic findings of all the parameters under study, have been summarized in **Table 3, Chart 2**, and presented as follows:

Echogenicity: In our study, a high percentage (100%) of unsound Race horses showed lesion hyperechogenicity (P<0.014), subsequently being 85.7% in unsound Polo Horses (P<0.014) and 83.3% in unsound Draft Horses (P<0.037), respectively (**Chart 2**).

Conclusively, due to the high percentage of unsound horses showing hyperechogenicity [100% in unsound Race horses (P<0.014); 85.7% in unsound Polo Horses (P<0.014) and 83.3% in unsound Draft Horses (P<0.037)], the results were directly correlated with the severity and chronicity of the lesions, suggesting more granulation tissue deposition and healing with fibrosis, respectively, in Race, Polo and Draft purpose horses.

Table 3. Statistical Analysis of Sonographic Parameters.

Group	A (Race Horses)	B (Polo Horses)	C (Draft Horses)
Parameters		**P values**	
Echogenicity	0.014**	0.014**	0.037*
Homogeneity	0.002**	0.002**	0.039*
Fiber pattern	0.007**	0.002**	0.021*
Severity of injury	0.003**	0.062	0.003**
Soundness via ultrasound	0.002**	0.002**	0.012**
Status of prognosis	0.001**	0.006**	0.006**

Inference

Echogenicity: Lesion hyperechogenicity was more pronounced in Race and Polo horses (P<0.014) as compared to Draft horses (P<0.037).

Homogeneity: Lack of homogeneity/ heterogenous tissue texture was more pronounced in Race and Polo horses (0.002), than Draft horses (P<0.039).

Fiber Pattern: Disruption in fiber pattern was more pronounced in Polo horses (P<0.002), followed by Race (P<0.007) and Draft horses (P<0.021) horses, respectively**.**

Severity of injury: Severity of injury was more pronounced in Race and Draft-purpose horses (P<0.003), respectively.

Soundness via ultrasound: Unsound Race and Polo horses, showed greater unsoundness (P<0.002), as compared to Draft horses (P<0.012).

Degree of prognosis: Performance prognosis was poorer for Race horses (P<0.001) followed by the Polo and Draft horses (P<0.006), respectively.

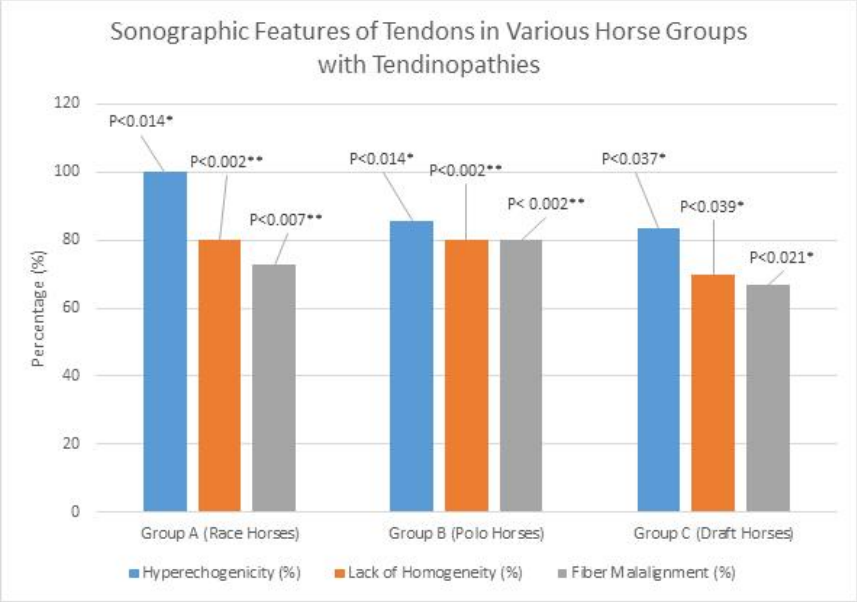

Chart 2. Sonographic Features of Tendons in Various Horse Groups with Tendinopathies.

Key: Sonographic features of lesion hyperechogenicity and lack of homogeneity (i.e., heterogenous echotexture) were highly significant in the Race horses, followed by the Polo and Draft horses, respectively. Fiber disruption was more marked in Polo horses, followed by Race and Draft horses, respectively.

Homogeneity: Homogeneity in healed tendon/ ligament tissue is a desirable outcome post-injury, and depicts near-normal collagen deposition, whereas heterogenous tissue characteristics signify healing with scar/ fibrosis.

In our study, a high percentage (80%) of unsound Race and Polo horses showed absence of homogeneity in tendon fibers (P<0.002); 70% of unsound Draft purpose horses lacked homogeneity (P<0.039), while only 16.7% unsound draft purpose horses depicted presence of homogeneity in tendon fibers. Overall, heterogeneity was more marked in Race Horses, followed by Polo, and Draft-purpose Horses, respectively (**Chart 2, Figures 1 to 6**).

Fiber Pattern: Fiber Pattern in unsound horses examined, showed marked disruption and irregularity, with highly significant values for Groups B (P≤0.002) and A (P≤0.007), and a significant value for Group C (P≤0.037), thus signifying more marked lesions with greater fiber irregularities in Groups B (Polo) and A (Race), followed by Group C (Draft), respectively, i.e. (Polo>Race>Draft Horses), **Chart 2**.

Severity of Injury: Severity of injury was highly significant for Groups A and C (P≤0.003), and non-significant for Group B.

In the Race Horse Group, A, 12.5% horses depicted a mild tendon tear, 50% showed moderate tears, 25% showed severe tears, while 12.5% showed severe tendon tears with synovitis and fibrosis of the tendon fibers, P<0.003.

In the Polo Horse Group B, mild tears were shown in 12.5% unsound Polo horses, moderate tears in 37.5%, while 12.5% unsound Polo horses depicted sever

tears, severe tendon tears with fibrosis and severe tendon tears with synovitis and fibrosis, respectively, P<0.062.

In the Draft-Purpose Horse Group C, mild tears were recorded in 25% unsound horses, moderate tears in 50%, while 12.5% horses depicted severe tears with fibrosis and severe tendon tears with synovitis and fibrosis, respectively, P<0.003. Consequently, the severity of injury was highly significant in Race and Draft-purpose Horses, respectively.

Soundness via Ultrasound: Statistically, values were highly significant for Groups A and B (P≤0.002), and significant for Group C (P≤0.012); these results suggested marked unsoundness in Groups A (Race) and B (Polo), as compared to Group C (Draft).

Regarding assessment of soundness via ultrasound, 80% of Race and Polo horses were unsound (P<0.002); while 77.8% of Draft Horses were unsound (P<0.012), respectively.

Degree of Prognosis: Status of prognosis via ultrasound showed a highly significant value for all three groups, being more highly significant for Group A (P≤0.001), followed by Groups B and C (P≤0.006), respectively.

Consequently, status of prognosis was inferred to be less favorable/ poorer for the Race Horses, followed by the Polo and Draft Horses, respectively.

DISCUSSION

Horses are widely used across Pakistan for Polo, Race and Draft purposes. Sports' horses kept for Polo and Race, commonly present with flexor tendinopathies (especially Superficial Digital Flexor Tendinitis) and ligament strains/ tears either individually, or occurring concurrently with arthropathies. Draft horses, subjected to excessive workloads, are commonly presented with osteoarthritis and/or ankylosis post-trauma. Maintenance of soundness of the lame athletic horse poses a true challenge, since flexor tendinitis and ligament injuries take a somewhat longer time to heal, and commonly result in reduced performance in face of lack of rest (Genovese *et al.*, 1990), or early retirement from competition if not properly treated (Kristoffersen *et al.*, 2005). A thorough clinical examination along with nerve blocking, serves as an invaluable tool, to localize the seat of lameness. Radiography complements clinical examination enabling diagnosis of bone disorders; while sonography indispensably enables direct visualization of soft tissue derangements, including evaluation of soft tissue components of joints, and regularity of bony contours (Smith, 2008). Furthermore, it also serves as a vital diagnostic tool for monitoring the healing process.

Regarding prevalence of lameness associated with joint injury, lameness due to elbow pain is usually seen in those horses which frequently perform arm motions and exert over-stress on elbow joint during exercise, i.e., Polo horses (Lin *et al.*, 2012). However, unless for an external trauma, the incidence of elbow lameness is rare (Baccarin, 2016). The same was also observed during our study, in which elbow lameness formed 0% of all the recorded cases. Osteoarthritis of the carpus (8.33%) and hock (16.67%) were the commonest cases in draft horses examined. On the other hand, fetlock osteoarthritis and accompanying fetlock collateral ligament strains were recorded as being highest in incidence i.e., 41.67% among all recorded cases in Race and Polo horses (**Figures 1 to 4**). This is in agreement with the findings of Pool and Meagher (1990) and Mostafa *et al.* (2008) that due to its gross anatomical location, rotatory function and sustenance of high forces during acceleration, the equine fetlock joint is most prone to the largest number of traumatic and degenerative lesions. Cases of stifle arthritis were relatively low, rather, one horse was presented with an organized hematoma (**Figure 7**) at the right stifle, with intact joint capsule, middle patellar ligament and trochlear ridge. Superficial Digital Flexor Tendinitis accounted for approximately 16.67% of all clinical cases examined in athletic (Race and Polo) horses, and our findings of a moderate to high case load of horses presented with tendinitis correlate well with the findings of other scientists (Marr, 1992; Oikawa and Kasashima, 2002).

Among various soft tissue injuries at the palmar aspect of the metacarpus, superficial digital flexor tendinitis in the mid-metacarpus region of forelimbs, predominates (O'Sullivan, 2007); on the other hand, DDFT injuries are generally located in the distal metacarpus region or pastern, within the tendon sheath (Whitcomb, 2005). Our findings were also in close agreement with these, since SDF-tendinitis prevailed and DDF-tendinitis cases were seldom found in the mid-metacarpal region.

Clinically, SDFT injuries are initially diagnosed on visualizing the swelling as a curved/ rounded contour of the palmar metacarpus (Whitcomb, 2005). The swelling may subside or persist, depending on the degree of tendon damage (Geburek *et al.*, 2015). At times, distention and thickening of the digital flexor tendon sheath may make accurate palpation very difficult (Redding, 2016). Lameness associated with SDF-tendon injuries is typically fairly mild, approximately 1 to 2 grades out of 5, and very mild cases may not depict lameness. However, severity of the lesion may aggravate lameness. Likewise, in the acute inflammatory stage (i.e., a few days post-injury), the injured site appears warm and palpation may induce pain (O'Sullivan, 2007), which tends to subside as the injury enters the sub-acute reparative phase (weeks post-injury) and chronic remodeling stage (months post-injury), respectively (Smith and Schramme, 2003). The degree of swelling and pain, however, do not correlate well with the severity of the lesion (O'Sullivan, 2007) and ultrasonographic

evaluation is generally necessary. Nevertheless, the chronically injured tendon, either due to repeated blister application (Rinnovati *et al.*, 2020), or repetitive re-injury, appears thickened (O'Sullivan, 2007), and inelastic due to fibrous scar tissue formation (Smith and Schramme, 2003), thus reducing performance and athletic life of the horse (Genovese *et al.*, 1990). In our study, we examined athletic horses (Race and Polo) with chronic tendinitis, i.e. weeks to months post-injury, and blister application still being opted by most owners, justified our findings of permanently deformed, swollen, thick, inelastic SDF-tendons with varying degrees of pain and sensitivity (Beerts *et al.*, 2013), correlating well with all the studies quoted above. In some cases, extensive thickening and fibrosis of the digital flexor tendon sheath made distinction of the SDFT and DDFT very difficult, with permanent deformity of the tendons. As reported by Reef (2001), owners usually consider flexor tendon injuries to have healed when the injured tendon becomes cold, non-painful, and adequate time has passed for tendon healing to occur; hence the horse is returned to sports activities without adequate rest (Genovese *et al.*, 1990), only to find recurrence of the tendon injury, which is then subjected to blistering. In our study, too, we found a good correlation between lameness and severity of the lesion, possibly because a majority of cases examined, were those with repeated blister application and persistence of lameness at trot, attributable to severe tendon lesions (O'Sullivan, 2007), either healing with fibrosis (**Figures 1 to 6**), or depicting re-injury due to non-compliance of the owner (Genovese *et al.*, 1990; Rinnovati *et al.*, 2020).

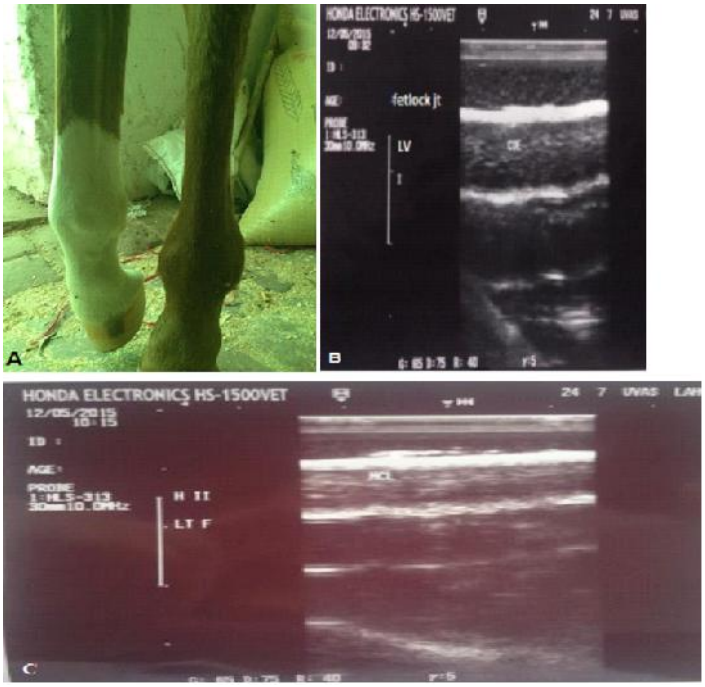

Figure 1. A, A Race horse with bilateral fetlock joint swelling in fore legs. Sonograms were obtained using gel stand-off pads. **History**: The horse was suffering from chronic pain, marked lameness, decreased range of motion of both fetlock joints. Blistering had been tried earlier to change chronic inflammation to acute in an attempt to promote healing. **B,** Sonogram showing Common Digital Extensor Tendon (**CDET)** in the Left Fetlock: abnormal, hyperechoic, coarse fiber pattern with multiple hypoechogenicities; hyperechoic tendon parenchyma due to blistering; **C,** Sonogram showing Medial Collateral Ligament (**MCL)** in the Left Fetlock showing abnormal, hyperechoic, coarse fiber pattern with a small hypoechoic area, signifying granulation tissue with no evidence of healing.

In addition to clinical findings, sonographic evidence is mandatory to standardize the type, severity and stage of tendon/ ligament injury (Smith and McIlwraith, 2012). Sonographic changes in echotexture, fiber pattern, homogeneity have extensively been reported by scientists (Marr *et al.*, 1993; Martinoli *et al*. 1993; Tsukiyama *et al.*, 1996; Dowling *et al.*, 2000; Reef, 2001; Whitcomb, 2005; Dehgan *et al.*, 2007; O'Sullivan, 2007; Schramme *et al.*, 2010; Smith and McIlwraith, 2012; Zuffova *et al.*, 2013; Domingo *et al.*, 2017; Zielińska *et al.*, 2020) to predict severity of the injury, state of soundness, and future career prognosis of the athletic horses (Genovese *et al.*, 1990; Alzola *et al.*, 2018). Early phases of injured tendon/ ligament healing appear 'hypoechoic', due to fibrin clot and granulation tissue formation; during the remodeling phase (6-12

months post-injury), the lesion may become isoechoic or hyperechoic, or even depict a persisting injury for a prolonged duration, such as heterogenous fiber pattern (Smith and McIlwraith, 2012), heterogeneously hyperechoic echotexture (Marr *et al.*, 1993; Zuffova *et al.*, 2013) and inhomogeneity (Whitcomb, 2005; Geburek *et al.*, 2015) in chronic cases with extensive scar formation, as also observed during our study. Consequently, extensive peritendinous/ periligamentous fibrosis decreases their elasticity, thereby making the horse more vulnerable to re-injury and a poorer career prognosis (Genovese *et al.*, 1990; Reef, 2001; Smith and Schramme, 2003).

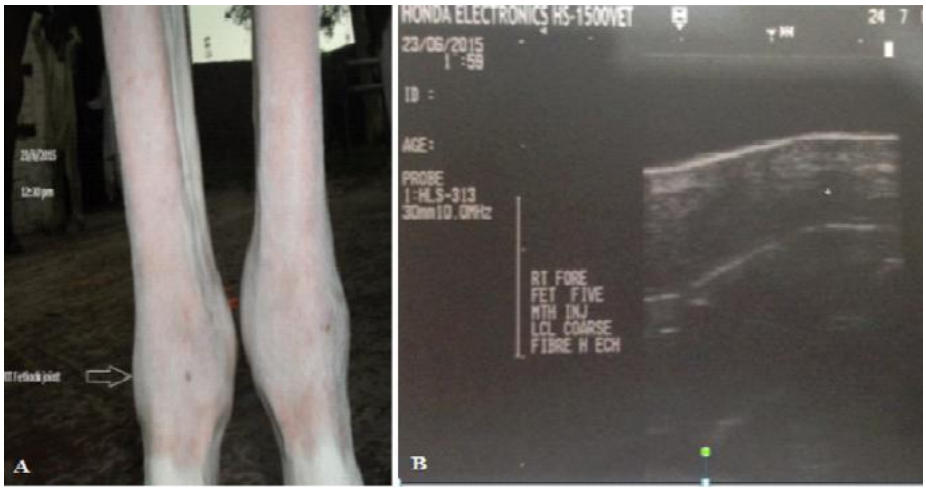

Figure 2. A, A Race Horse at the Race Club, Lahore, suffering from a 5-mo old injury at the right Fore-Fetlock, with marked lameness. **B,** Sonogram showing the Lateral Collateral Ligament of the Right Fetlock with a coarse echotexture and disruption of fibers seen as large hypoechoic lesions.

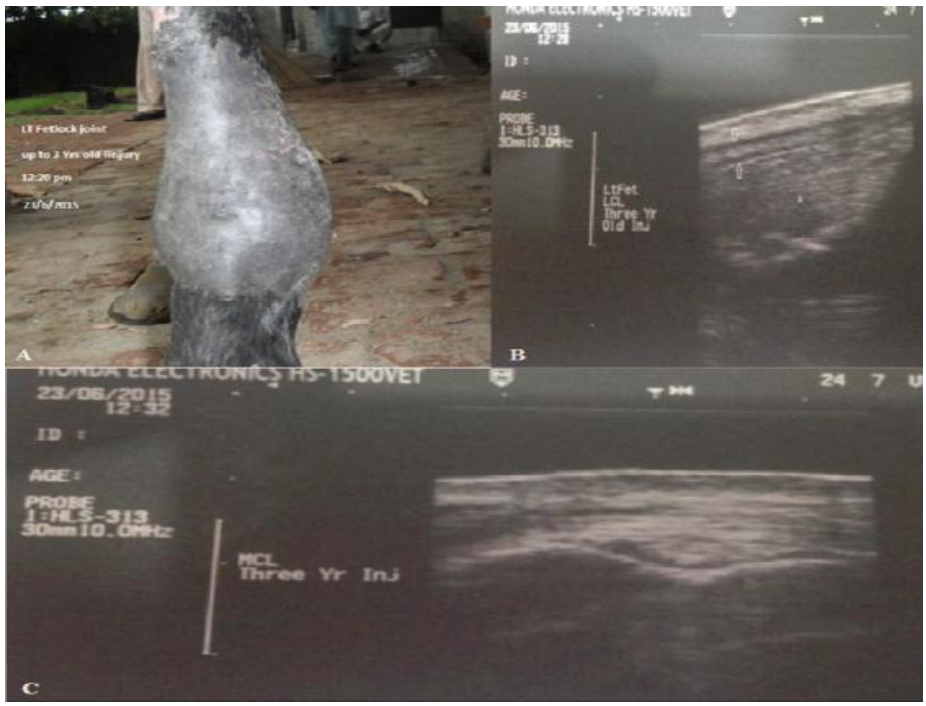

Figure 3. **A,** A Race Horse suffering from a 3-year-old chronic injury of the left Fore- Fetlock Joint. Despite repeated blister application, the joint was painful with a decreased range of motion and marked (Grade 4) lameness. **B,** Sonogram showing the hyperechoic Lateral Collateral Ligament (LCL) with coarse echotexture indicating healing with fibrosis. **C,** Sonogram showing a hyperechoic Medial Collateral Ligament (MCL) with coarse fiber pattern.

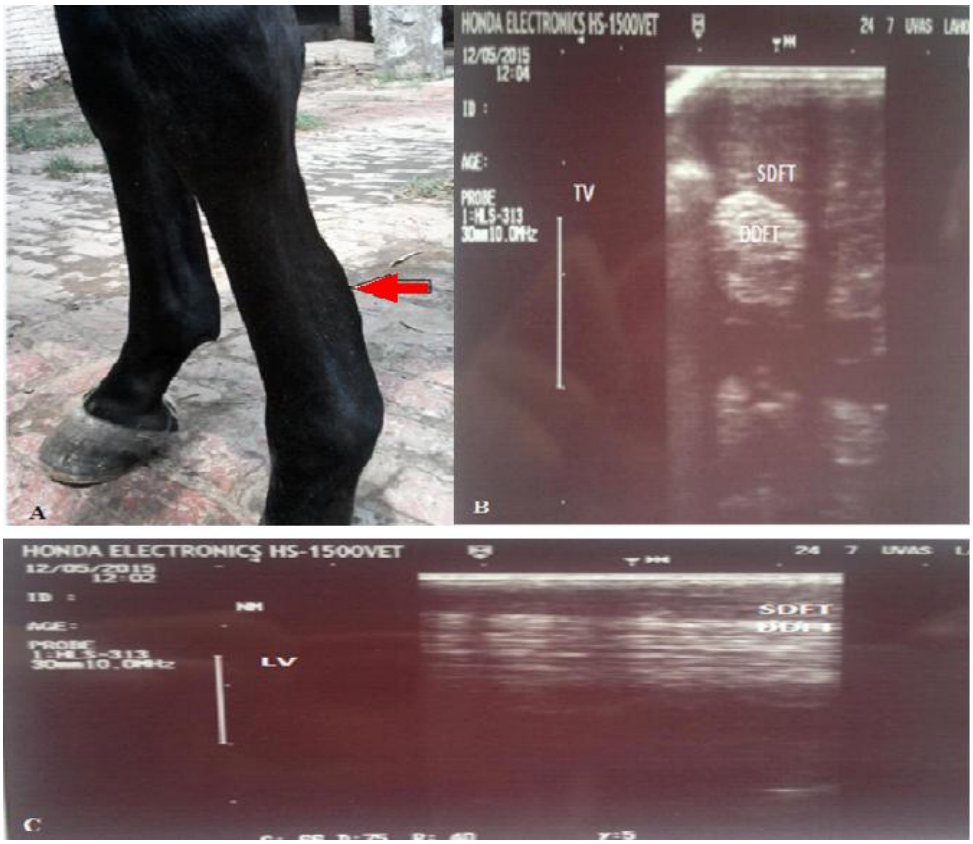

Figure 4. **A,** A Racing Stallion, suffering from **Chronic Tendonitis with a permanent deformity (arrow) of the flexor tendons**. **B,** Transverse sonogram, showing pathologic flexor tendons with hypoechoic SDFT and hyperechoic DDFT. The scan was performed on the palmar aspect of the cannon bone at level 2. **C,** A Sonogram taken from the palmar aspect of forelimb, showing a longitudinal view of the superficial digital flexor tendon (SDFT) with a hypoechoic lesion in the center. The Deep Digital Flexor Tendon (DDFT) is also markedly hyperechoic indicating healing with fibrosis.

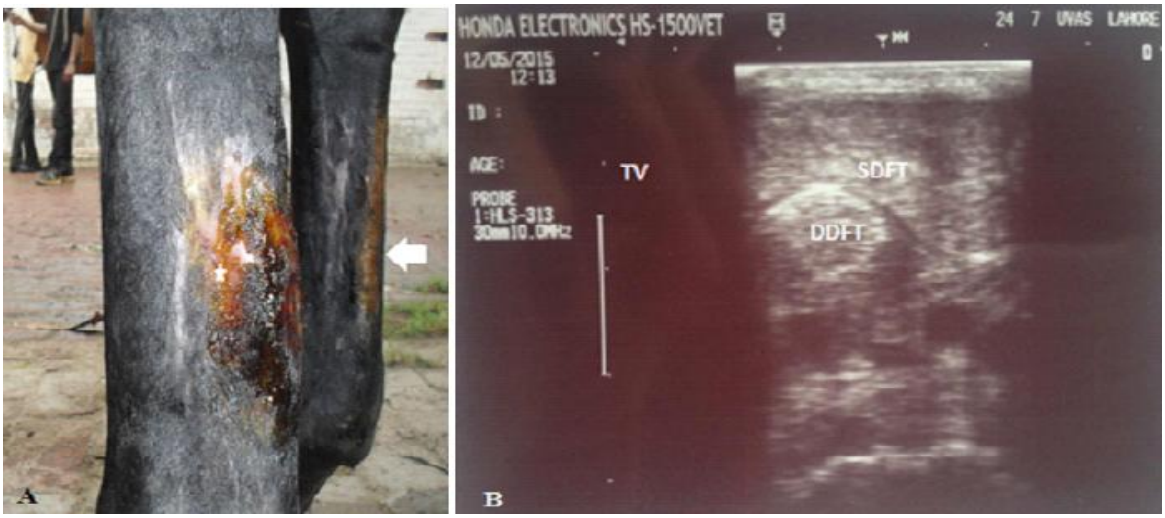

Figure 5. **A,** A Race horse showing a **chronic deformity of the flexor tendons**; the horse was repeatedly treated using blistering on both limbs (white star and white arrow). **B,** Transverse sonogram of flexor tendons, showing cross-section of the SDFT and the hyperechoic DDFT with multiple hypoechoic lesions in both tendons, suggesting presence of granulation tissue; the **SDFT is additionally enlarged due to swelling** after repeated blistering while the DDFT appears hyperechoic suggesting healing with fibrosis.

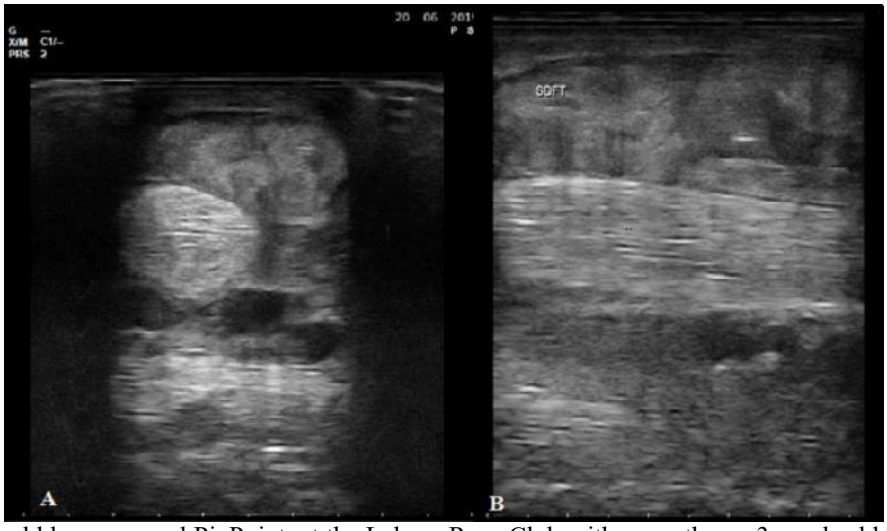

Figure 6. A 4-year-old horse named PinPoint, at the Lahore Race Club with more than a 3-week-old Tendinitis swelling at the palmar aspect of the metacarpus. **A**, SDFT in transverse section showing hypoechoic lesions, anechoic tears, and heterogenous echotexture. **B**, Longitudinal section of the flexor tendons showing massive swelling of the SDFT, fiber pattern disruption and heterogenous echotexture.

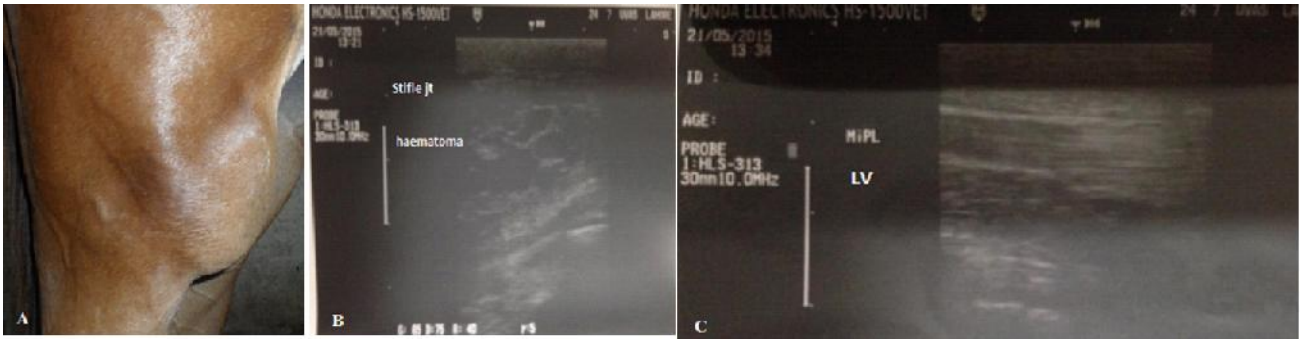

Figure 7. **A**, A race horse at a Stud Farm in Lahore, suffering from an acute, non-painful swelling on the craniodorsal aspect of the right stifle joint. **B**, Sonogram showing a longitudinal scan over the swelling. The scan revealed a large, soft cavity filled with anechoic fluid and separated by thin, echogenic trabeculae. This was diagnosed to be an organized hematoma. It resolved over time, through regular application of Kaolin poultice. **C**, Longitudinal scan of the middle patellar ligament (MiPL) in the same horse. The MiPL appears hyperechoic, which was attributed to constant poultice application, however, fiber pattern is smooth indicating no major abnormality.

In our study, lesion hyperechogenicity was highly significant in the Race horse Group A, followed by the unsound Polo and Draft Horse Groups B and C, respectively. Likewise, fiber heterogeneity was more marked in Race Horses, followed by Polo, and Draft-purpose Horses, respectively. In these unsound horses, fiber pattern also showed disruption, being highly significant for the Polo Horse Group B, followed by the Race horse Group A and Draft-purpose Horse Group C, respectively (Polo>Race>Draft Horses). Since these horses were extensively and repeatedly treated with blister application, hence, our sonographic findings of hyperechoic, heterogenous scar tissue formation with thick adhesions in some cases, and persisting fiber disruption showing no evidence of healing, strongly correlate with the findings reported above, and profoundly emphasize the fact that blister application deteriorates healed tendon/ ligament quality, with high incidence of re-injuries (Rinnovati *et al.*, 2020).

In our study, a greater percentage (80%) of Race and Polo horses were found to be unsound ($P<0.002$), as compared to (77.8%) unsound Draft Horses ($P<0.012$), (Race>Polo>Draft). Consequently, the severity of injury was highly significant in Race and Draft-purpose Horses, respectively. Statistically, the status of prognosis was less favorable for the Race Horses, followed by the Polo and Draft Horses, respectively, (Race>Polo>Draft). Given that athletic horses in Pakistan are usually older in age (>2 years' old), manifest long toe, low heel conformation, are deprived of adequate rest despite

injuries, and are still subjected to obsolete methods of treatment (blistering), with lack of a controlled rehabilitation plan, the findings of this study are in good agreement with those reported by other scientists, whereby, strain-induced SDF-tendinopathies are high in incidence in athletic horses undergoing high speed exercises, and depict less favorable prognosis if not adequately treated (with regenerative therapies and controlled exercise program), (Dowling *et al.*, 2000; Reef, 2001; Oikawa and Kasashima, 2002; Smith and Schramme, 2003; Pinchbeck *et al.*, 2004; O'meara *et al.*, 2010; Zuffova *et al.*, 2013; Alzola *et al.*, 2018; Rinnovati *et al.*, 2020; Zielińska *et al.*, 2020).

Finally, from this study, we conclude that the occurrence of SDF-tendinopathies prevails in our Polo horses, while fetlock collateral ligament strains with associated arthropathies, are more common in our Race horses, respectively.

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