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Original research

Trunk muscle activation, fatigue and low back pain in tennis players

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ABSTRACT

Objectives: To analyze differences in trunk endurance time, fatigue and activation in tennis players with and without low back pain.
Design: Observational study, cross-sectional design.
Methods: Thirty-five tennis players completed an isometric trunk endurance protocol comprising four tasks (flexor, extensor and side bridge tests). LBP history was obtained through the Nordic Musculoskeletal Questionnaire. Endurance time was recorded for each test. Surface electromyographic activity was recorded bilaterally from rectus abdominis, external obliques, iliocostalis lumborum and longissimus thoracis. Average electromyographic amplitude and median frequency slopes during the tests were calculated and used as indicators of change in muscle activation and fatigue.
Results: Asymptomatic players had greater flexor ($p = 0.004$) and right side bridge ($p = 0.043$) endurance times. These players produced a greater increase in avrEMG during the right side bridge test for the left ES-I ($p = 0.046$) and right EO ($p = 0.008$). Players with LBP in the last 7 days showed reduced activation of the left ($p = 0.014$) and right ($p = 0.013$) ES-I and left longissimus thoracis (ES-L, $p = 0.047$) in the extensor test. In the left side bridge test there was a lower avrEMG slope of the left EO ($p = 0.024$) and left RA MF slope ($p = 0.011$). In the right side bridge test a lower left ES-I avrEMG slope was found ($p = 0.048$).
Conclusions: Symptomatic players show lower activation of extensor muscles, less co-contraction patterns and less abdominal endurance. Tennis coaches and clinicians should consider these factors in their approach to players with LBP.

1. Introduction

The trunk plays an important role on the kinetic chain of tennis strokes, being part of the force generating and transmission sequence.[1] Trunk activation during the tennis serve can be elevated and asymmetric in various muscles.[2,3] The serve presents significant trunk musculoskeletal demands, most notably during the wind-up phase, where players perform a trunk hyperextension, lateral flexion and rotation movement.[4] Although this allows for greater storage of elastic energy for the acceleration phase, it places great stress on the posterior spinal structures, and is thought to be the main causative factor for spondylolysis in tennis players.[5] Eccentric activity of the rectus abdominis (RA) is important to support the trunk and avoid excessive spinal stress. Afterwards, in the acceleration phase, a counter rotation occurs, eliciting forceful concentric activity of the trunk flexors and rotators. Finally, during the follow-through phase, eccentric control of the erector spinae (ES) is necessary to assure a correct deceleration of the serve motion.[2,3]

The serve also involves high trunk motion speeds and imposes spinal loads of up to nearly 3000 N.[6] Studies on lumbar kinematics during the tennis serve have also shown higher lateral flexion moments in players with LBP, which may be a potential injury mechanism.[7,8] The repetitive nature of tennis, involving a majority of serve and forehand strokes, leads to asymmetrical musculoskeletal adaptations (e.g. in the shoulder and hip) that are commonly associated with injury.[9] Evidence of trunk adaptations in tennis players has arisen in imaging studies of RA muscle volume[10] and spinal osteoarticular changes (pars lesions, disk pathology and facet arthropathy).[11]

To the best of the authors' knowledge, studies of trunk activation and low back pain (LBP) in tennis players have only comprised the extensor muscles. Tennis players with LBP history showed decreased ES activation during trunk extension.[12,13] Despite these findings, there is a lack of research on trunk fatigue and activation in tennis players. Studies on sedentary and athletic populations have illustrated that there are different trunk endurance patterns between various muscle groups.[14,15] However, very little is known about trunk endurance patterns between muscles in tennis players. Given the previously stated role of different trunk muscle groups on spinal loads during tennis strokes, it is likely their

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activity and fatigability will also be associated with LBP symptoms. Decreased trunk activation and co-contraction patterns have been found in LBP patients.[16] Trunk co-contraction patterns have also been shown to increase spinal stability and decrease spinal load.[17]

Muscle fatigue is associated with decreased tennis performance and impaired injury protection mechanisms.[18] The onset of fatigue also promotes a loss in neuromuscular control, decreasing spinal stability.[19]

Thus, the objectives of this study were to (1) analyze differences in trunk endurance time between tennis players with and without LBP; (2) analyze differences in EMG slopes (amplitude and median frequency) during fatiguing trunk isometric tasks between tennis players with and without LBP; and (3) verify the existence of a relation between endurance time and EMG slopes. We hypothesize that (1) players with LBP history show endurance time differences in various trunk muscle groups; (2) players with LBP history present differences in the fatigability and activation pattern of various trunk muscles; and (3) there is a correlation between endurance time and EMG parameters.

2. Methods

Thirty-seven tennis players volunteered for the study. Thirty-five (28 male, 7 female, 18.54 ± 3.00 years old) met the study's criteria and were included in the final sample. There were 2 asymptomatic female players and 5 in all of the LBP subgroups. Inclusion criteria were (1) minimum 3 years of tennis practice, (2) minimum 6 h/week of tennis practice in the last year and (3) currently competing at a national level or higher. Exclusion criteria were (1) history of surgery to the trunk/spine, (2) history of serious trunk musculoskeletal pathology (trunk surgery, tumor, infection, structural scoliosis, spinal fracture), (3) practice of another sport for 3 or more times/week (excluding physical training) and (4) being unable to assume testing positions. Players were recruited without regard to their current LBP status.

One player was excluded due to previous trunk surgery and another was unable to assume testing positions due to an ankle sprain. All players were able to complete the protocol regardless of current LBP. Thirty-four of the 35 players were right-handed and 16 were minors. Full sample description is detailed in Table 1.

All tests were performed by the same researcher at tennis clubs nationwide.

All players (or their legal tutors) gave written consent for participation in the study. The study was approved by the Research Ethics Committee of the Faculty of Human Kinetics, University of Lisbon (approval number 5/2012). All procedures were taken in accordance with the Declaration of Helsinki.

Players completed a trunk endurance protocol as described in McGill et al.,[14] comprising four isometric tests (trunk flexor, extensor, and left/right side bridge tests, Fig. 1). This protocol has been considered a safe, reliable and cost-effective way of evaluating trunk endurance[14,20] and was applied in order to evaluate the fatigue-related behavior of trunk muscles relevant to tennis practice. Players were encouraged to hold the positions for as long as they could and were given the opportunity to experience positions for a few seconds before measurement. Test order was randomized and 5 min of rest were given between tests. Tests began as soon as players assumed position. The termination criteria of the original protocol were used.[14] Standard corrections were provided if players started deviating from the test position. The beginning and end of the recording were done via a keyboard trigger. All players reported fatigue as the reason for termination.

LBP history was obtained through an adapted Portuguese version of the Nordic Musculoskeletal Questionnaire[21] (NMQ) containing three yes/no questions on the lumbar region: (1) existence of symptoms over the last 12 months (LBP condition), (2) over the last 7 days (LBP-7d condition) and (3) being unable to train or play over the last 12 months because of LBP (LBP-TR condition). The last 2 questions were only answered by the players who answered question 1 affirmatively.

Table 1
Sample description.

		N	Minimum	Maximum	Mean ± SD
Age (years)	Whole sample	35	16	28	18.54 ± 3.00
	Asymptomatic	15	16	20	17.53 ± 1.25
	LBP	20	16	28	19.3 ± 3.68
	LBP-7d	8	16	28	20.5 ± 4.28
	LBP-TR	7	16	26	19.57 ± 3.82
Height (m)	Whole sample	35	1.56	1.97	1.76 ± 0.09
	Asymptomatic	15	1.68	1.97	1.77 ± 0.08
	LBP	20	1.56	1.88	1.75 ± 0.09
	LBP-7d	8	1.56	1.88	1.70 ± 0.11
	LBP-TR	7	1.63	1.84	1.77 ± 0.07
Weight (kg)	Whole sample	35	50.90	93.00	68.80 ± 9.85
	Asymptomatic	15	55.3	93.00	67.77 ± 9.25
	LBP	20	50.9	85.0	68.56 ± 10.44
	LBP-7d	8	50.9	85.0	65.51 ± 12.59
	LBP-TR	7	55.0	84.3	67.63 ± 9.39
BMI (kg/m^2)	Whole sample	35	18.69	26.31	22.04 ± 1.85
	Asymptomatic	15	18.69	25.20	21.57 ± 1.71
	LBP	20	19.04	26.31	22.40 ± 1.91
	LBP-7d	8	20.70	24.44	22.47 ± 1.57
	LBP-TR	7	19.04	24.90	21.50 ± 1.78
Years of practice	Whole sample	35	3	24	9.7 ± 4.12
	Asymptomatic	15	3	14	9.16 ± 3.13
	LBP	20	3	24	10.1 ± 4.76
	LBP-7d	8	3	24	10.37 ± 6.26
	LBP-TR	7	10	18	11.57 ± 2.94
Practice hours/week	Whole sample	35	6	40	17.06 ± 8.95
	Asymptomatic	15	6	40	19.5 ± 10.79
	LBP	20	6	29.5	15.23 ± 7.02
	LBP-7d	8	7	28.5	14.81 ± 7.97
	LBP-TR	7	10	29.5	16.79 ± 7.95

SD: standard deviation; BMI: body mass index; LBP: players with LBP in the last 12 months; LBP-7d: players with LBP in the last 7 days; LBP-TR: players prevented from training or playing due to LBP in the last 12 months.