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Fitness, motor competence and body composition are weakly associated with adolescent back pain

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ABSTRACT

Study Design

Cross-sectional survey

Objectives

The objective of this study was to assess the associations between adolescent back pain and fitness, motor competence and body composition.

Background

Although deficits in physical fitness and motor control have been shown to relate to adult back pain, the evidence in adolescents is less clear.

Methods

In this cross-sectional study, 1608 'Raine' cohort adolescents (mean age 14 years) answered questions on lifetime, month and chronic prevalence of back pain, and participated in a range of physical tests assessing aerobic capacity, muscle performance, flexibility, motor competence and body composition. A history of any diagnosed back pain in the adolescent was obtained from the primary carer.

Results

After multivariate logistic regression analysis, increased likelihood of back pain in boys was associated with greater aerobic capacity, greater waist girth and both reduced and greater flexibility. Back pain in girls was associated with greater abdominal endurance, reduced kinaesthetic integration, and both reduced and greater back endurance. Lower likelihood of back pain was associated with greater bimanual dexterity in boys and greater leg power in girls.

Conclusion

Physical characteristics are commonly cited as important risk factors in back pain development. Although some factors were associated with adolescent back pain, and these differed between boys and girls, they made only a small contribution to logistic regression models for back pain. The results suggest future work should explore the interaction of multiple domains of risk factors (physical, lifestyle and psychosocial) and subgroups of adolescent back pain, for whom different risk factors may be important.

Key words: Spinal pain; physical performance; motor control; Raine

INTRODUCTION

Over half of adolescents may have had back pain at some point in their lives[14], one third of these having sought professional help[11] and 20% having experienced a reduced quality of life[11]. The identification of risk factors to facilitate effective prevention and better management of adolescent back pain is therefore important, particularly as adolescent back pain has also been associated with future back pain[11]. Previous research into adolescent back pain has established that certain lifestyle and psychosocial factors such as computer use[37] or poor mental health[40] are important, but the contribution of physical risk factors in adolescence is still unclear.

In adults, obesity[4], deficits in aerobic fitness[27], poorer muscle performance[4,5,27] and reduced motor control[8] are established physical risk factors, and interventions for adult back pain aimed at countering spinal deconditioning reflect this[12]. Such factors may render the spine vulnerable to tissue strain and pain[28], and reinforce the pain avoidance / depression cycle[39]. However, the association between such physical factors and back pain may be different in adolescence, as a result of factors such as the growth spurt, which is known to lead to musculoskeletal changes[18,19].

Current evidence of a relationship between adolescent back pain and physical risk factors is conflicting or limited. Adolescent back pain has been associated with increased adiposity in some studies (e.g.[19,35]) but not others (e.g.[16,31]). No studies have examined the relationship between objectively measured aerobic capacity and adolescent back pain, although a recent study of adolescents found aerobic capacity to be unrelated to undifferentiated neck/back pain[3]. Reduced trunk muscle endurance has been shown to be a risk factor (e.g.[16,32]), but not by all studies[31], and no studies have investigated the influence of limb muscle performance.

Reduced lumbar or hamstring flexibility has been shown to relate to back pain in some studies (e.g.[16,19,32,35]), but not by all[16,24,31]. Finally, the association between motor competence and adolescent back pain is yet to be reported, although pre-pubertal children with lower motor competence report more back pain[7].

Differences in study design or definitions of back pain across different studies may partially explain discrepancies between studies. For example, back pain was variously defined as the history of at least one episode [16] , pain lasting more than a day[24] , pain interfering with function for at least one week [19] ,or pain that did not include menstrual or traumatic pain[35]. Failure to show effects in some studies may also be due to limitations such as insufficient sample size, with most having samples of <100 (e.g.[16,19,31, 32,35]). One drawback of all the previous literature into physical factors and back pain has been to consider only relationships modelled by a straight line (rectilinear), which may fail to identify those more appropriately modelled by a regular curve (curvilinear), despite reports of curvilinear relationships between spinal pain and activity[40] and computer use[37]. Another potential limitation has been inadequate multivariate analysis. Though most studies have looked at several variables, these have mostly, within a given study, focussed on only one or two domains of physical fitness, such as trunk muscle performance[31]or flexibility [19,31]. It is therefore unclear whether variables associated with pain are merely correlates of other (possibly more clinically relevant) aspects that have not been considered.

Therefore the aim of this study was to investigate, within a large cohort, the relationships between a broad range of physical risk factors (body composition, aerobic fitness, muscle performance, flexibility, motor competence), allowing for curvilinear relationships and different risk factor relationships for adolescent boys and girls.

METHODS

Design

This was a cross-sectional epidemiological study. The study was approved by the Human Research Ethics Committees of Curtin University of Technology and Princess Margaret Hospital. Adolescents provided written informed assent and their parent/guardian provided written informed consent prior to participation. The rights of all participants were protected.

Participants

Data from 1608 adolescents (783 girls, 825 boys) of mean (SD) age 14.06 (0.20) yrs were collected as part of their participation in the Western Australian Pregnancy Cohort "Raine" Study (www.rainestudy.org.au). This long term project started with a cohort of women attending antenatal clinics at King Edward Memorial Hospital for Women, Perth, Australia between 1989 and 1991. The children have been followed at birth, 1, 2, 3, 5, 8, 10, and now 14 years of age. Inclusion criteria for the women included gestational age between 16 and 20 weeks, sufficient proficiency in English to understand the implications of participation, and an intention to remain in Western Australia so that follow-up would be possible. There were 2337 adolescents eligible for the 14 year follow-up, of which 1704 (73%) consented to some aspect of the follow-up and 1608 (69%) completed the data collection requirements for the analysis reported in this paper. There were no exclusion criteria for this follow up cohort.

Outcome measures

Participants completed a questionnaire on a laptop at an assessment centre with the help of a research assistant. The questionnaire contained 130 questions concerning a broad range of physical, medical, nutritional, psychosocial and developmental issues. The back pain questions were: Have you ever had back pain? ("yes" or "no"), Has your back been painful in the last month? ("yes" or "no"), and Did your back pain last for more than 3 months? ("yes" or "no").

Prior questions (not relevant to this report) on neck pain and limb pain alerted participants that "back pain" did not include neck or limb pain. The full questionnaire took about 1 hour to complete, and the back pain questions occurred in the first half. Similar versions of these questions have been validated[14].

Information on diagnosed back pain was obtained from the primary carer, who was asked, "Does your child have now, or has your child had in the past, any of the following health professional diagnosed medical conditions or health problems?". The primary carer had to indicate which medical diagnoses their child had experienced from a short list of general medical problems, which included "back pain". This question was part of a questionnaire given to the primary carer, covering many other factors not relevant to this report.

A physical assessment of the child was carried out after the questionnaire. All tests were carried out by trained and experienced graduate research assistants with a nursing or human movement background. With shoes removed, height (m) was measured with a stadiometer, body mass (kg) with digital scales, waist girth (cm) was measured at the umbilical level with a cloth tape, and arm girth (cm) was measured at the mid-humeral point with a cloth tape. A series of physical performance tests were then conducted, all of which have been previously validated in very similar forms[6,20,22,25,30,34,38]. Reliability of comparable forms of these tests is also good[15,20,21,22,25,30] though there are no reports on the reliability of the basketball throw. Most of these validity and reliability studies were conducted on pre-adults [15,22,30,34,38]. These tests are described as follows.

Maximal aerobic capacity was estimated using heart rate recordings during sub-maximal cycle ergometry using the Physical Work Capacity 170 protocol[10]. Trunk endurance was assessed by the sustained back extension test[5] and the number of abdominal curls performed in 3 minutes[1]. Limb muscle performance was evaluated by standing long jump[22], seated basketball throw[1] and grip strength[22]. Hamstring flexibility was tested using a unilateral sit and reach test[1]. Finally, motor competence was assessed using the McCarron Assessment of Neuromuscular Development (MAND)[22]. This assessment measures sensorimotor neuromuscular development normalised to age, and an overall score between 0 (poorest) and 100 is obtained - the Neuromuscular Developmental Index (NDI)[22]. The NDI score is based on performance in ten sensorimotor tests, and eight of these make up the 4 sub-indices of Bimanual Dexterity, Muscle Power, Kinaesthetic Integration and Persistent Control (Table 1). Bimanual Dexterity measures co-ordination across the upper limbs, Muscle Power measures upper limb strength and lower limb power, Kinaesthetic Integration measures gross balance, and Persistent Control measures the ability to produce smooth controlled movements[22].

Insert Table 1 about here

Data analysis

All statistical analysis was carried out using SPSS version 15 (SPSS Inc., Chicago, USA). Gender differences were analysed using independent t tests for each of the continuous variables, and Chi squared tests for the categorical variables. To facilitate the interpretation of non-linear relationships, continuous variables were categorised into the bottom 25%, inter-quartile range and top 25%, and the proportions of subjects with back pain in these categories were compared.

Univariate logistic regression models predicting lifetime, last month, chronic (lasting more than 3 months) and diagnosed back pain from each physical performance characteristic were calculated, with statistical significance set at $p < 0.05$, and the interquartile range (IQR) of each continuous variable (the range between the 25^{th} and 75^{th} percentiles) was defined as the reference category. Corrections for multiple univariate tests were not performed as the multivariate results were the end point of the study. Male and female data were analysed independently as a previous study has reported significantly different physical performance between genders[13].

Backwards stepwise likelihood ratio multivariate logistic regression models were used to evaluate the combined associations of performance factors for boys and for girls separately, with the probability for entry and removal of the likelihood ratio score statistic being $p = 0.05$ and 0.10 respectively, in line with standard practice. Height and weight were included in an initial step, with the all other tested physical characteristics included in a second step, regardless of whether they were significant on univariate testing. BMI and arm girth were omitted as they were highly related to waist girth, which is a more valid health-related measure of body composition[23]. Similarly, NDI was omitted as it was a composite of the four factor scores, which were more specific measures. For both the lowest and highest quartiles of each physical factor, results were presented as the odds of having back pain (95% confidence intervals), relative to the reference category. The strength of the multivariate predictive model was estimated by Nagelkerke R^2. Alpha was set at 0.05 for the multivariate tests.

RESULTS

Back pain

Back pain ever was experienced by 46.0% of the participants, back pain in the past month by 28.1%, 'chronic' (lasting more than 3 months) by 11.3% and diagnosed back pain by 11.4%. Girls had a tendency ($p<0.1$, >0.05) for a higher prevalence of diagnosed back pain, back pain ever and back pain in the past month (see Table 2).

Insert Table 2 about here

Physical risk factors

Descriptive statistics for physical characteristics are given in Table 2. Girls had significantly higher mean scores for BMI, back endurance, sit and reach, and the motor competence factors of Persistent Control, Kinaesthetic Integration and Bimanual Dexterity. Boys obtained significantly higher mean scores for waist girth, aerobic capacity, abdominal curl number, standing long jump, basketball throw distance, grip strength and the motor competence factor of Muscle Power. Males were also taller and heavier.

Relationships between physical risk factors and back pain

Univariate results

Tables 3 and 4 display the results of univariate analyses of physical risk factors and the four measures of back pain for boys and girls.

Multivariate results in boys

After multivariate logistic regression analysis, increased likelihood of back pain in the last month was associated with greater aerobic capacity (OR=1.65 (95% CI: 1.10-2.46)), and increased likelihood of diagnosed back pain was associated with greater waist girth (OR=2.20 (1.11-4.36)), and both reduced flexibility (OR=1.95 (1.06-3.58)) and greater flexibility (OR=2.14 (1.17-3.90)). Lower likelihood of back pain in the past month was associated with greater bimanual dexterity (OR=0.58 (0.34-0.99)). There were no other significant multivariate associations between the physical risk factors and the four types of back pain. The Nagelkerke R^2 of multivariate logistic regression models ranged from 0.019 to 0.070.

Multivariate results in girls

Increased likelihood of back pain in the past month was associated with greater abdominal endurance (OR=1.56 (1.018-2.38)) and there was a trend ($p<0.1$) for an association with reduced muscle power (OR=1.43 (0.97-2.10)). Increased likelihood of chronic back pain was associated with reduced kinaesthetic integration (OR=1.72 (1.02-2.92)), and increased likelihood of diagnosed back pain was associated with both reduced back endurance ((OR=2.05 (1.16-3.60)) and greater back endurance (OR=2.00 (1.10-3.60)). Lower likelihood of back pain ever was associated with greater leg power (OR=0.58 (0.39-0.85)). There were no other significant multivariate associations between the physical risk factors and the four types of back pain. The Nagelkerke R^2 of multivariate logistic regression models ranged from 0.019-0.044.

Insert Table 3 about here

Insert Table 4 about here.

DISCUSSION

This study confirms that back pain is common in adolescents, with almost half having experienced back pain, 20% of whom experienced prolonged episodes. It is therefore a problem requiring attention with regard to both prevention and management.

Although our univariate analyses suggested several physical factors might be related to back pain, many of these were not significant after multivariate analysis, presumably because of competition from more strongly associated factors. Our study is the first to include a wide variety of physical risk factors in the multivariate analysis, representing an advantage over previous studies in terms of permitting a more comprehensive analysis. Accordingly, only multivariate results will be discussed below. The cross-sectional approach does not allow any assumptions about the direction of any causality, but plausible mechanisms will be discussed.

Diagnosed back pain was over twice as likely in boys with the greatest waist girth. This concurs with other studies, though these studies did not find gender differences[19,35]. Our recent research has documented a relationship between hyperlordotic postures and increased BMI in adolescents, with an associated increased risk of LBP in this postural group[36]. It may be that the increased risk of LBP associated with waist girth in boys is linked to altered patterns of spinal loading due to excess weight. Our lack of any body composition associations in girls resembles the findings of Kujala and colleagues[19], who noted an unadjusted longitudinal association between high BMI and subsequent back pain in boys only.

This is the first study to report associations between objectively measured aerobic capacity and adolescent back pain and showed that boys with the highest aerobic capacity had a greater risk of back pain in the past month. Aerobically fitter boys may have been at greater risk for back pain due to more prolonged or intense activity, which might increase spinal loading beyond a threshold of tissue tolerance[2]. The association of back pain with higher aerobic capacity solely in boys may relate to previous findings of a higher risk of back pain in boys involved in organised sport[19]. However, our lack of activity measurements precludes any firm conclusions.

A relationship between back pain and abdominal endurance was absent for boys. However, girls with *greater* abdominal endurance had a higher risk of back pain in the past month, although this risk was small. This association has not been previously reported, although adolescent back pain has been related to increased trunk flexor strength[26]. The mechanism for our finding is not clear although it is known that the trunk flexors can exert significant flexion/compression loading forces on the lumbar spine[17]. Our results conflict with the previous finding that *reduced* abdominal endurance is associated with back pain in both genders[16], although this difference may relate to differing definitions of pain. Reasons for the gender difference in our study are unknown.

Trunk extensor endurance also showed no association with pain in boys, but girls showed a U shaped relationship between this variable and diagnosed back pain. Previous findings have either showed no effect[31] or have shown a relationship between low extensor endurance and back pain[32]. This inconsistency may be because previous studies were not designed to detect curvilinear relationships, and highlights the importance of such study design. The finding that both deficits and excesses of back muscle performance are related to LBP is supported by previous reports of different LBP subgroups presenting with excesses and deficits in back muscle activity levels[9].

For the measures of limb muscle performance, only the association between greater jump distance and lower risk of back pain ever in girls was significant. Adult studies have shown an analogous relationship of greater back pain with reduced leg power[27]. Although highly speculative, the association could relate to those with better lower limb muscle performance making greater use of the leg than trunk muscles during vigorous lower limb activities, possibly reducing spinal stress[17]. Equally, those with back pain may avoid activities that promote leg power.

The sit and reach distance, an indication of both spinal flexion and hamstring flexibility, was unrelated to back pain in girls. These findings concur with results in both genders in other adolescent studies using the same test[16,24]. However, in boys there was a U shaped relationship with diagnosed back pain. Again, the lack of previous observation of such a U shaped relationship may relate to the linear assumptions of previous work. It is possible that both high and low levels of bending flexibility could induce increased spinal strain during normal activities, high flexibility possibly placing strain on neural structures[33], and low flexibility potentially inducing strain on intra-articular structures[19]. However lower flexibility could also be a result, rather than a cause, of back pain. It should be noted that the sit and reach test does not differentiate hamstring from spinal flexibility and so findings should be treated with caution.

Some aspects of motor competence related to back pain, with greater Bimanual Dexterity associated with less risk of back pain in the past month in boys, and poorer Kinaesthetic Integration linked to a greater risk of chronic back pain in the past month in girls. Bimanual Dexterity, in this context, is a measure of coordination of fine motor skills across both upper limbs, and Kinaesthetic Integration refers to the ability to maintain both static and dynamic balance[22]. This is the first adolescent study to demonstrate a relationship between aspects of motor competence and back pain, and it appears to concur with findings in younger children[7] and adults[8]. This finding suggests that the quality of synergist coordination may be important in adolescents, in addition to quantitative factors such as strength. This is consistent with theories of muscle control of the spine[28].

The notable gender differences in the way physical risk factors associated with back pain may relate to differences in the levels and types of physical activity adopted by boys and girls[13]. It may also be related to anthropometric differences, as differing heights and weights may lead to differing spinal torques during the same activities. It could also relate to other structural differences, and should be the focus of future research.

Although back pain was associated with various physical factors, these associations were weak, with Nagelkerke R^2 of multivariate logistic regression models ranging from 0.019 to 0.070. This could not be attributed to missed curvilinear relationships as these were accounted for in the analysis. It is unlikely that the lack of strength in the measured relationships were because the physical measures failed to adequately capture key physical constructs as most have been validated and widely used. Back pain is not a simple construct and the lack of strong relationships may also have resulted from the measures of back pain used. However we used four different measures of back pain, including a primary carer report of diagnosed back pain. This suggests the weaknesses associated with self-report of back pain, such as trivial cases being reported, were not the reason for limited associations.

One of the strengths of this study, compared to previous work, was the broad range of physical variables included in the analysis, but it is still possible that the lack of strong relationships could also be a result of some physical characteristics interacting with other risk factors not examined in this study. For example poor motor competence may only be important for people with high exposure to spinal loading. Similarly, certain psychosocially-defined sub-groups may differ in how their back pain relates to muscle performance. Hence further studies should assess interactions between physical characteristics and other psychosocial and lifestyle risk factors. Similarly, the lack of any sub-grouping of back pain may have led to stronger relationships between physical performance characteristics and specific types of back pain remaining undetected. For example, poor back muscle endurance may only be important for boys with back pain associated with motor control impairments into flexion[29]. Finally, although the age of participants was very narrowly distributed, likely variations in maturation could have confounded results, and future work should consider this issue. The associations seen in this study between back pain and physical factors such as body composition, aerobic fitness, muscle performance, flexibility and motor competence should be viewed as representing just one part of the multifactorial basis of adolescent back pain.

CONCLUSION

Physical characteristics are often regarded as important risk factors in back pain development. However, although some factors were associated with adolescent back pain, these differed between boys and girls, and they made only a small contribution to the logistic regression models for back pain. This suggests future work should explore the interaction of multiple domains of risk factors (physical, lifestyle and psychosocial) and subgroups of adolescent back pain, for whom different risk factors may be important.

KEY POINTS

Findings

Aspects of fitness, motor competence and body composition were related to adolescent back pain and differed between genders.

Implications

Whilst physical characteristics were associated with back pain in adolescents, the weak and varied relationships suggests adolescent back pain should not be assumed to be the same as adult back pain.

Caution

Lifestyle and psychosocial characteristics were not included in this study. Back pain was treated as a homogeneous entity, with no analysis of subgroups.

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Test	*Details*	*Competence assessed*
Rod slide	*Moving a bead as slowly and smoothly as possible along a rod, repeated with both hands.*	*PC*
Finger/nose finger	*The accuracy and smoothness of movement of the index finger from nose to opposite hand's index finger is observed, repeated on both sides. Eyes open and closed.*	*PC*
Hand strength	*Hand grip strength is measured with a hand dynamometer, repeated on both sides*	*MP*
Standing long jump	*The distance and quality of a two footed jump is recorded.*	*MP*
Heel toe walk	*The quality of forward and backwards walking along a 10 foot line is recorded.*	*KI*
Standing on one leg	*With eyes open the time the participant can balance on each leg is recorded, repeated with eyes closed*	*KI*
Beads on rod	*Number of cylindrical beads placed on a metal rod held in non-dominant hand in 30 seconds, repeated with eyes open and then closed*	*BD*
Nut and bolt	*Time taken to turn a large bolt, held in the dominant hand, fully onto a nut, repeated with a small bolt.*	*BD*
Finger tapping	*Number and quality of taps of index finger in 10 seconds, repeated on both hands*	-
Beads in box	*Number of beads moved from one box to an adjacent box in 30 seconds, repeated for both hands.*	-

TABLE 1. Summary of MAND tests. PC=Persistent Control, MP=Muscle Power, KI=Kinaesthetic Integration, BD=Bimanual Dexterity.

Pain variable	***All Participants % (count) with history of pain***	***Male % (count) with history of pain***	***Female % (count) with history of pain***	***Gender difference*** ***P***
Back pain ever	*46.0 (734)*	*43.7 (356)*	*48.5 (378)*	*0.052*
Back pain in last month	*28.1 (449)*	*26.1 (213)*	*30.2 (236)*	*0.070*
Chronic back pain	*11.3 (180)*	*10.8 (88)*	*11.8 (92)*	*0.535*
Diagnosed back pain	*11.4 (177)*	*9.9 (79)*	*12.9 (98)*	*0.069*

Physical variable	***All Participants mean (sd)***	***Males***		***Females***		***Gender difference***
		mean (sd)	***IQR***	***mean (sd)***	***IQR***	***P***
Height	*1.64 (0.08)*	*1.66 (0.09)*	*1.61-1.73*	*1.62 (0.06)*	*1.50-1.67*	*<0.001*
Weight	*57.7 (13.2)*	*58.6 (14.1)*	*50.0-66.0*	*56.7 (12.1)*	*49.2-61.9*	*0.004*
BMI	*21.29 (4.15)*	*21.05 (4.14)*	*18.30-22.79*	*21.53 (4.16)*	*18.91-23.38*	*0.022*
Waist girth (cm)	*75.5 (10.8)*	*76.3 (11.4)*	*68.5-81.0*	*74.6 (10.1)*	*67.5-79.2*	*0.002*
Arm circumference (cm)	*25.2 (3.3)*	*25.3 (3.4)*	*23.0-27.2*	*25.1 (3.3)*	*23.0-27.0*	*0.244*
PWC_{170} score (W)	*111.2 (29.9)*	*124.3 (31.7)*	*102.5-143.8*	*97.2 (19.9)*	*84.9-108.2*	*<0.001*
Back muscle endurance (seconds)	*80.9 (60.4)*	*77.8 (60.1)*	*26.0-121.0*	*84.2 (60.5)*	*32.0-120.0*	*0.034*
Abdominal muscle endurance (number of curls in 3min)	*21.4 (17.4)*	*25.4 (18.8)*	*12.0-36.0*	*17.2 (14.6)*	*7.0-23.0*	*<0.001*
Standing long jump distance (metres)	*1.46 (0.29)*	*1.59 (0.28)*	*1.42-1.78*	*1.32 (0.23)*	*1.4217-1.47*	*<0.001*
Basketball throw (metres)	*5.3 (1.0)*	*5.7 (1.0)*	*5.1-6.4*	*4.8 (0.7)*	*4.4-5.2*	*<0.001*
Total hand strength (kg)	*51.8 (13.5)*	*57.0 (14.8)*	*47.0-66.0*	*46.3 (9.1)*	*40.0-52.0*	*<0.001*

Sit and reach distance (right leg) (cm)*	*24.8 (9.1)*	*21.1 (8.0)*	*16.0-26.5*	*28.8 (8.6)*	*23.3-35.0*	*<0.001*
NDI score	*97.2 (17.4)*	*97.3 (18.1)*	*85.0-111.0*	*97.0 (16.6)*	*85.0-110.0*	*0.758*
Persistent Control factor score	*103.3 (25.4)*	*99.9 (26.4)*	*80.0-125.0*	*106.8 (23.7)*	*90.0-125.0*	*<0.001*
Muscle Power factor score	*95.9 (20.2)*	*102.4 (19.8)*	*90.0-120.0*	*89.2 (18.5)*	*75.0-100.0*	*<0.001*
Kinaesthetic Integration factor score	*96.9 (15.2)*	*96.7 (15.7)*	*85.0-110.0*	*97.2 (14.7)*	*90.0-110.0*	*<0.001*
Bimanual Dexterity factor score	*97.1 (19.3)*	*95.1 (19.3)*	*85.0-110.0*	*99.1 (19.1)*	*85.0-110.0*	*<0.001*

TABLE 2. Summary of pain prevalence and performance in the physical tests in boys and girls. IQR=interquartile range.

*The right leg sit and reach distance did not differ from the left for boys or girls, so all analyses used the right sit and reach distance.

		% with back pain			low vs IQR		high vs IQR	
		low	*IQR*	*high*	*OR*	*95%CI*	*OR*	*95%CI*
Back Pain Ever								
Height		*38.0*	*42.7*	*51.9*	*0.82*	*0.59-1.15*	*1.45**	*1.02-2.06*
Weight		*36.5*	*44.9*	*48.5*	*0.70**	*0.50-1.00#*	*1.16*	*0.83-1.62*
Body composition	*BMI*	*38.9*	*44.0*	*47.2*	*0.81*	*0.58-1.14*	*1.14*	*0.81-1.60*
	Waist girth	*35.4*	*45.7*	*48.0*	*0.65**	*0.46-0.92*	*1.09*	*0.78-1.54*
	Arm girth	*37.7*	*45.7*	*46.8*	*0.72*	*0.51-1.00*	*1.04*	*0.74-1.47*
Aerobic	*PWC_{170}*	*39.4*	*42.2*	*52.9*	*0.89*	*0.63-1.26*	*1.53**	*1.08-2.17*
Muscle performance	*Back end*	*46.3*	*40.6*	*46.2*	*1.27*	*0.90-1.78*	*1.26*	*0.89-1.77*
	Curls	*40.8*	*43.2*	*45.9*	*0.91*	*0.64-1.28*	*1.11*	*0.79-1.57*
	Jump	*41.4*	*46.6*	*39.9*	*0.81*	*0.58-1.14*	*0.76*	*0.54-1.08*
	Basketball	*36.6*	*45.3*	*47.0*	*0.70**	*0.49-0.99*	*1.07*	*0.77-1.51*
	Grip strength	*36.2*	*46.4*	*47.4*	*0.66**	*0.47-0.92*	*1.04*	*0.74-1.47*
Flexibility	*Sit and reach*	*42.1*	*43.9*	*42.5*	*0.93*	*0.66-1.31*	*0.95*	*0.67-1.33*
Motor competence	*NDI*	*43.0*	*44.9*	*42.4*	*0.93*	*0.66-1.30*	*0.90*	*0.64-1.27*
	PC	*43.8*	*46.0*	*39.6*	*0.91*	*0.65-1.28*	*0.77*	*0.54-1.09*
	MP	*39.0*	*44.4*	*48.1*	*0.80*	*0.57-1.12*	*1.16*	*0.78-1.71*
	KI	*41.0*	*45.8*	*41.7*	*0.82*	*0.59-1.15*	*0.85*	*0.58-1.23*
	BD	*45.3*	*44.8*	*38.4*	*1.02*	*0.75-1.38*	*0.77*	*0.51-1.15*
Back Pain Month								
Height		*22.5*	*24.6*	*33.7*	*0.89*	*0.60-1.32*	*1.56**	*1.07-2.28*
Weight		*21.2*	*26.1*	*31.2*	*0.76*	*0.51-1.14*	*1.28*	*0.89-1.86*
Body composition	*BMI*	*21.7*	*25.3*	*32.2*	*0.82*	*0.55-1.22*	*1.40*	*0.97-2.03*
	Waist girth	*20.6*	*26.8*	*30.1*	*0.71*	*0.47-1.06*	*1.18*	*0.81-1.72*
	Arm girth	*20.3*	*26.9*	*31.3*	*0.69*	*0.47-1.03*	*1.24*	*0.85-1.80*
Aerobic	*PWC170*	*21.2*	*24.6*	*35.2*	*0.83*	*0.55-1.25*	*1.67***	*1.15-2.43*
Muscle performance	*Back end*	*25.9*	*26.1*	*24.6*	*0.99*	*0.67-1.45*	*0.92*	*0.62-1.37*
	Curls	*25.5*	*25.1*	*27.0*	*1.02*	*0.69-1.52*	*1.11*	*0.75-1.63*
	Jump	*24.2*	*26.7*	*26.6*	*0.88*	*0.59-1.30*	*0.99*	*0.67-1.47*
	Basketball	*22.8*	*25.6*	*29.2*	*0.86*	*0.58-1.27*	*1.20*	*0.82-1.75*
	Grip strength	*19.3*	*28.3*	*29.9*	*0.60**	*0.40-0.90*	*1.08*	*0.74-1.57*
Flexibility	*Sit and reach*	*25.7*	*25.9*	*23.5*	*0.99*	*0.67-1.46*	*0.88*	*0.59-1.30*
Motor competence	*NDI*	*25.0*	*26.6*	*26.3*	*0.92*	*0.63-1.36*	*0.99*	*0.67-1.45*
	PC	*27.4*	*26.2*	*24.9*	*1.06*	*0.73-1.55*	*0.93*	*0.63-1.38*
	MP	*22.0*	*27.3*	*27.9*	*0.75*	*0.51-1.11*	*1.03*	*0.67-1.60*
	KI	*24.1*	*27.8*	*24.3*	*0.83*	*0.57-1.20*	*0.84*	*0.54-1.29*
	BD	*28.9*	*26.3*	*20.3*	*1.14*	*0.81-1.60*	*0.71*	*0.44-1.16*
Back Pain Chronic								
Height		*7.5*	*10.3*	*16.0*	*0.71*	*0.39-1.29*	*1.67**	*1.01-2.77*
Weight		*4.4*	*12.2*	*14.4*	*0.33***	*0.16-0.69*	*1.21*	*0.74-1.97*
Body composition	*BMI*	*8.4*	*11.4*	*12.1*	*0.71*	*0.40-1.27*	*1.06*	*0.63-1.79*
	Waist girth	*5.7*	*12.0*	*13.3*	*0.45**	*0.23-0.86*	*1.12*	*0.67-1.86*
	Arm girth	*5.6*	*12.8*	*12.9*	*0.41***	*0.22-0.77*	*1.01*	*0.61-1.69*
Aerobic	*PWC170*	*9.3*	*10.6*	*13.0*	*0.87*	*0.48-1.55*	*1.25*	*0.74-2.13*
Muscle performance	*Back end*	*12.2*	*9.7*	*12.3*	*1.29*	*0.76-2.20*	*1.31*	*0.76-2.24*
	Curls	*11.7*	*9.8*	*12.2*	*1.22*	*0.71-2.10*	*1.28*	*0.75-2.19*
	Jump	*7.6*	*12.8*	*10.1*	*0.56*	*0.31-1.02*	*0.77*	*0.44-1.34*
	Basketball	*8.9*	*10.5*	*13.4*	*0.84*	*0.47-1.50*	*1.32*	*0.79-2.22*
	Grip strength	*6.4*	*12.0*	*13.4*	*0.50**	*0.27-0.93*	*1.13*	*0.68-1.89*
Flexibility	*Sit and reach*	*11.9*	*11.5*	*8.0*	*1.04*	*0.62-1.76*	*0.67*	*0.37-1.22*
Motor competence	*NDI*	*12.5*	*10.4*	*10.6*	*1.23*	*0.73-2.08*	*1.02*	*0.59-1.77*
	PC	*12.5*	*10.6*	*9.6*	*1.20*	*0.71-2.01*	*0.90*	*0.51-1.58*
	MP	*8.0*	*12.4*	*10.1*	*0.62*	*0.35-1.10*	*0.79*	*0.42-1.50*
	KI	*12.3*	*10.8*	*9.0*	*1.16*	*0.70-1.92*	*0.82*	*0.43-1.56*
	BD	*12.5*	*10.7*	*7.5*	*1.18*	*0.74-1.90*	*0.68*	*0.33-1.40*
Diagnosed Back Pain								
Height		*8.1*	*9.2*	*14.0*	*0.87*	*0.48-1.58*	*1.62*	*0.94-2.78*
Weight		*5.1*	*9.7*	*15.4*	*0.49*	*0.24-1.01*	*1.69**	*1.01-2.81*
Body	*BMI*	*6.0*	*9.1*	*15.9*	*0.64*	*0.33-1.26*	*1.90**	*1.13-3.17*

composition	*Waist girth*	*4.5*	*9.4*	*16.9*	*0.46**	*0.22-0.96*	*1.96**	*1.18-3.26*
	Arm girth	*4.9*	*10.4*	*14.9*	*0.44**	*0.22-0.88*	*1.50*	*0.90-2.51*
Aerobic	*PWC170*	*10.4*	*9.7*	*11.2*	*1.09*	*0.61-1.93*	*1.17*	*0.66-2.07*
Muscle	*Back end*	*13.0*	*9.3*	*7.3*	*1.47*	*0.86-2.51*	*0.77*	*0.40-1.50*
performance	*Curls*	*11.2*	*8.1*	*10.6*	*1.43*	*0.81-2.54*	*1.35*	*0.75-2.43*
	Jump	*11.7*	*9.7*	*8.4*	*1.23*	*0.71-2.12*	*0.85*	*0.46-1.58*
	Basketball	*9.0*	*8.7*	*13.3*	*1.03*	*0.57-1.87*	*1.61*	*0.94-2.77*
	Grip strength	*8.3*	*9.3*	*13.4*	*0.89*	*0.49-1.61*	*1.52*	*0.88-2.61*
Flexibility	*Sit and reach*	*11.6*	*6.9*	*13.0*	*1.77*	*0.99-3.17*	*2.02**	*1.14-3.59*
Motor	*NDI*	*10.1*	*9.0*	*11.1*	*1.14*	*0.64-2.03*	*1.26*	*0.71-2.24*
competence	*PC*	*10.0*	*10.8*	*7.9*	*0.91*	*0.53-1.59*	*0.71*	*0.38-1.32*
	MP	*10.6*	*9.7*	*9.0*	*1.10*	*0.64-1.91*	*0.93*	*0.46-1.85*
	KI	*11.8*	*10.0*	*6.5*	*1.20*	*0.71-2.02*	*0.62*	*0.30-1.30*
	BD	*11.0*	*9.1*	*10.2*	*1.23*	*0.74-2.05*	*1.13*	*0.57-2.22*

TABLE 3. Univariate relationship between physical performance characteristics and back pain in boys

OR = Odds Ratio, 95%CI = 95% confidence interval, IQR = interquartile range, BMI = body mass index, PWC = physical work capacity, NDI = Neuromuscular Developmental Index, PC = persistent control, MP = muscle power, KI = kinesthetic integration, BD = bimanual dexterity. *P<0.05, **P<0.01. #The actual lower CI was <1.00 but rounded up to 1.00, so OR was still significantly less than 1.00.

		% with back pain			low vs IQR		high vs IQR	
		low	*IQR*	*high*	*OR*	*95%CI*	*OR*	*95%CI*
Back Pain Ever								
Height		42.3	49.9	52.4	0.74	0.57-1.11	1.11	0.78-1.57
Weight		45.2	47.4	54.1	0.91	0.13-1.31	1.31	0.93-1.85
Body	*BMI*	48.2	45.4	54.7	1.12	0.79-1.58	1.45*	1.03-2.06
composition	*Waist girth*	43.2	47.2	55.9	0.85	0.05-1.42	1.42	0.99-2.01
	Arm girth	44.9	48.0	55.1	0.88	0.13-1.33	1.33	0.92-1.92
Aerobic	*PWC170*	44.5	47.5	53.0	0.89	0.22-1.25	1.25	0.87-1.79
Muscle	*Back end*	49.7	46.4	49.2	1.14	0.81-1.61	1.12	0.79-1.58
performance	*Curls*	49.3	47.2	48.6	1.08	0.77-1.53	1.06	0.74-1.51
	Jump	52.7	51.5	36.7	1.05	0.00-0.55	0.55**	0.38-0.78
	Basketball	51.0	48.2	47.5	1.12	0.89-0.97	0.97	0.68-1.40
	Grip strength	49.1	47.2	49.7	1.08	0.77-1.51	1.11	0.78-1.57
Flexibility	*Sit and reach*	51.3	46.2	50.3	1.23	0.87-1.73	1.18	0.82-1.68
Motor	*NDI*	51.7	48.7	42.9	1.13	0.19-0.79	0.79	0.56-1.12
competence	*PC*	51.1	46.7	49.6	1.19	0.87-1.65	1.12	0.75-1.68
	MP	53.3	48.0	41.5	1.24	0.15-0.77	0.77	0.54-1.10
	KI	50.3	48.9	44.7	1.06	0.40-0.85	0.84	0.57-1.25
	BD	46.6	49.9	47.8	0.88	0.63-1.22	0.92	0.64-1.32
Back Pain Month								
Height		31.7	29.0	31.4	1.14	0.79-1.65	1.12	0.77-1.64
Weight		28.9	28.5	35.1	1.02	0.70-1.49	1.36	0.94-1.96
Body	*BMI*	31.4	26.3	36.8	1.29	0.88-1.88	1.63**	1.13-2.36
composition	*Waist girth*	26.4	30.1	34.2	0.84	0.31-1.21	1.21	0.84-1.76
	Arm girth	29.2	29.7	32.9	0.98	0.68-1.40	1.16	0.78-1.72
Aerobic	*PWC170*	28.6	29.2	33.7	0.97	0.28-1.24	1.23	0.84-1.81
Muscle	*Back end*	34.9	27.3	28.3	1.43	0.98-2.07	1.05	0.71-1.55
performance	*Curls*	33.7	26.3	31.5	1.43	0.98-2.07	1.29	0.88-1.90
	Jump	32.7	33.2	21.3	0.98	0.68-1.41	0.55**	0.36-0.82
	Basketball	33.9	29.0	28.6	1.26	0.87-1.81	0.98	0.66-1.47
	Grip strength	32.9	28.2	30.5	1.25	0.87-1.79	1.12	0.76-1.64
Flexibility	*Sit and reach*	30.4	29.6	29.5	1.04	0.72-1.51	1.00	0.67-1.47
Motor	*NDI*	31.7	30.5	27.4	1.06	0.44-0.86	0.86	0.58-1.27
competence	*PC*	33.2	29.3	26.6	1.20	0.56-0.87	0.87	0.56-1.37
	MP	36.3	29.5	23.3	1.36	0.13-0.73	0.73	0.48-1.10
	KI	29.4	31.9	25.0	0.89	0.62-1.28	0.71	0.46-1.10
	BD	29.5	31.0	28.6	0.93	0.65-1.33	0.89	0.60-1.32
Back Pain Chronic								
Height		10.1	13.2	10.6	0.74	0.43-1.27	0.79	0.45-1.36
Weight		12.7	11.3	11.9	1.14	0.68-1.93	1.06	0.62-1.81
Body	*BMI*	13.9	9.8	13.5	1.49	0.88-1.52	1.43	0.84-2.44
composition	*Waist girth*	11.9	11.1	13.4	1.14	0.68-1.93	1.06	0.62-1.81
	Arm girth	11.9	10.6	14.6	1.15	0.69-1.92	1.44	0.83-2.49
Aerobic	*PWC170*	10.4	11.1	14.9	0.93	0.21-1.40	1.40	0.83-2.37
Muscle	*Back end*	13.3	10.0	11.0	1.39	0.82-2.36	1.12	0.64-1.96
performance	*Curls*	12.1	11.3	9.9	1.08	0.63-0.87	0.87	0.49-1.55
	Jump	13.5	11.0	10.1	1.26	0.76-0.91	0.91	0.51-1.62
	Basketball	12.8	10.5	13.0	1.26	0.74-2.13	1.28	0.74-2.24
	Grip strength	14.6	9.0	12.8	1.71*	1.02-2.88	1.48	0.85-2.58
Flexibility	*Sit and reach*	11.3	11.3	12.1	1.01	0.59-1.73	1.09	0.63-1.89
Motor	*NDI*	11.9	10.4	12.6	1.16	0.68-1.99	1.24	0.72-2.13
competence	*PC*	10.0	11.4	14.5	0.87	0.34-1.33	1.33	0.74-2.38
	MP	14.4	9.0	12.5	1.70*	1.01-2.85	1.44	0.81-2.54
	KI	16.0	10.4	9.1	1.63*	1.00-2.67##	0.86	0.44-1.67
	BD	12.7	10.6	11.5	1.22	0.73-2.03	1.10	0.62-1.93
Diagnosed Back Pain								
Height		9.5	14.7	12.7	0.61	0.35-1.05	0.84	0.50-1.42
Weight		10.5	13.7	13.6	0.74	0.43-1.27	0.99	0.60-1.65
Body	*BMI*	10.6	13.5	13.2	0.76	0.44-1.32	0.98	0.59-1.63
composition	*Waist girth*	12.5	13.1	12.6	0.95	0.56-1.61	0.96	0.56-1.62

	Arm girth	*10.9*	*13.3*	*14.7*	*0.80*	*0.48-1.34*	*1.13*	*0.67-1.93*
Aerobic	*PWC170*	*11.4*	*12.6*	*15.3*	*0.89*	*0.51-1.57*	*1.25*	*0.75-2.10*
Muscle performance	*Back end*	*15.0*	*9.5*	*15.1*	*1.69**	*1.00-2.87##*	*1.71**	*1.00-2.91##*
	Curls	*12.8*	*12.6*	*10.4*	*1.01*	*0.60-1.70*	*0.80*	*0.45-1.43*
	Jump	*11.9*	*12.8*	*13.7*	*0.92*	*0.54-1.56*	*1.07*	*0.64-1.81*
	Basketball	*10.0*	*14.0*	*12.7*	*0.68*	*0.39-1.19*	*0.90*	*0.52-1.55*
	Grip strength	*10.1*	*13.2*	*15.2*	*0.75*	*0.43-1.28*	*1.19*	*0.72-1.96*
Flexibility	*Sit and reach*	*13.5*	*12.4*	*11.5*	*1.10*	*0.66-1.84*	*0.91*	*0.52-1.61*
Motor competence	*NDI*	*11.11*	*11.81*	*16.30*	*0.93*	*0.54-1.61*	*1.45*	*0.88-2.41*
	PC	*12.05*	*12.35*	*15.97*	*0.97*	*0.59-1.60*	*1.35*	*0.76-2.39*
	MP	*11.43*	*12.84*	*14.04*	*0.88*	*0.52-1.48*	*1.11*	*0.65-1.88*
	KI	*12.50*	*13.04*	*13.28*	*0.95*	*0.57-1.59*	*1.02*	*0.57-1.83*
	BD	*10.92*	*13.88*	*13.14*	*0.76*	*0.46-1.27*	*0.94*	*0.55-1.60*

TABLE 4. Univariate relationship between physical performance characteristics and back pain in girls.

OR = Odds Ratio, 95%CI = 95% confidence interval, IQR = interquartile range, BMI = body mass index, PWC = physical work capacity, NDI = Neuromuscular Developmental Index, PC = persistent control, MP = muscle power, KI = kinesthetic integration, BD = bimanual dexterity. *P<0.05, **P<0.01. ##The actual lower CI was >1.00 but rounded down to 1.00, so OR was still significantly greater than 1.00.