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RESEARCH PAPER

Isometric torso muscle endurance profiles in adolescents aged 15–18: normative values for age and gender differences

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Abstract

Objective: The aim of this study was to establish normative values for torso muscle endurance in adolescents aged 15–18 years. It was hypothesized that torso endurance profiles of adolescents differs between males and females and between adolescents and adults.
Background: Decreased torso muscle endurance has been identified as a potential personal risk factor for low back pain development in both adolescents and later years together with being detrimental for athletic performance.
Design: Measurement of torso muscle endurance, established through four tests performed in random order in a healthy adolescent population.
Setting: High school in Novi Sad, Province of Vojvodina, Republic of Serbia.
Methods: Two hundred and ninety-four adolescents from one high school (178 males and 116 females) were grouped into four age strata. Selected isometric torso muscle endurance tests were: Biering-Sørensen test for extensor endurance; Flexor endurance test; right and left Side Bridge tests. The mean, ratio, standard deviation and 25th, 50th and 75th percentile scores were determined for each gender/age strata.
Results and conclusion: Males had higher lateral torso endurance than females. Adolescents in general demonstrate their peak lifetime endurance as they appear more endurable than children and comparable adult groups. These data of endurance times, their ratios and percentiles in healthy normal subjects form a database bridging existing data for children and adults that may be useful for guiding training and rehabilitation.

Keywords

Adolescents, isometric torso muscle endurance, normative values, torso endurance tests

History

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Introduction

Static muscular endurance is defined as the muscle ability to sustain a contraction for an extended period of time (Clarkson & Gilewich,1989; Foss & Keteyian, 1998). Studies have suggested that torso muscle endurance may be associated with current back disorders, predict future disorders and influence performance. While decreased muscle flexibility and trunk strength have been suggested as risk factors for low back pain (LBP) development (Kujala et al., 1992; Schmidt-Olsen et al., 1991), some studies suggest that endurance of back muscles may be a more important factor in prevention and treatment of LBP (Champagne et al., 2009; Morris et al., 1961; Udermann et al., 2003). In addition, McGill et al. (2003a) also found that isometric endurance is more dominant then strength, from a mechanical perspective when considering spine stability, while McGill et al. (2003b) found that endurance deficits rather than strength were more strongly associated with having recurrent back pain episodes. Others (e.g. Andersen et al., 2006; Biering-Sørensen, 1984; McGill et al., 1999; McGill, 2007; Smith et al., 2010) have found that subjects with poor torso static endurance were more intolerant to low back pain. Several mechanisms to explain the role of endurance have been proposed. Spine stability requires the maintenance of a guy wire system providing stiffness all around the spine (McGill, 2007). This requires constant contraction tuned to the task, together with a co-ordinated interplay between muscles, both of which are endurance variables. In addition, some studies have reported that endurance variables of torso muscles are important for enhanced performance (Evans et al., 2007; Leetun et al., 2004). There is yet to be a comprehensive study documenting torso muscle endurance in healthy adolescents. Hence, that was a motivating factor for our data collection.

Measuring torso muscle endurance in adolescents was a goal of this study. One rationale was that adolescent populations seem to share similar relationships between LBP and torso muscle endurance as adults. Sjolie & Ljunggren (2001) suggested that insufficient low back endurance and increased lumbar mobility may influence the link with spine stability and future LBP in adolescents. Johnson et al. (2009) reported that decreased isometric back extensor endurance was associated with current LBP in adolescents aged

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11–19 years. Similarly, Salminen et al. (1992) and Andersen et al. (2006) documented less incidence of LBP in those with higher isometric back muscle endurance, specifically males and females of 17 years old with high isometric muscle endurance were less prone to LBP. Andersen et al. (2006) documented that taller female adolescents were more prone to LBP than males. Further, Evans et al. (2007) reported that injury-free performances among athletes were linked with 'optimal' trunk muscle endurance. While there appears to be an association between torso muscle endurance and LBP in adolescents (Hakala et al., 2002), there is yet to be a comprehensive study documenting torso muscle endurance in healthy adolescents. Therefore, the purpose of this study was 2-fold; (1) to establish a gender and age database of normative values for four standardized torso muscle endurance tests obtained from adolescents aged 15–18 years and (2) to investigate the ratios between torso extensors, flexors and lateral torso flexor muscles.

Methods

Adolescent males and females were tested for torso muscle endurance at a Serbian high school using established protocols.

Subjects

This study involved 294 (178 males and 116 females) white European healthy adolescents; without LBP episodes 3 months prior to this data collection. Participants were involved in regular physical activity, 3-times per week, as per their physical education classes. They were then grouped, according to age, into four age groups (ages 15–18). Groups varied by their respective height, mass and group size; males aged 15 years ($n = 30$, 176.61 ± 6.55 cm; 73.65 ± 14.38 kg), 16 years ($n = 57$; 181.20 ± 7.53 cm; 74.48 ± 11.95 kg), 17 years ($n = 50$; 180.09 ± 6.89 cm; 76.58 ± 12.78 kg) and 18 years ($n = 41$; 179.38 ± 9.22 cm; 75.13 ± 11.59 kg); and females aged 15 years ($n = 28$; 163.77 ± 3.85 cm; 60.90 ± 12.92 kg), 16 years ($n = 38$; 165.89 ± 7.11 cm; 59.92 ± 8.42 kg), 17 years ($n = 27$; 164.00 ± 5.47 cm; 60.11 ± 9.36 kg) and 18 years ($n = 23$; 166.21 ± 7.31 cm; 59.87 ± 9.37 kg).

The testing and data collection methods were approved by the Dean and Parents' Committee of the High School, as well as from the Teaching and Scientific Council, at the University. All parents signed the informed consent form prior to data collection. Each test was explained and demonstrated in front of the test group to reduce injury risk and enhance familiarity. Inclusion criteria were: (a) aged 15–18 years of age; (b) no neurological or orthopaedic issues; and (c) no sickness 4 weeks before testing.

Data collection

Test apparatus included a Box (dimensions $1500 \times 1100 \times 500$ mm) for the Biering-Sørensen test, covered with soft pad, 50 mm thick, elevated 500 mm from the floor, with a soft pad for arm support placed on the floor. Straps with soft pads secured the pelvis, knees and ankles. For the flexor endurance test, a Norris Judo mat of $2000 \times 1000 \times 50$ mm was used; a jig angled 50° from the floor to set the torso/hip posture while the ankles were secured with straps. In the lateral test, the mat was used, soft enough to prevent discomfort in elbows, knees and feet. Time was measured with a stopwatch: TAG Heuer electronic Microsplit MS200.

Isometric torso muscle endurance (TE) was documented with four tests following the methods of McGill et al. (1999) and Dejanovic et al. (2012b): Biering-Sørensen extension test (EXT) (see Figure 1), right and left Lateral side bridge torso test (RSB and LSB) (see Figure 2) and Flexor endurance test (FLEX) (see Figure 3). Generally for all torso muscle endurance tests used here a similar philosophy for fatigue was used, in that any deviation from initial position was considered fatigue. There was a single correction of posture given and upon the second failure to maintain isometric contraction the test is terminated due to fatigue. McGill et al. (1999) found these tests to be reliable with a reliability coefficient >0.97 when tested consecutively over a 5-day period. Evans et al. (2007) also confirmed that lateral endurance tests have high reliability.

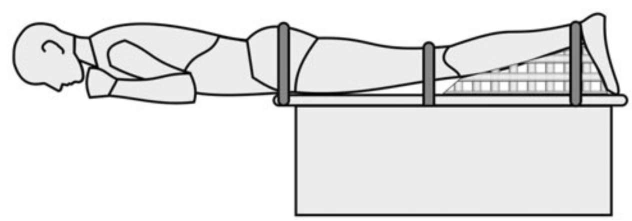

Figure 1. Back Extension Test (EXT): the subjects lay prone with the iliac crest at the edge of the table. The pelvis and lower limbs are supported and the torso and head posture are maintained by the extensors.

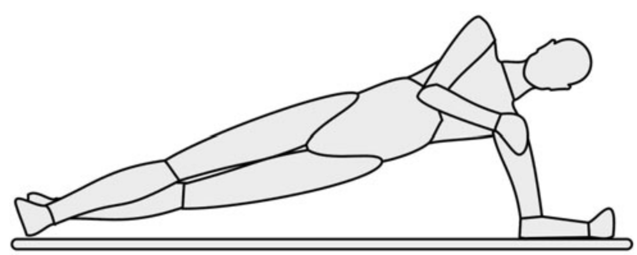

Figure 2. Lateral Test (Left Side Bridge (LSB) shown here also performed on the right side): the subjects supported their body weight through the feet and elbow. The foot of the superior limb was placed anterior to the inferior limbs foot and the superior arm reached across the chest to support the shoulder joint.

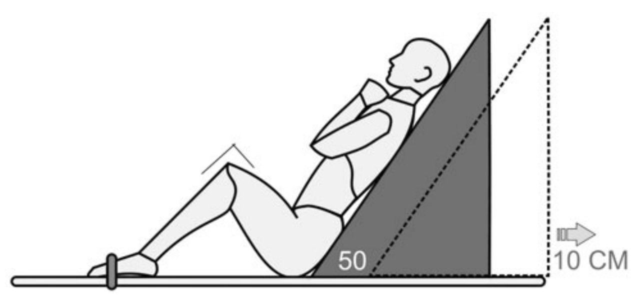

Figure 3. Flexor Endurance Test (FLEX): the subjects' torso was positioned at a 50° angle from the horizontal with the feet fixed, knees at a 90° angle and the arms crossed in front of the chest.

Back extension test (EXT)

Back muscle endurance was obtained with the Biering-Sørensen position where the body was cantilevered out over the end of a test bench, crossed arms on the chest and with the pelvis, knees and hips secured with straps together with an assistant holding for ankles. The test was ended by the examiner when the subject lost a horizontal position, started to wiggle, move their head and torso up or down, change arm position or when they reached 400 seconds. During the test, the subjects were allowed to be verbally cued to make position corrections twice, whereupon the test ended.

Lateral test: Left side bridge and right side bridge (LSB and RSB)

Lateral torso muscle endurance was tested with the subject lying in the full side-bridge position: Legs were extended; the top foot was placed in front of the lower foot for support, as they leant on their elbow while bridging their hips off the floor. The test was terminated when the subject lost a straight body posture (torso side bending) or when the hips or knee touched the floor or when a maximum time of 400 seconds was reached.

Flexor Endurance Test (FLEX)

Subjects were in sit-up position, crossed arms on the chest, hands placed on the opposite shoulder, ankles secured under straps or an assistant's palms and the back and head resting against a jig angled 50° from the floor. Knees and hips were flexed 90°. The test began when the jig was pulled back 10 cm while the subject held this position as long as possible. The position of the jig then allowed the clinician to form a reference point for deviation from the started position. Test termination occurred when the subjects back touched the jig, flexion of cervical and/or thoracic spine or when a maximum time of 400 seconds was reached.

Data analyses

The 294 adolescents were subsequently clustered into four levels of endurance ability: less than 25th percentile represented poor endurance, 25–49th percentile represented an average endurance, 50–74th percentile was considered as good and above 75th was considered as optimal endurance. The values are presented as mean ± standard deviation. The mean, ratios of different endurance scores and standard deviation of the 25th, 50th and 75th percentile scores were determined for two gender/four age categories. Ratio scores are also presented for comparisons between muscle endurance by age and gender (Table 1).

Statistical analysis was conducted with a univariate General Linear Model (GLM) approach for a 2-way analysis of variance (ANOVA) in SPSS. Observations of the omnibus test were made for significant differences within each factor and followed-up with pairwise comparisons using the protected F-test so that group-wise comparisons can be evaluated to identify the sub-group differences. The two-factor ANOVA was based on gender (males and females) and age (15, 16, 17 and 18 year olds) for each of the four endurance tests.

Results

The mean endurance values for tests, ratio for endurance times with back extension scores as base and percentile data for the muscle endurance tests, about the three axes of all participants by gender and age, are presented in Table 1.

Difference between males and females collapsed over age

Males and females were significantly different in mean endurance times for LSB and RSB. Males tested higher than females for the LSB (males, 93.46 s ± 36.05; females, 66.03 s ± 30.93; $F = 45.73$; $p < 0.001$); and RSB (males, 95.80 s ± 36.68; females, 65.72 ± 30.82; $F = 53.13$; $p < 0.001$). On the contrary, there were no significant differences found between genders for the FLEX test (males, 153.00 s ± 62.33; females, 151.89 ± 76.44; $F = 0.0$; $p = 0.994$) or the EXT test (males, 172.71 ± 53.36, females, 172.50 ± 73.94; $F = 0.004$, $p = 0.95$).

Differences in age collapsed across gender

Age was found to have a significant effect when examining the LSB and RSB ($F = 6.04$, $p = 0.001$; $F = 5.935$, $p = 0.001$; respectively). When following up the omnibus test both groups showed the same differences among the 16 years of age group with significant lower endurance times (see Table 1 for means, SD and significant scores). When examining the FLEX there were no differences found in age ($F = 1.452$, $p = 0.23$). Finally, in the EXT age was found to contain differences, however, these were mitigated by the interaction effect between age and gender (Age*Gender $F = 7.47$, $p < 0.001$).

Interaction effects with age and gender

Examining this interaction of age and gender demonstrated a significant increase in females when compared to males at the age of 18 years with a mean difference of 64.51 seconds ($p < 0.001$) (see Figures 4–6).

Discussion

To our knowledge, this is the first study of torso muscle endurance about the three axes of the torso in adolescents aged 15–18. This study suggested that adolescent males have higher lateral torso endurance than female counterparts. Given the established links between injury and torso muscle endurance these data may be considered as a reference data set.

Adolescents appear to be unique and distinguishable from younger children and adults in terms of torso endurance. For example, the values reported in this study are much larger than those from younger children reported by Dejanovic et al. (2012a) (for examples 110 seconds for EXT in 7 year old boys compared with 176 seconds in 15 year old boys in this study). Conversely, the 15 year old boys here also had a higher EXT than the adult firefighters (average age 37 years) reported by McGill et al. (2013) who scored 86 seconds on average. This has been observed before, as Salminen et al. (1992) noticed that adolescents aged 15 held the back extension test 20 seconds longer than middle aged men and achieved a 3-times

Table 1. Test variables, mean and percentile reference values for torso muscle endurance tests of all adolescents by age and gender ($n = 294$).

Subjects				Endurance time, sec						
Age	TET	Gender	*n*	Mean ± SD	Mean ratio	Minimum	25th percentile	Median	75th percentile	Maximum
15	EXT	M	30	176.0 ± 65.1	1.0	26.0	139.2	177.5	245.0	310.0
		F	28	171.6 ± 62.8	1.0	51.0	125.0	165.0	210.5	337.0
	FLEX	M	30	127.9 ± 51.6	0.73	66.0	76.0	125.0	155.2	250.0
		F	28	161.4 ± 78.2	0.94	75.0	95.2	137.5	197.0	302.0
	LSB	M	30	97.1 ± 32.6	0.55	34.0	77.0	93.0	122.5	161.0
		F	28	70.2 ± 31.5	0.41	12.0	51.5	65.0	86.2	161.0
	RSB	M	30	97.2 ± 28.5	0.55	45.0	74.2	95.0	122.5	140.0
		F	28	68.2 ± 27.4	0.40	17.0	51.7	65.5	83.7	140.0
16	EXT	M	57	166.6 ± 49.5	1.0	81.0	134.5	161.0	198.5	304.0
		F	38	147.7 ± 66.3	1.0	45.0	115.7	145.0	179.7	400.0
	FLEX	M	57	154.6 ± 72.3	0.93	34.0	105.5	138.0	193.0	349.0
		F	38	135.5 ± 69.8	0.92	25.0	91.0	127.0	178.5	386.0
	LSB	M	57	80.7 ± 29.6	0.48	24.0	62.0	75.0	106.0	156.0
		F	38	55.7 ± 26.4	0.38	18.0	38.7	51.5	64.2	138.0
	RSB	M	57	83.4 ± 33.7	0.50	23.0	62.0	77.0	104.5	181.0
		F	38	55.2 ± 29.5	0.37	19.0	34.2	49.0	66.2	166.0
17	EXT	M	50	185.4 ± 58.7	1.0	63.0	143.7	180.5	212.7	364.0
		F	27	161.1 ± 78.9	1.0	22.0	107.0	152.0	209.0	364.0
	FLEX	M	50	159.8 ± 60.0	0.98	59.0	119.5	146.5	205.0	278.0
		F	27	143.1 ± 72.0	0.87	49.0	101.0	123.0	182.0	346.0
	LSB	M	50	102.4 ± 42.3	0.49	44.0	70.5	91.5	131.2	201.0
		F	27	73.5 ± 35.4	0.44	30.0	48.0	71.0	86.0	180.0
	RSB	M	50	104.1 ± 41.4	0.56	40.0	71.7	98.5	125.0	211.0
		F	27	75.1 ± 31.5	0.40	19.0	56.0	70.0	94.0	155.0
18	EXT	M	41	163.2 ± 38.9	1.0	77.0	137.0	172.0	185.5	249.0
		F	23	227.7 ± 67.5	1.0	111	180.0	222.0	282.0	400.0
	FLEX	M	41	160.6 ± 54.0	0.98	52.0	126.0	158.0	190.5	264.0
		F	23	177.4 ± 85.6	0.79	10.0	89.0	183.0	255.0	301.0
	LSB	M	41	97.4 ± 34.5	0.60	35.0	77.5	94.0	111.5	247.0
		F	23	69.0 ± 28.8	0.30	30.0	48.0	63.0	88.0	122.0
	RSB	M	41	101.7 ± 36.4	0.62	23.0	77.5	101.0	123.0	213.0
		F	23	68.8 ± 32.8	0.30	36.0	48.0	56.0	67.0	182.0

TE, test for torso muscle endurance; EXT, back extension; FLEX, torso flexors; LSB, left side bridge; RSB, right side bridge; M, male; F, female. Mean ratio represents the test score over the back extension score. Minimum and maximum columns indicate the range of the scores and percentile columns represent the value of endurance in seconds of that particular percentile.

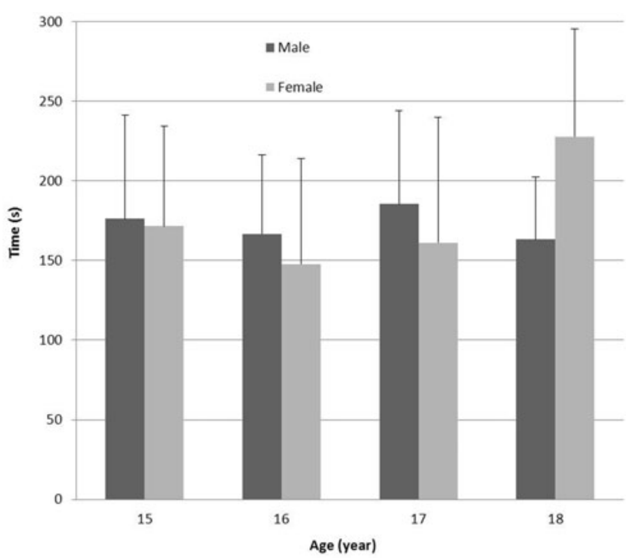

Figure 4. Mean values of EXT in males and females aged 15–18.

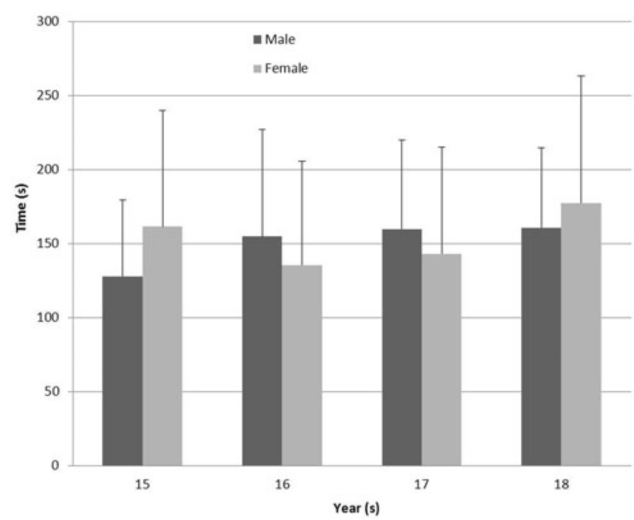

Figure 5. Mean values of FLEX in males and females aged 15–18.

higher flexor endurance score. McKeon et al. (2006) obtained a time duration for back extension of 168.5 seconds for healthy and 111.1 seconds for LBP persons. Stewart et al. (2003) documented that Australian coal miners achieved mean back extensor scores at 113 seconds. Tekin et al. (2009) found a significant difference in Biering-Sørensen test within Turkish coal miners with and without LBP; 99.9 ± 19.8 vs 128.6 ± 15.2 seconds, respectively. Chan (2005) tested 32 intercollegiate rowers and revealed that torso flexors

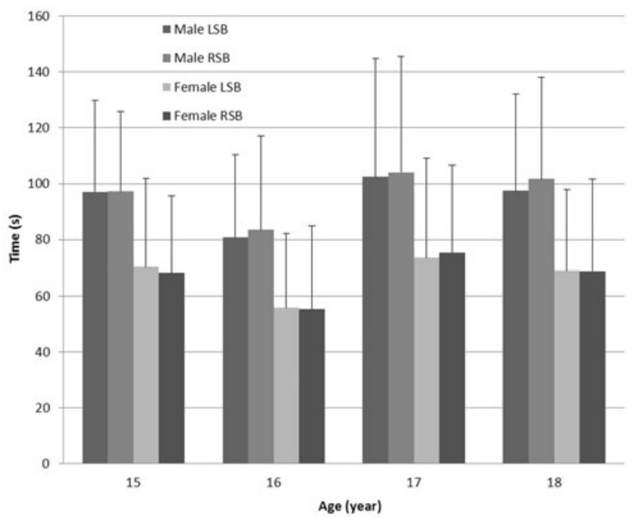

Figure 6. Mean values of LSB and RSB in males and females aged 15–18.

(176.56 seconds) were more durable than back extensors (114.28 seconds).

Gender differences were evident in the frontal plane, yet absent in the sagittal plane for this adolescent population. The current study design was not capable of identifying a causative effect for this relationship. However, now that such an effect has been discovered future studies can better address the underlying mechanisms identified here. Meanwhile, one might speculate that some anthropometric dimensions which were linked with torso endurance scores (Dejanovic et al., 2012b) may have influence on clear gender bias. In young adults, McGill et al. (1999) showed that mean back endurance test times for males and females (31 male and 44 female, 23 years $\pm$ 2.9) were 146 seconds and 189 seconds, respectively, suggesting the females were more endurable. Moreau et al. (2001) found similar results with a back endurance times of 84–195 seconds for healthy men and from 142–220.4 seconds for women. However, with advancing age this female advantage may wane as Ayanniyi et al. (2008) recorded in 376 healthy African adults aged 21–62 years back extensor scores for men 199 $\pm$ 49.8 seconds and for women 109 $\pm$ 47 seconds.

The side bridge scores in this study appear to be in line with the young adult scores reported by McGill et al. (1999) (in males 94 or 97 seconds and for females 72 and 77 seconds). Generally there were low side endurance scores for females, age-matched to males. This has also been observed by Leetun et al. (2004), who found that females have increased endurance compared to males (84 seconds in males and 58 seconds in females at 19 years of age).

The literature appears to be converging on the notion that torso muscle endurance plays an important role in prevention and rehabilitation of low back pain. Several authors have noted the specific link between deficits in extensor endurance and the risk of future back pain (e.g. Biering-Sørensen, 1984). However, others have noted an association between the ratio of extensor endurance and the endurance about the other two axes, for example Huang et al. (2000) have suggested that misbalanced abdominal and low back muscles may be the cause of lumbar syndrome. Lee et al. (1999) reported that high ratios difference between torso flexion and back extension might be a predictor of low back pain in adolescents (mean age 17 $\pm$ 2). McGill et al. (2003b) showed that those with pain had less back extensor endurance when expressed as a ratio with flexor endurance, when compared with those performing the same job and without pain. Perhaps the data reported here in adolescents aged 15–18 in percentile rank and in ratios may be important for profiling potential candidates for prophylactic training in the future.

Some limitations exist for interpreting and applying the results of the current study. This study was conducted with healthy high school students and the comparisons made here highlight their uniqueness and differences with older and younger people. The data were collected on Serb High School adolescents who may or may not represent students of similar age globally. While efforts were made to encourage motivation it was not possible to fully control uniformity of effort. Finally, subjects were not categorized into athletic and non-athletic groups.

In conclusion, adolescent males appear to have higher lateral torso muscle endurance than females and adolescents appear to be more endurable than both younger and older aged people. This data set of averages, percentiles and ratios may assist clinicians, physical educators, athletic trainers and fitness and rehabilitation specialists in designing training and intervention strategies for disorders such as low back pain.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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