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ORIGINAL ARTICLE

The association between isoinertial trunk muscle performance and low back pain in male adolescents

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Abstract The literature reports inconsistent findings regarding the association between low back pain (LBP) and trunk muscle function, in both adults and children. The strength of the relationship appears to be influenced by how LBP is qualified and the means by which muscle function is measured. The aim of this study was to examine the association between isoinertial trunk muscle performance and consequential (non-trivial) low back pain (LBP) in male adolescents. Healthy male adolescents underwent anthropometric measurements, clinical evaluation, and tests of trunk range of motion (ROM), maximum isometric strength (STRENGTH) and peak movement velocity (VEL), using an isoinertial device. They provided information about their regular sporting activities, history and family history of LBP. Predictors of "relevant/consequential LBP" were examined using multivariable logistic regression. LBP status was reassessed after 2 years and the change from baseline was categorised. At baseline, 33/95 (35%) subjects reported having experienced consequential LBP. BMI, a family history of LBP, and regularly playing sport were each significantly associated with a history of consequential LBP ($p < 0.05$). 85/95 (89%) boys participated in the follow-up: 51 (60%) reported no LBP at either baseline or follow-up (never LBP); 5 (6%) no LBP at baseline, but LBP at follow-up (new LBP); 19 (22%) LBP at baseline, but none at follow-up; and 10 (12%) LBP at both time-points (recurrent/persistent LBP). The only distinguishing features of group membership in these small groups were: fewer sport-active in the "never LBP" group); worse trunk mobility, in the "persistent LBP" group, lower baseline sagittal ROM in the "never LBP" and "new LBP" ($p < 0.05$). Regular involvement in sport was a consistent predictor of LBP. Isoinertial trunk performance was not associated with LBP in adolescents.

Keywords Muscle strength · Range of motion · Sports · Adolescents · Low back pain

Introduction

Low back pain (LBP) often presents during the teenage years [1]. Some cross-sectional studies have reported an association between LBP and decreased trunk muscle strength [2–4], and endurance of the trunk extensors [4, 5], and flexors [6, 7]. However, others have not found any significant correlations between trunk muscle function and LBP [8, 9]. Indeed, a recent review of the literature, focusing on modifiable risk factors for LBP in adolescents, concluded that there is no evidence that muscle strengthening has a preventive effect on LBP in schoolchildren [10].

Part of the confusion might be accounted for by the specific methodology used to assess function and the lack of control of possible confounders. Where functional tests

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are used that are heavily influenced by extraneous factors, e.g., by motivation or pain-tolerance for muscular endurance [11] or by anthropometric factors [12, 13] for field strength tests that use body weight as the resistance (e.g. sit-ups, push-ups, curl-ups, etc.)—it is possible that the confounding factors are, themselves, stronger determinants of LBP than the physiological characteristic that they purport to measure. The situation is not helped by the fact that, in some studies, the terms "muscle strength" and "muscle endurance" are used interchangeably [4], despite the fact that these are two quite distinct attributes, governed by different structural and metabolic characteristics of the muscle [14, 15]. Further, the velocity of movement, or power output (the product of torque and velocity), during maximal exertions has rarely been considered in predictor studies, despite the fact that the speed of movement has been shown to be one of the performance characteristics that best distinguishes between individuals with LBP and controls [16]. Finally, the interrelationships between participation in sport and LBP per se, and sport and physical capacity, may obscure relationships between physical capacity and LBP when sport is not included as a possible confounder using multivariable analysis. Conceivably, also, the means by which LBP itself is characterized may play a role in determining the factors associated with its presence. The discrepancies in terminology in existing epidemiological studies of LBP—and their consequences [17]—have only recently been appreciated and addressed [18, 19] showing that the risk factors for the commonly used criterion "any LBP" (without further qualification) are very different and much more "psychology-based" than are those for incidents that lead to medical attention or work-loss. Indeed, the latter authors suggested that in risk factor studies the focus rather be placed on "significant" or "consequential" LBP.

The objective of this study was to examine whether trunk performance capacity—measured as range of motion, isometric strength and maximal trunk velocity—has any association with "consequential" LBP in adolescent boys. The influence of participation in sport was taken into consideration as a possible confounder.

Methods

Subject population

With the approval of the school authorities (Fribourg, Switzerland), healthy male adolescents aged 13–14 years were invited by the school physical education teachers or coaches of their extramural sports clubs to participate in the study. Recruitment was restricted to males to obtain a more homogeneous cohort and avoid possible confounders. Owing to the voluntary nature of participation, it was not possible to obtain a truly random sample from the school or sports clubs. Instead, it was hoped that the recruitment of individuals with a range of sporting interests would allow the main questions to be answered regarding any associations between muscle performance and LBP, when controlling for sports participation.

Subject medical evaluation

All potential subjects and their parents received a letter informing them of the study purpose and schedule. Willing participants contacted the study secretary and booked an appointment for their first evaluation.

The evaluation consisted of:

1. A brief semi-structured interview that included sports-related questions:
    a. Regular sport activity in the past (if any, type/duration)?
    b. Current regular physical activity outside of the school system (Y/N)? If Y,
        i. Type of sport?
        ii. Hours/week?
        iii. Since when?
2. Four questions about LBP:
    a. Ever had LBP to an extent that required medical care*, radiographs, or treatment (Y/N)? (*in the interview, it was made clear that doctors, physiotherapists, chiropractors, etc. all counted as medical care)
    b. Ever had LBP to an extent that interfered with leisure activities, sports training or school activities (Y/N)?
    c. Last episode of relevant/consequential LBP (up to 1 week ago, 1–4 weeks ago, 1–3 months ago or 3–12 months ago)?
    d. Parents/siblings ever been treated for LBP (Y/N)?

During the evaluation, participants were shown a drawing of the human body with the lumbar region (between the costal margin and the gluteal folds) shaded. LBP was later quantified in relation to those reporting a positive answer to either 2a or 2b (medical treatment or interference with everyday activities).

A physical examination was then performed to record height and weight and to carry out various clinical assessments; for these tests, the subjects were dressed in their underclothes. Lumbar mobility was measured using the modified Schober test [20]. Trunk flexion was assessed by measurement of the fingertip to floor distance. The examination also included assessment of hypermobility (using Beighton criteria; 4 or more was categorised as hypermobile) [21]. All test results were recorded on standardized forms.

Trunk muscle performance

Trunk muscle performance was evaluated using a triaxial trunk dynamometer (Isostation B-200, Isotechnologies, Inc., Hillsborough, NC). The Isostation B200 is an iso-inertial (constant resistance) dynamometer under the control of a personal computer. Transducers measure angular velocity (degrees/s), torque (Nm) and angular position (degrees, °) in each measurement axis (flexion–extension, lateral flexion and rotation) at a data sampling rate of 50 Hz (8-bit data acquisition system). Additional details of the testing apparatus can be found elsewhere [22].

Subjects were advised to wear comfortable, loose-fitting clothing on the day of testing. The trunk muscle performance tests were administered by an Isotechnologies' certified physiotherapist, according to the manufacturer's instructions. Standard dynamometer testing protocols were used [23]. Each subject was positioned in standing and restrained in the B200 trunk dynamometer according to the protocol outlined in the Isotechnologies B200 user's manual. In addition to a chest pad, thoracic strap, and thigh straps, the B200 restraint system securely restrains the pelvis (both translation and rotation) and isolates subsequent trunk rotation to the thoraco-lumbar spine.

Subjects first performed an unresisted range of motion (ROM) test in each of the three anatomic axes. They then carried out maximum isometric strength tests in: (1) flexion (F), (2) extension (E), (3) right lateral flexion (RLF), (4) left lateral flexion (LLF), (5) right rotation (RR), and (6) left rotation (LR). During the isometric tests, subjects were instructed to push against the machine and gradually build up to their maximum effort during the first 3 s of each 5-s trial, and then maintain this effort throughout the last 2 s of each trial.

For isoinertial (dynamic) testing, the machine's resistance was set to 50% of the subject's maximum F/E, R and LF isometric strength, and five repetitions of F/E, RR/LR, and RLF/LLF were performed. During the isoinertial tests, subjects were asked to move as quickly as possible over their maximum ROM. The testing protocol was in agreement with published recommendations that have previously shown the tests to be reliable [24].

Follow-up

Two years after the original assessment, the whole assessment battery was repeated again. Only the data relating to the questionnaire assessment of LBP over the intervening 2 years are presented here.

Data and statistical analysis

The data from each of the B200 muscle performance trials were processed using custom software written to read the B200 binary data files. In each case, the range of motion (ROM), maximum isometric torque (STRENGTH) and peak velocity (VEL) were determined for each direction of movement, in each movement plane. Values for the five repeated trials were averaged. For the purposes of data reduction, average values are given for parameters where symmetrical muscles on different body sides were tested (i.e., in lateral bending and rotation); however, since the generation of force in the sagittal plane requires different muscle groups for flexion than for extension, these were reported separately.

Descriptive data for continuous variables (if approximately normally distributed, as assessed with normal probability plots) are reported as means ± standard deviations. For continuous data, unpaired t-tests (two groups) or one-way analyses of variance (more than two groups) were used to examine differences in mean values between independent samples (e.g., LBP-status sub-groups); for non-normally distributed variables, Mann–Whitney tests (two groups) or Kruskal–Wallis tests (more than two groups) were used. Associations between categorical data were examined using contingency analysis and Chi-squared tests. Multivariable logistic regression analysis was used, using the forward selection procedure, to identify independent predictors accounting for group membership with regards to LBP status at baseline (binomial logistic regression). Results are presented in adjusted odds ratio (OR) with 95% confidence interval (95% CI).

Statistical significance was accepted at $p < 0.05$. No corrections were made for multiple testing, as previously recommended [25].

The study aimed to recruit a total of approximately 100 subjects, replicating the design of the published series of Sjolie et al. studies [4, 26, 27].

Assuming a prevalence of LBP between 30 and 40% this would have allowed the identification of odds ratios between 1.99 and 2.07 corresponding to a change in incidence between 16 and 18%, assuming a type I error probability of 5% and a type II error probability of 15% (i.e. power of 85%).

Results

Study group

A total of 95 subjects were recruited. Their mean age, height, body mass and body mass index were 14.0 (SD 1.7) years, 1.71 (0.10) m, 58.5 (SD 11.9) kg, and 20.0 (SD 3.0) kg m^{-2}, respectively.

Twenty-two (23.2%) adolescents were considered "sedentary", i.e. they attended physical education lessons at school, but engaged in no physical activity outside of the school system. 73 (76.8%) of the group played sport regularly [14 swimming, 29 basketball, 28 football, and 2 others (cycling, athletics)], and were members of an extramural team or club with an official license to participate at competitive events. On average, these children spent 4.5 (SD 1.9) h/week pursuing their sports endeavours, and had been doing so for 4.9 (SD 2.8) years.

Ten subjects did not take part in the follow-up assessment after 2 years (nine refused, and one had moved to a foreign country). This resulted in a follow-up rate of 89.5% (85/95) for the prospective assessment of LBP status.

LBP status at baseline and follow-up

At baseline, LBP requiring medical attention was reported by 14/95 subjects (14.7%); LBP interfering with activities, by 28/95 (29.5%); and LBP with either or both of these consequences (i.e., relevant/consequential LBP), by 33/95 (34.7%). Of the latter group, 15.6% reported having had the last episode up within the preceding week, 31.3% 1–4 weeks ago, 25.0% 1–3 months ago, and 28.1% 3–12 months ago. A positive family history of LBP requiring treatment was reported by 42/95 (44%) subjects.

Two years after the initial assessment, 15/85 (17.6%) of the subjects reported having had consequential LBP in the intervening period 10/15 (66.7%) of these had already reported such LBP at the baseline assessment, and the remainder reported it for the first time. There was a significant association between LBP-status at baseline and follow-up (Chi-squared, $p = 0.003$).

Overall, 51 (60%) reported no LBP at either baseline or follow-up (LBP status, never LBP); 5 (6%) reported no LBP at baseline but LBP at follow-up (new LBP); 19 (22%) had LBP at baseline but none at follow-up (LBP remission); and 10 (12%) had LBP at both time-points (recurrent/persistent LBP).

Personal characteristics in relation to LBP status at baseline: bivariate analyses

The baseline physical, clinical, and performance characteristics of the participants, split by their LBP-status at baseline (presence/absence of consequential LBP), are summarized in Table 1.

Sedentary subjects reported a lower prevalence of LBP than subjects who were regularly involved in sport. Almost all the subjects (31/33; 94%) who reported LBP were involved in regular sport; in contrast, only 42/62 (68%) with no history of LBP played regular sport ($p = 0.004$; Table 1). The average number of years playing sport was also significantly higher in the LBP group.

Those subjects with a history of LBP had a slightly, but significantly higher BMI ($p = 0.02$) than their LBP-free counterparts; a considerably higher proportion of them (64%) had an immediate family member who had undergone treatment for LBP, compared with those who had no LBP history (34%) ($p = 0.005$).

Few performance factors were associated with LBP: the unrestricted range of motion in the sagittal plane (i.e., flexion and extension) was significantly higher in those with a history of LBP than those with no such history ($p = 0.03$), as was maximum isometric rotation torque ($p = 0.04$) and peak angular velocity in extension ($p = 0.05$).

Personal characteristics in relation to LBP status at baseline: multivariable analyses

In multivariable logistic regression analyses, only three variables made a unique contribution to explaining the variance in consequential LBP (Table 2) (i.e., contributed to the model when all other variables were considered too). Independent predictors of the occurrence of LBP were the regular playing of sport, family history of LBP, and higher BMI.

Personal characteristics in relation to the course of change in LBP status over 2-year follow-up

Although the low incidence of new LBP and small group sizes limited the potential for analysis, in univariate analyses a few factors were nonetheless associated with the change in LBP-status over the 2-year period (« never LBP », « new LBP », « recurrent/persistent LBP », « LBP remission ») ($p = 0.05$–0.10):

- *Participation in sport*: lower participation rate in the "never LBP" group (69%) than the other groups (91%).
- *Family history of LBP*: lower proportion in the "never LBP" (31%) and "new LBP" (40%) than the others (66%).
- *Fingertip to floor distance*: greater distance, i.e. worse trunk mobility, in the "persistent LBP" group (18.2 cm) than the other groups (8.9 cm).
- *Baseline sagittal ROM*: lower for "never LBP" (93.7°) and "new LBP" (92.3°) than the others (97.9°).

Discussion

The present study sought to examine whether, controlling for sporting habits, isoinertial trunk muscle performance differed in teenagers with a history of non-trivial LBP

Table 1 Comparison of physical characteristics, sporting habits, clinical variables, and trunk muscle performance in subjects with and without a history of consequential LBP. Values are means (SD) unless otherwise stated

Variable	LBP ($n = 33$)	No LBP ($n = 62$)	p
Physical characteristics			
Body mass (kg)	61.7 (15.0)	56.9 (9.7)	0.06
Height (m)	1.71 (0.10)	1.70 (0.10)	0.93
BMI (kg m^{-2})	21.0 (3.9)	19.5 (2.3)	0.02
Age (years)	13.9 (1.2)	14.0 (1.0)	0.75
Sporting habits			
Play sport now? (yes, %)	31/33	42/62	0.004
If yes, type of sport (% distribution)	(93.9%)	(67.7%)	0.40
Basketball	35.5%	42.8%	
Football	38.7%	38.1%	
Swimming	25.8%	14.2%	
Other	0%	4.9%	
Years in sport (years)	4.8 (3.0)	3.3 (3.2)	0.03
Hours/week sport (h/week)	4.0 (2.1)	3.1 (2.6)	0.08
Clinical assessment/history			
Schober value (cm)	6.2 (1.0)	6.5 (1.0)	0.15
Fingertip floor dist (cm)	11.0 (9.5)	8.8 (8.8)	0.27
% with hypermobility (Beighton score $\geq$ 4/9)	9.1%	14.5%	0.53
Family history LBP (yes, %)	63.6%	33.9%	0.005
Isoinertial tests (B200)			
Unresisted ROM (degrees)			
Horizontal plane (total, right and left rotation)	90.2 (4.3)	88.3 (5.8)	0.11
Sagittal plane (total, flexion and extension)	97.3 (6.3)	94.1 (7.1)	0.03
Frontal plane (total, right and left lateral flexion)	85.3 (8.2)	85.9 (8.2)	0.73
Maximum isometric torque (ft lbs)			
Horizontal plane (mean, right and left rotation)	49.1 (15.7)	43.0 (12.3)	0.04
Sagittal plane			
Flexion	58.0 (20.3)	54.3 (18.6)	0.37
Extension	87.4 (28.0)	85.6 (26.1)	0.76
Ext:flex ratio	1.55 (0.31)	1.63 (0.33)	0.29
Frontal plane (mean, right and left lat flexion)	73.0 (21.6)	68.8 (19.0)	0.33
Peak angular velocity (degrees/s)			
Horizontal plane (mean, right and left rotation)	126.5 (22.8)	119.9 (19.3)	0.14
Sagittal plane			
Flexion	146.0 (24.2)	138.4 (19.1)	0.10
Extension	168.6 (33.3)	156.9 (23.5)	0.05
Frontal plane (mean, right and left lat flexion)	155.0 (33.7)	149.0 (28.6)	0.37

Table 2 Independent predictors of consequential LBP at baseline (=1) versus no LBP at baseline (=0)

Variables	Adjusted OR (95% CI)	p
BMI	1.27 (1.04–1.54)	0.020
Sport now (n0, y1)	9.46 (1.86–48.23)	0.007
Family history (n0, y1)	3.61 (1.28–10.17)	0.015

In the final model, playing sport, a family history of LBP, and a higher BMI were significant independent predictors

compared with their LBP-free counterparts. We also examined whether there was any association between performance and the change in LBP-status over a 2-year period. Quantitative assessment of trunk muscle performance has long been proposed to be clinically relevant for the prevention and diagnosis of spinal disorders [28, 29], and patients with chronic LBP and certain spinal disorders have been shown to display abnormal trunk muscle function [30–32]. Dynamic trunk muscle performance testing has been used to identify specific patterns of motion associated with spinal pathologies [33] Isoinertial trunk dynamometry testing has been used to evaluate adults with LBP and to compare different groups of athletes [34–36], but it has not previously been used in an adolescent population to establish the relationship between muscle performance and consequential LBP. Isoinertial dynamometric measures may offer a more standardised and controlled assessment of dynamic strength or power than do “field tests” of strength, in which the actual load being resisted is difficult to ascertain.

A number of studies have shown that the velocity of trunk movement might be important in relation to LBP [37, 38]. In an adult population, Marras et al. showed that the velocity of movement during various trunk functional tests was one of the few parameters that was capable of distinguishing between groups of individuals with LBP and controls [16]. Further, Merati et al. indicated that the velocity of test movement may be important in identifying trunk strength differences between children with and without back pain [39]. However, in the present study, no associations between reduced isoinertial performance (either strength or velocity) and LBP could be identified; on the contrary, in bivariate analyse, those with LBP tended to show higher values for these aspects of muscular performance. Our interpretation of this is that the relationship between these performance parameters and LBP is indirect, exerted via the relationship between regular participation in sport per se and LBP (with the latter occurring more frequently in relation to, for example, the muscle strains, and joint strains, etc. common in sport). In other words, we hypothesise that ROM and some torque/velocity measures were higher in the LBP group, because more athletes than non-athletes had LBP, and athletes tend to have higher performance capacity than non-athletes. Indeed, when controlling for participation in sports, in the multivariable analysis, the importance of most of the muscle performance variables was drastically diminished. We consider it important to consider such potentially confounding factors in studies of the association between muscular performance and LBP in order to avoid erroneous conclusions from being reached.

In examining the literature, the relationship between LBP and physical activities seems to be controversial. Some studies report an increased risk of LBP among sports-players whilst others find a protective effect of physical activity. Recently Wedderkopp et al. showed that a high level of physical activity in childhood seems to protect against LBP and mid-back pain in early adolescence [40], although, specific sports activities were not taken into account. In a large study including almost 7,000 Finnish teenagers, it was shown that boys participating in volleyball, gymnastics, gym-training, downhill skiing or snowboarding had a higher prevalence of LBP, whereas those involved in cross-country skiing reported less LBP [41]. Finally, Skoffer et al. found that a sedentary lifestyle or being engaged in some specific sports (most notably jogging, handball and gymnastics) were associated with an increased risk of function-limiting LBP [42].

In analyzing a large Finnish national cohort (*n*: 5,999; age 15–16 years), Auvinen et al. [43] found a significantly increased prevalence of consultation for LBP in the 6 months preceding the survey among adolescents reporting >6 h/week of brisk physical activity compared with those active for just 2–3 h/week. The authors recommended prospective evaluations of the relationship between activity or inactivity and LBP to be able to define the optimum activity level for adolescents.

Other predictors of LBP

Our results showed that BMI was significantly higher in adolescents with LBP than in those who were pain free. The difference was particularly striking when the analysis was limited to those involved in sports activities (data not shown). BMI does not provide any information about the body composition and might thus be influenced by muscle mass as well as by fat tissue; involvement in sports might therefore be considered a confounder, as more active adolescents may be expected to be more muscular. Nonetheless, BMI remained a significant predictor in the multivariable analysis, even when involvement in sports had already been controlled for. Hence, the finding may be more than incidental.

The literature shows discordant findings about the possible relationship between BMI and LBP. In an entire cross-sectional cohort of Swedish military recruits (>48,000 people) stratified into underweight ($\text{BMI} < 18.499$), normal weight ($\text{BMI} = 18.5–24.999$), overweight ($\text{BMI} = 25.0–29.999$), and obese ($\text{BMI} > 30.0$), only being underweight was significantly associated with having back problems (adjusted $\text{OR} = 1.2$) [44]. However, in another paper [45, 46], in which a slightly different classification for BMI was used, a moderately increased prevalence ($\text{OR} = 1.3$) of some LBP during the preceding year was shown in overweight (BMI 25–29) subjects compared with underweight ($\text{BMI} < 20$) and heavily overweight ($\text{BMI} > 29$) individuals.

Specifically in relation to adolescents, Sjolie found a significant positive (association between BMI and LBP) [27], whilst Bernard et al. showed no difference in BMI between subjects with chronic LBP and controls [47].

Our findings on the association between family history of LBP and adolescent LBP confirm those of a previous survey in the same area of Switzerland [48] and those of other studies [49–51]; however, there are also studies that report no familial clustering [52]. Whether the association, when observed, is a question of “nature or nurture” remains open to speculation. There is increasing evidence of a hereditary aspect to low back pain [53, 54] although exposure to the nature of the problem (and its need for treatment or not) by virtue of upbringing might also play a role. It has been shown that parents who sought more treatment for their own pain were more likely to have children reporting higher levels of pain [51]. As our question specifically mentioned “having been treated for LBP” this might have influenced our findings.

Prevalence and recurrence rates

Recent studies in children and adolescents have reported high figures for the prevalence of back pain. In a study of 144 pre-pubertal subjects (77 boys) (11.9 ± 0.3 years) where the enquiry about back pain was limited to the previous 6 months, but not restricted to the lumbar area, 42.9% of the participants reported back pain more than once [39]. However, the “severity” or impact of LBP (medical attention, time off school, etc.) was not reported.

The prevalence of non-trivial LBP in our study (36%) was much higher than that previously reported for LBP requiring medical treatment in adult male collegiate athletes [55] (8.7%). However, our figures compare reasonably well with those of Skoffer et al., where 24.2% of adolescents 15–16 years experienced decreased functioning or need of care because of LBP during the preceding 3 months [42]. Similarly, in the study of Masiero et al., the annual prevalence of LBP interfering in some way with activities was reported to be 20.5% [49]. We have no clear explanation for the decreased prevalence of LBP recorded at follow-up. However, this is in agreement with the study of Sjolie where a reduction of LBP in the preceding year from 58 to 39% was seen at the 3-year follow-up [26]. Interestingly, in a longitudinal study, Grimmer et al. showed that incident cases of LBP showed an irregular pattern among boys with a decrease around the age of 15 years [56].

In the present study there was a high recurrence rate of LBP over the 2-year period; baseline reports of LBP were significantly associated with reports at the 2-year follow-up. This agrees with the results published by Sjolie [26], where 53% of those who reported LBP at baseline (59% among girls and 45% among boys) still reported LBP at follow-up.

In the “prospective” part of the study an interesting association between persistent LBP and reduced trunk flexion during the “fingertip to floor” test was found. This test primarily assesses hip flexion, which tends to be limited by hamstring tightness. Similar associations between muscle tightness and LBP were reported by Sjolie et al. [27] and by Feldman et al. [9]. Bernard et al., in contrast, found a decreased flexibility among boys compared with girls, but it had no association at all with LBP [47]. Clearly further studies are required to investigate this parameter and its role in LBP in adolescents.

Limitations

The main part of our study had the usual limitations of a cross-sectional study, in that no causal relationships could be established between the variables that showed statistically significant relationships. Secondly, our study population was composed of only boys and the findings may not necessarily apply to girls. There are contradictory findings in the literature concerning the association of LBP with gender [7] [57, 58].

Our definition of consequential LBP (LBP requiring medical attention and/or limiting activities), although clinically relevant, dramatically reduced the number of cases (especially incident cases of new LBP at the 2-year follow-up) and therefore limited the statistical power of the prospective part of the study. We therefore suggest that this part of the investigation be repeated in larger studies, to clarify baseline factors associated with an “unfavourable LBP status” over time.

In conclusion, regular involvement in sport was associated with the presence of LBP in adolescents. It likely explained the bivariate associations between better isoinertial trunk muscle performance and the presence of LBP that were no longer evident in multivariable analysis, when involvement in sports was controlled for. Isoinertial trunk performance per se does not appear to be associated with LBP in adolescents. As such, exercise programmes aimed at specifically improving these aspects of function as “preventive” measures for LBP do not appear to be warranted.

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