Eur Spine J (2016) 25:2809–2821
DOI 10.1007/s00586-016-4629-7

ORIGINAL ARTICLE

Multivariable modeling of factors associated with spinal pain in young adolescence

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Received: 2 September 2015 / Revised: 26 May 2016 / Accepted: 27 May 2016 / Published online: 8 June 2016

Abstract

Purpose To investigate the factors related to the 1-month period prevalence of low back pain (LBP), neck pain (NP) and thoracic spine pain (TSP) in young adolescents, thereby considering potential correlates from the physical, sociodemographic, lifestyle, psychosocial and comorbid pain domains.

Methods In this cross-sectional baseline study, 69 factors potentially associated with spinal pain were assessed among 842 healthy adolescents before pubertal peak growth. With consideration for possible sex differences in associations, multivariable analysis was used to simultaneously evaluate contributions of all variables collected in the five domains.

Results A significantly higher odds of LBP was shown for having high levels of psychosomatic complaints (odds ratio: 4.4; 95 % confidence interval: 1.6–11.9), a high lumbar lordotic apex, retroversed pelvis, introverted personality, and high levels of negative over positive affect. Associations with a higher prevalence and odds of NP were found for psychosomatic complaints (7.8; 2.5–23.9), TSP in the last month (4.9; 2.2–10.8), backward trunk lean, high levels of negative over positive affect and depressed mood. Having experienced LBP (2.7; 1.3–5.7) or NP (5.5; 2.6–11.8) in the preceding month was associated with a higher odds of TSP, as were low self-esteem, excessive physical activity, sedentarism and not achieving the Fitnorm.

Conclusions Psychosomatic symptoms and pain comorbidities had the strongest association with 1-month period prevalence of spinal pain in young adolescents, followed by factors from the physical and psychosocial domains. The role that "physical factors" play in nonadult spinal pain may have been underestimated by previous studies.

Keywords Adolescent · Spinal pain · Multivariate analysis · Back pain · Neck pain

Electronic supplementary material The online version of this article (doi:10.1007/s00586-016-4629-7) contains supplementary material, which is available to authorized users.

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Introduction

On a global basis, spinal pain represents a common and significant condition with a tremendous social and economic impact [1–5]. Since adult spinal pain problems might originate in childhood and young adolescence

[6–13], thorough understanding of spinal pain at young age is needed for designing effective prevention and management strategies.

Idiopathic adolescent spinal pain (IASP) cannot be explained straightforwardly in simple models as it has many aspects. Accordingly, a multidimensional approach to the understanding of IASP is currently accepted as the most appropriate perspective. Such an approach should incorporate factors from all domains of the biopsychosocial model, including developmental, educational and cultural background [14–18]. Earlier studies [9, 13, 17–34] and reviews [15, 35–41] identifying risk factors for IASP have attempted to evaluate the contribution of multiple different physical, psychosocial, demographic, environmental and socioeconomic factors to the development of spinal pain at young age, mostly in relation to low back pain (LBP) [9, 19, 20, 22–26, 35–38].

However, interpreting the literature on associated and risk factors is complicated by 4 factors. First, methodological approaches differ substantially across studies, including inconsistency and lack of standardization of spinal pain definitions. Second, most previous studies (e.g., refs. [10, 18–22, 42, 43]) relied on statistical procedures such as multivariate logistic regression, whether or not preceded by univariate logistic regression analysis, that are less well suited to deal with large numbers of correlated factors relative to the sample size [44]. As a consequence, some risk factors may have been obscured or inflated [44]. Furthermore, such analyses do not allow weighing the importance of clusters of variables constituting (putative) risk domains. Third, despite accruing evidence for gender-specificity in spinal pain figures and/or pain sensitivity [8–10, 15, 17, 21–25, 27–32, 35, 40, 42, 45–55] as well as in associative or risk factors for IASP [8, 21, 25–27, 42, 54–58], the potentially profound influence of gender on factors related to the development and maintenance of IASP has not yet been deeply scrutinized. Fourth, previous research has identified biological maturation or pubertal development as a better predictor for IASP than age [59–62]. Still, the maturational or developmental age of non-adult study populations has rarely been considered and, importantly, the vast majority of research overlooks the well-known gender difference in timing of biological maturation with girls being advanced, on average, about 2 years when compared to boys [63]. As a result, there is debate as to the nature of and relationships among the factors that underlie IASP.

The aim of the current study was to investigate the (phenotypic) factors related to spinal pain prevalence in young adolescents before pubertal peak growth using a comprehensive multivariable approach that assessed the contribution of factors from multiple domains.

Materials and methods

A cross-sectional population-based study was conducted from September 2008 to February 2009 in Flanders, Belgium. 64 schools were selected to represent educational networks and levels within Flemish mainstream education. From these schools, girls in year 5 of primary education (age: 10.6 ± 0.47 years) and boys in year 1 of secondary education (age: 12.6 ± 0.54 years) [64] were eligible to participate. These gender-specific age groups were chosen as the mean age of peak linear growth is known to range from 11.6 to 12.1 years in girls and from 13.8 to 14.1 years in boys [63]. The study was restricted to children without neurological conditions, rheumatic disorders, metabolic or endocrine diseases, major congenital anomalies, skeletal disorders, connective tissue disorders, previous spinal fracture or previous spinal surgery. Parental/guardian as well as child consent, was obtained before enrolment. Ethical approval was granted by the ethics committee of the Ghent University Hospital.

In the class room or at the local pupil guidance center, with the investigator present, children were asked to complete a questionnaire on spinal pain and its potential associated factors. Presumed associated factors included physical, sociodemographic and lifestyle characteristics, psychosocial factors, and measures of comorbid pain conditions. Physical measurements took place between 3 and 5 days after questionnaire assessment. Sociodemographic data with regard to parental education and employment were collected through a parental questionnaire.

Outcome measures: spinal pain

The 1-month period prevalence of LBP, neck pain (NP) and thoracic spine pain (TSP) was determined by self-complete questions including a preshaded manikin [58, 64, 65]. The questions relevant to this study included the following: “Has your low back/neck/upper back been painful in the last 4 weeks?”. The 3 categories listed were not mutually exclusive.

Spinal pain was defined as follows: a discomfort or pain in the back or neck that is considered to be a local, uncomfortable feeling in the back or neck, with the possibility of radiation to other parts of the body. Problems due to fatigue related to a single exercise are not considered as back or neck problems. The discomfort or pain can be intermittent or constant, gradually developed or with a sudden onset. Spinal pain due to menstruation is not taken into account. The definition as such was not presented to the adolescents, but it was orally “translated” in a language that could be understood by the adolescents. This was done during the instructions before completion. During completion, an examiner blinded to the results of spinal measurements was present to provide assistance if needed.

Associated factors

Collected parameters covered a broad range of measurements from 5 domains. The variables included in this study are listed in Online Resource 1.

Physical factors

The study investigators measured body height and weight using a standardized procedure [64]. Body mass index was calculated as the ratio of weight to square height and was transformed into 3 categories (thin, normal, and overweight or obese) using the cut-off points for age and gender defined by Cole and colleagues [66, 67]. To determine the proportion of trunk length to body length, sitting height was measured [64]. Habitual standing posture in the sagittal plane was quantified as described previously [56, 64]. More specifically, data were collected regarding gross body segment orientations (i.e., trunk lean, body lean, and anteroposition of the head), specific spinopelvic characteristics (i.e., pelvic orientation (pelvic tilt, sacral inclination), spinopelvic extensiveness parameters (number of vertebrae included in the thoracic kyphosis and lumbar lordosis, vertebral level of the thoracic apex, lumbar apex, and intercristal line), magnitude of spinal curves (thoracic kyphosis, lumbar lordosis) and knee alignment. Furthermore, postural subgrouping according to global body alignment (neutral, sway-back, and leaning-forward) was applied using the categorization proposed by Dolphens et al. [58, 68]. In full flexion and extension position, the thoracic and lumbar spine, and trunk and sacral inclination were recorded using a skin-surface electromechanical device, the Spinal Mouse (Idiag; Voletswil, Switzerland). Based on these data combined with the data obtained in upright standing, the ranges of flexion and extension motion were determined for the thoracic and lumbar spine. For spinopelvic range of motion assessment, all motions and subsequent measurements were performed according to the manufacturer's specifications. The presence of a gibbus deformity was evaluated using the forward-bending test. To assess generalized joint laxity, the Beighton score was determined [69]. A participant was classified as hypermobile when a Beighton score of $\geq$4/9 was obtained [69]. Hand dominance was recorded.

Sociodemographic factors

Data on gender, chronological age, and rough indications of biological age (years from age at peak height velocity (PHV), maturity status classification, percentage of adult stature and predicted growth remaining) [64, 70–72] were collected. In girls, information was gathered on whether they had started menstruating. The respondent's level of education (only in boys) and educational network were recorded. The proxy measures of family characteristics were family composition, family size, parental educational attainment, parental employment status, and parental social class as obtained via coding occupational information [International Standard Classification of Occupations (ISCO88) [73]].

Lifestyle factors

For assessing physical activity levels and sedentary behavior, the participants completed a questionnaire based on the Flemish Physical Activity Questionnaire [74]. The pen and paper version of this questionnaire has been shown to be a reliable and reasonably valid instrument in the appropriate age group [75]. Physical activity levels were assessed by combining the amount of active transportation, physical activity at school and physical activity during leisure time. The amount of screen behavior, time spent on homework and time spent reading outside of school hours were recorded to compute a composite index of sedentary behavior. Furthermore, according to the Dutch physical activity guidelines for subjects younger than 18 years, the children were asked whether they achieved the Dutch Norm for Health-enhancing Physical Activity (i.e., 1 h or more of at least moderate-intensity physical activity each day) and Fit-norm (i.e., 20 min or more of vigorous-intensity physical activity on at least 3 days each week). Participants who met at least 1 of the 2 previous mentioned norms adhered the so-called "Combi-norm" [74, 76, 77]. Finally, participation in physical activity in leisure time versus not was recorded as a categorical lifestyle marker.

Psychosocial factors

Psychosocial factors were recorded using the Self-Perception Profile for Adolescents [78, 79] with the less cumbersome question format proposed by WichstrØm [80], the Rosenberg Self-Esteem Scale [81, 82] the Short Amsterdam Biographical Questionnaire for Children designed to assess personality traits [83], Positive And Negative Affect Schedule [84, 85], the short version of the Depression Questionnaire for Children [86], the Satisfaction With Life Scale [87, 88], the Subjective Vitality Scale [89], and the Inventory of Parent and Peer Attachment [90, 91]. For detailed information see Online Resource 1.

Comorbid (psycho) somatic complaints

To ascertain the participants' experience of spinal pain, the 1-month period prevalence of pain in each of the 3 spinal regions was asked (LBP, NP, TSP) [58, 64, 65, 68]. For assessing the prevalence of other common somatic symptoms (e.g., headache, abdominal pain, sore throats, etc.), a psychosomatic complaints list was used with 26 items and five response categories: "seldom or never", "almost every month", "almost every week", "more than once a week" and "almost every day". Scores range from 26 to 130, with high scores reflecting more frequent psychosomatic complaints [92].

Statistical analysis

For each of the considered outcomes, a logistic regression model was fitted using bi-level selection methods [93, 94] on all the variables collected in the 5 domains of interest described above. These methods are specifically designed for predicting an outcome measure in the presence of a large number of correlated factors, thereby taking advantage of the grouping structure in the domains of interest to estimate regression coefficients and to select variables by making use of a group-structured penalty. The resulting odds ratios (ORs) and associated 95 % confidence intervals (CIs) were reported. Level of significance was set at $\alpha < 0.05$. The relative importance of each variable was evaluated using variable importance scores (VISs). For each domain, the average VIS was calculated as was the average group ranking. Further insight into the relative importance of the different domains was obtained by contrasting the Nagelkerke R^2 between the final selected model and submodels obtained upon applying bi-level selection methods on subsets of the 5 domains.

See Online Resource 2 for a more detailed description.

All statistical analysis was performed using the libraries grpreg and logistf in RStudio Version 0.97.320 statistical software (RStudio, Inc., 2009–2012).

Any variable with more than 85 missing values (8.0 %) was excluded from the analysis and 354 incomplete cases (29.6 %) were discarded, thus leaving a total of 69 variables collected on 842 participants of whom 385 were girls and 461 boys. Dummy variables were created for categorical variables having more than 2 levels. Logarithmic and square root transformations were used where appropriate. See Online Resource 1 for more detail.

Results

LBP, NP and TSP were present in 102 (12.1 %), 77 (9.1 %) and 43 (5.1 %) of the 842 pre-PHV subjects, respectively.

On the domain level, the set of variables comprising the comorbid pain domain were most important in explaining 1-month period prevalence of spinal pain as can be concluded from this domain's low mean rank and high average importance score (Table 1). Based on the average group ranking, this domain was followed by the physical and psychosocial domains, respectively, in each of the 3 spinal pain sites, whereas the sociodemographic and lifestyle domains were relatively less important.

The ORs, 95 % CIs and p values estimated for the factors that were retained using bi-level selection in the final regression model are shown in Table 2. All variables whose coefficients are not included in Table 2 were removed in the variable selection process.

For LBP, 7 variables had VIS values of 0.80 or greater (Fig. 1; Table 2), four of which reached statistical significance. In particular, the adjusted odds of reporting LBP in the past month was more than 4 times higher in children who reported high levels of psychosomatic complaints. Having a lumbar apex that is located at a higher vertebral level, introverted personality and high levels of negative affect over positive affect were associated with LBP prevalence. Having more posterior tilt of the dorsal surface of the sacrum in habitual standing was significantly associated with a higher odds of LBP, but corresponded to a VIS of 0.71. Three out of the top 7 factors based on VIS did not reach statistical significance, implying marginal evidence that children who had experienced TSP or NP in the preceding month were more likely to report LBP, as were children who attended general as opposed to vocational education.

For NP, four variables had VIS values of 0.80 or greater (Fig. 1; Table 2) of which 3 reached statistical significance: psychosomatic complaints and 1-month period prevalence of TSP from the comorbid pain domain, and the affect-balance score from the psychosocial domain. The presence of high levels of psychosomatic symptoms and the presence of TSP in the last month were associated with a nearly 8 (95 % CI 2.5–23.9) and nearly 5 (95 % CI 2.2–10.8) times higher odds of NP. Having high levels of negative over positive affect significantly increased the odds of NP. In contrast, the 1-month period prevalence of LBP from the comorbid pain domain, a top clinical predictor based on VIS, was only marginally associated with a higher odds of NP. Statistically significant associations were also found for 6 factors with a VIS below 0.80. Higher odds of NP were shown for backward trunk lean in habitual standing and high scores on the depression questionnaire. Though weak, statistically significant associations with an increased odds of NP were also observed for high levels of pelvic retroversion in full extension, high extension motion levels of the thoracic and lumbar spine in standing posture, and attending subsidized publicly run schools compared to subsidized privately run schools.

For TSP, both factors with VIS values of 0.80 or greater (Fig. 1; Table 2) reached statistical significance: the presence of pain in spinal regions adjacent to the thoracic spine

Table 1 Average importance score and average group ranking per domain for low back pain (LBP), neck pain (NP) and thoracic spine pain (TSP) ($N = 842$)

	LBP		NP		TSP	
	Average importance score	Mean rank	Average importance score	Mean rank	Average importance score	Mean rank
Physical domain	0.35	2.57	0.27	2.36	0.08	2.57
Sociodemographic domain	0.44	3.45	0.24	3.50	0.06	3.94
Lifestyle domain	0.49	4.16	0.20	4.61	0.23	3.85
Psychosocial domain	0.55	3.42	0.46	3.42	0.09	3.39
Comorbid pain domain	0.91	1.40	0.93	1.11	0.84	1.25

For each of the spinal pain sites:

- Important domains have higher average importance scores of the set of variables comprising that domain (most important: 1.00; least important: 0.00)

- Domains that are retained in the bootstrapping procedure have low values of the average group ranking (most important: 1.00; least important: 5.00)

(NP, LBP) in the preceding month was associated with a higher odds of reporting TSP. Although not reaching VIS scores of 0.80 or higher, having a high extent of sedentary behavior was significantly associated with an increased probability of reporting TSP, as were not achieving the Fitnorm, showing high levels of physical activity, and having low self-esteem.

Pseudo R^2 values displayed in Table 3 for the variables included in the present study, equaled 20, 33 and 23 % for LBP, NP and TSP prevalence, respectively. We evaluated how much these are affected by the exclusion of certain domains, and found that the comorbid pain domain has the biggest impact on predictive ability. This suggests that if only 1 domain (or factor) could be investigated, future researchers in this area should choose (a variable from) the comorbid pain domain. On the other hand, when a slenderized model should be pursued in terms of number of included domains (i.e., a 4-domain model instead of a 5-domain model), omitting the physical domain would lead to the greatest information loss in LBP and NP, and to limited loss of information in TSP. Comparatively less predictive ability would be lost when omitting the set of variables constituting the comorbid pain domain (LBP and NP) or the psychosocial domain (TSP).

For each of the considered outcomes, the contribution of the sociodemographic and lifestyle domain on predictive ability is small (Table 3).

Discussion

This paper reports the results of the first population-based study among pre-PHV subjects evaluating 69 putative risk factors for spinal pain, with the goal to ascertain which variables and domains were related to the 1-month period prevalence of LBP, NP and TSP in this group of study participants. Greater numbers of psychosomatic complaints and pain in another spinal region were the most important factors associated with elevated spinal pain prevalence. Specific physical characteristics were related to spinal pain at young age, as were adverse psychosocial factors. In contrast, the role of sociodemographic and lifestyle factors was limited. This is the first study to show that physical factors, including several biometric and postural measurements, are crucial for understanding spinal pain at young age and that the impact of physical factors in IASP may have been underestimated in earlier studies.

Out of the extensive list of investigated variables, only a limited number showed a significant association with the 1-month period prevalence of spinal pain. In the more mobile regions of the spine (i.e., the lumbar and cervical areas), one of the strongest associations with pain was to the frequency and number of psychosomatic symptoms reported by the participant. More specifically, it was found that the presence of high levels of psychosomatic symptoms was associated with more than 4 times higher odds of LBP and nearly 8 times higher odds of NP. The increased likelihood of reporting LBP or NP with frequent and high numbers of psychosomatic complaints agrees with previous prospective [8, 9, 13, 46, 53] and cross-sectional [18, 19, 27, 48] studies in adolescent [9, 13, 18, 19, 27, 40, 46, 48, 53] and young adult [8] study populations.

Interestingly, unlike the models for LBP and NP, the co-occurrence of psychosomatic complaints appeared to play only a minor role in 1-month period prevalence of TSP. Instead, strong links were found between TSP and pain in the adjacent areas of the spine (i.e., the odds of TSP was more than 5.5 and 2.6 times higher when NP and LBP,

Table 2 The final model showing the odds of 1-month period prevalence of spinal pain associated with selected phenotypic measures from 5 domains (physical characteristics, sociodemographics, lifestyle factors, psychosocial characteristics, and presence of other pain complaints) ($N = 842$)

	Low back pain Pain: 102/No pain: 740 (12.1 %)			Neck pain Pain: 77/No pain: 765 (9.1 %)			Thoracic spine pain Pain: 43/No pain: 799 (5.1 %)		
	OR (95 % CI)	*p* value	VIS	OR (95 % CI)	*p* value	VIS	OR (95 % CI)	*p* value	VIS
Physical factors									
Height	0.99 (0.93–1.06)	0.81	0.23						
Weight				0.45 (0.13–1.55)	0.21	0.06			
Body mass index									
Thinness vs normal	0.69 (0.34–1.40)	0.30	0.41						
Overweight/obese vs normal	1.25 (0.57–2.77)	0.58	0.34				2.04 (0.95–4.39)	0.07	0.39
Proportion of trunk length to body length	0.89 (0.70–1.13)	0.32	0.52						
Sagittal knee alignment									
Hyperextension vs neutral									
Flexion vs. neutral	0.70 (0.30–1.62)	0.40	0.55						
Global body alignment									
Leaning-forward vs neutral				1.51 (0.87–2.61)	0.14	0.36			
Sway-back vs neutral	1.16 (0.62–2.15)	0.65	0.42						
Trunk lean	1.00 (0.90–1.12)	0.94	0.35	1.16 (1.05–1.27)	**0.003**	0.73			
Body lean	1.06 (0.84–1.34)	0.64	0.38						
Generalized joint laxity	0.71 (0.39–1.30)	0.27	0.58	0.77 (0.39–1.49)	0.43	0.32			
Pelvic tilt	0.99 (0.93–1.06)	0.83	0.37						
Vertebral level of the lumbar apex	0.69 (0.49–0.98)	**0.04**	*0.85*						
Spinal level iliac crest	0.91 (0.66–1.27)	0.59	0.42						
# of vertebrae included in lumbar lordosis				1.26 (0.97–1.63)	0.08	0.44	0.89 (0.59–1.34)	0.57	0.01
Sacral inclination	0.95 (0.90–1.00)	**0.03**	0.71				0.98 (0.93–1.04)	0.45	0.03
Vertebral level of the thoracic apex	0.99 (0.72–1.36)	0.95	0.32						
Thoracic kyphosis	0.99 (0.96–1.01)	0.36	0.19						
Anteroposition of the head	1.00 (0.96–1.04)	0.90	0.37						
Thoracic spine posture in forward bend position	1.03 (0.99–1.06)	0.12	0.42				0.97 (0.95–1.00)	0.09	0.07
Lumbar spine posture in forward bend position	1.01 (0.95–1.07)	0.80	0.20						
Sacral inclination in forward bend position	1.34 (0.46–3.90)	0.59	0.30						
Trunk inclination in forward bend position	0.99 (0.92–1.06)	0.76	0.25						
Sacral inclination in backward bend position				0.97 (0.94–0.99)	**0.008**	0.28			
Trunk inclination in backward bend position	1.01 (0.98–1.03)	0.71	0.30						
Extension mobility of the thoracic spine				0.98 (0.96–1.00)	**0.03**	0.25			
Extension mobility of the lumbar spine	0.99 (0.97–1.02)	0.59	0.32	0.96 (0.93–0.99)	**0.007**	0.29	1.03 (1.00–1.06)	0.05	0.20
Handedness	1.17 (0.66–2.07)	0.60	0.46	1.27 (0.65–2.49)	0.49	0.29			
Sociodemographic factors									
Educational network									
Community education vs subsidized privately run schools	0.66 (0.31–1.39)	0.27	0.58				1.70 (0.72–4.05)	0.23	0.11
Subsidized publicly run schools vs. subsidized privately run schools	1.21 (0.62–2.36)	0.57	0.52	1.92 (1.02–3.62)	**0.04**	0.58			
Chronological age	1.43 (0.95–2.15)	0.09	0.37						
Maturity status classification									
Early vs average maturers	1.83 (0.38–8.72)	0.45	0.48						
Late vs average maturers	1.15 (0.16–8.15)	0.89	0.42						

Table 2 continued

	Low back pain Pain: 102/No pain: 740 (12.1 %)			Neck pain Pain: 77/No pain: 765 (9.1 %)			Thoracic spine pain Pain: 43/No pain: 799 (5.1 %)		
	OR (95 % CI)	*p* value	VIS	OR (95 % CI)	*p* value	VIS	OR (95 % CI)	*p* value	VIS
Years from age at PHV	1.42 (0.14–14.50)	0.77	0.18						
Predicted growth remaining	1.04 (0.79–1.36)	0.79	0.17						
Secondary education level									
Technical vs general	0.75 (0.38–1.47)	0.40	0.55						
Vocational vs general	0.34 (0.10–1.20)	0.09	*0.84*						
Family composition				1.69 (0.97–2.94)	0.07	0.48	0.56 (0.25–1.27)	0.17	0.20
Family size	1.06 (0.92–1.23)	0.42	0.51						
Lifestyle factors									
Physical activity	1.45 (0.90–2.34)	0.13	0.76				2.31 (1.23–4.35)	**0.01**	0.33
Achieving the health-norm	0.64 (0.20–2.08)	0.46	0.60				1.84 (0.47–7.15)	0.38	0.14
Achieving the fit-norm	0.83 (0.51–1.36)	0.47	0.13				0.35 (0.17–0.75)	**0.006**	0.34
Sports or physical activity in leisure time	1.18 (0.51–2.73)	0.70	0.52	1.47 (0.58–3.75)	0.42	0.28			
Sedentary behavior	1.01 (0.64–1.59)	0.96	0.39	1.11 (0.69–1.80)	0.67	0.23	2.21 (1.11–4.38)	**0.02**	0.39
Psychosocial factors									
Scholastic competence	0.99 (0.91–1.08)	0.85	0.49	1.07 (0.97–1.17)	0.17	0.60			
Social acceptance	0.96 (0.87–1.05)	0.33	0.57	1.09 (0.99–1.21)	0.09	0.56			
Athletic competence	1.05 (0.97–1.14)	0.22	0.68	0.98 (0.90–1.06)	0.61	0.39			
Physical appearance	1.00 (0.91–1.09)	0.96	0.40						
Close friendship	1.08 (0.97–1.19)	0.16	0.66	0.91 (0.81–1.01)	0.06	0.50			
Self-esteem	1.00 (0.90–1.12)	0.93	0.35				0.86 (0.77–0.96)	**0.01**	0.23
Attachment to peers	0.99 (0.94–1.04)	0.64	0.40						
Attachment to mother	0.99 (0.95–1.03)	0.67	0.47	1.04 (0.99–1.09)	0.12	0.62			
Attachment to father	1.00 (0.97–1.04)	0.76	0.44	0.98 (0.94–1.02)	0.27	0.43			
Vitality				0.95 (0.90–1.01)	0.10	0.42			
Extraversion	0.90 (0.84–0.96)	**0.002**	*0.93*						
Neuroticism	1.03 (0.99–1.08)	0.19	0.65						
Depression	1.02 (0.97–1.08)	0.35	0.46	1.08 (1.03–1.14)	**0.002**	0.72	0.99 (0.93–1.04)	0.62	0.03
Affect	0.97 (0.94–1.00)	**0.03**	*0.82*	0.94 (0.91–0.98)	**0.002**	*0.81*			
Other pain symptoms									
Psychosomatic complaints	4.38 (1.62–11.86)	**0.004**	*0.99*	7.76 (2.52–23.88)	**0.001**	*0.99*			
Thoracic spine pain in the last month	2.05 (0.93–4.49)	0.07	*0.90*	4.86 (2.20–10.77)	**0.001**	*1.00*	NA	NA	NA
Low back pain in the last month	NA	NA	NA	1.59 (0.84–3.02)	0.15	*0.82*	2.69 (1.28–5.65)	**0.01**	*0.83*
Neck pain in the last month	1.44 (0.74–2.82)	0.28	*0.83*	NA	NA	NA	5.54 (2.61–11.75)	**0.000**	*0.98*

CI confidence interval, *NA* not applicable, *OR* odds ratio, *PHV* peak height velocity, *VIS* variable importance score

Bold *p* values—significant at $\alpha < 0.05$; Italic VISs—VIS values of 0.80 or greater

respectively, was experienced in the preceding month), whereas co-complaints at other sites in the spine were not significantly associated with LBP and NP. One exception to this pattern was the 1-month period prevalence of NP where TSP was a significant factor: the presence of TSP in the last month was associated with nearly 5 times higher odds of NP. The fact that other axial pains were not systematically significant, independent factors associated with LBP and NP was a rather surprising finding considering previous study results [46, 50, 95, 96]. While our data might reflect that the origin and mechanisms behind pain in diverse spinal regions may differ in certain respects, care is warranted when attempting to draw generalized conclusions. Lack of power cannot be rejected as an alternative explanation given that high VISs were obtained for all of the comorbid (psycho) somatic (pain) complaints (Table 2, Fig. 1). The frequent use in the literature of composite variables made up of responses to TSP, NP and/or LBP and of *p* value based variable selection may also add to the difficulties in comparing our results with previous research findings. In fact, replication is required in larger, longer studies and future research should penetrate the mechanisms behind the complex relationships between spinal pain and other (pain) complaints.

The literature is replete with studies examining the relationships between physical factors and spinal pain at young age [9, 13, 19–21, 24–26, 28–30, 54]. While the indexes of physical characteristics strongly vary across studies, the preponderance of evidence showed that at best weak associations exist between physical features and spinal pain. Nevertheless, it is these authors' contention that the role that "physical factors" may play in non-adult spinal pain might have been underestimated by previous studies (see also below). Based on the present data, 2 of the most important physical factors for elevated LBP prevalence were higher lumbar lordotic apex and more retroversed pelvis in customary standing. In this respect, one might draw attention to the fact that an increased proportion of adults with chronic LBP stand with a sagittal lumbopelvic alignment that is similar to the postural pattern described above, when compared to healthy referents [97, 98], yet caution remains warranted in drawing premature conclusions. Regarding the 1-month period prevalence of NP in our pre-PHV cohort, the most important associated factor from the physical domain was backward trunk lean (i.e., a greater angle subtended between the vertical and a line joining C7 to the greater trochanter) in habitual standing. Furthermore, weak effects were seen for a more retroversed pelvis in full trunk extension and for higher extension motion levels of the thoracic and lumbar spine in standing posture, suggesting that movement patterns associated with spinal extension in stance may play a role in NP. With respect to TSP, no statistically significant factors could be disclosed from the physical domain. Though the effects were more modest (VISs $\leq$ 0.80), tendencies towards an increased odds for TSP were found for overweight and obese subjects when compared to normal weight subjects and for adolescents displaying low extension mobility in the lumbar spine. Comparison with existing literature is not easily done, since this is the first study to analyze a wide array of putative risk factors for spinal pain in competition with each other, both within and between domains. On the other hand, the associations found in this study do not lack biological plausibility.

Based upon our results regarding the psychosocial factors, one might argue that aspects of subjective well-being such as affect, personality dispositions, depressed mood and self-esteem may contribute to spinal pain at young age. More specifically, the present study revealed that high levels of negative affect over positive affect were associated with an increased risk of pain in the lumbar and cervical areas. Some evidence was also found for "pain-prone personalities", since an increased likelihood of LBP was observed for more introverted personalities. The results obtained further demonstrated that depressed mood was significantly associated with an increased odds of NP, whereas high self-esteem was accompanied by a decreased odds of TSP, although these effects were weak. The present study results appear to corroborate the multiple findings from previous research highlighting (potentially reciprocal) relationships between poor psychological health and spinal pain in adolescents [9, 15, 17–22, 27, 34, 35, 38, 40, 49, 53, 55, 99] and adults [43, 100–102] albeit a wide variety of "psychosocial measures" and statistical procedures has been used. The exact mechanism whereby spinal pain and psychosocial factors are associated with each other—a matter which is not within the scope of the present study—is currently not understood, yet might be related to neuroendocrine, neurological, biomechanical and/or behavioural pathways [51, 99, 103–109].

Factors from the lifestyle and sociodemographic domains were least important in explaining spinal pain prevalence. Apparently, this lack of strong associations is in accordance with the available literature which generally points towards no evidence of an association between IASP and various lifestyle variables related to physical (in)activity [8, 9, 13, 17–22, 29, 32, 34–36, 38, 41, 49] or sociodemographic factors [22, 29, 38, 49], apart from a few exceptions [10, 24, 40]. Nonetheless, our results indicate that some lifestyle factors might be implicated in childhood TSP: both extremes in activity level and extremes of sedentary behavior were significantly associated with an increased 1-month period prevalence of TSP, whereas achieving 20 min or more of vigorous-intensity physical activity on at least 3 days each week (i.e., the Dutch "Fitnorm") might have a protective effect. Though these associations were weak (Table 2), they might suggest that an inactive spine as well as a spine subjected to high physical demands may entail a disadvantage for the thoracic spine in terms of pain at young age while a certain envelope of vigorous physical activity might imply benefits. Further investigation will be needed to truly understand this relationship, as high-quality research focusing on TSP as a separate entity is scarce. With respect to the 2 most important sociodemographic measures (secondary education level for LBP and educational network for NP), one might argue that none of these variables are likely to contribute directly to the 1-month period pain prevalence. Instead, other variables associated with these sociodemographics that were not depicted in the present model of spinal pain might be related to the variability in pain prevalence. Further exploration is needed in this regard.

On the risk domain level, i.e., when considering the (pre-defined) groups of factors potentially associated with spinal pain, a prominent contribution of comorbid pain

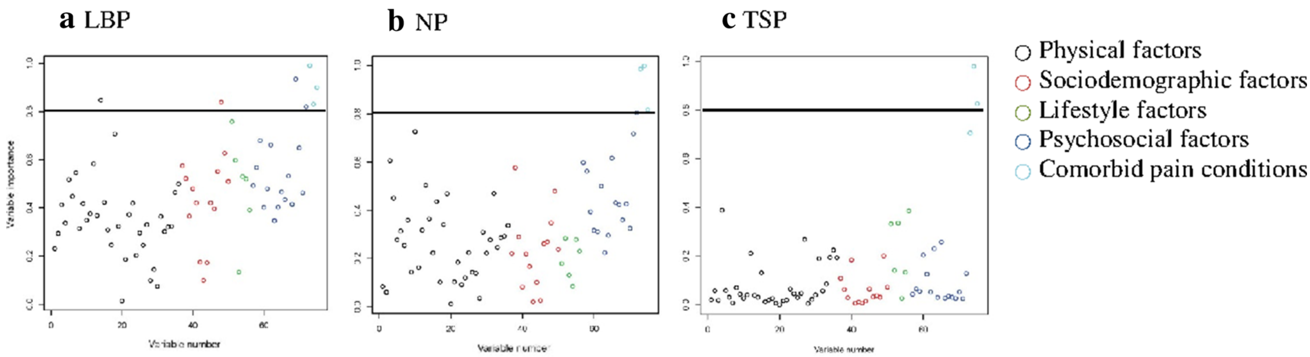

Fig. 1 Variable importance of associated factors (by variable number—see Online Resource 1) for **a** low back pain (LBP), **b** neck pain (NP), and **c** thoracic spine pain (TSP) in 842 subjects before pubertal peak growth

Table 3 The relative importance of the 5 domains in explaining the variance in low back pain (LBP), neck pain (NP) and thoracic spine pain (TSP) obtained by Nagelkerke R^2 ($N = 842$)

	LBP	NP	TSP
Explained variance by all 5 domains of interest (%)	20.2	32.8	22.6
% of reduction in total explained variance upon omitting			
Domain 1: Physical factors	25.2	40.7	13.7
Domain 2: Sociodemographics	5.4	10.1	0.0
Domain 3: Lifestyle characteristics	3.3	3.1	0.0
Domain 4: Psychosocial factors	21.8	20.8	5.1
Domain 5: Other pain symptoms	20.6	24.9	77.2
% of reduction in total explained variance upon omitting all domains except for			
Domain 1: Physical factors	73.4	68.7	61.1
Domain 2: Sociodemographics	83.1	89.1	91.1
Domain 3: Lifestyle characteristics	90.0	100.0	66.5
Domain 4: Psychosocial factors	69.9	75.9	59.7
Domain 5: Other pain symptoms	63.0	61.1	46.3

symptoms to the 1-month period prevalence of spinal pain was demonstrated (see the average importance scores and group ranking per domain in Table 1). Based on the mean rank (Table 1), the comorbid pain domain was followed by the physical domain, for which somewhat smaller—yet still pronounced—effects were found in each of the three spinal pain sites. The psychosocial domain was less important in explaining spinal pain prevalence whereas the lifestyle and sociodemographic domains did not turn out to be important domains, except maybe for TSP where the lifestyle domain reached a relatively high average importance score.

Going deeper into the domain level, two intriguing observations emerged from our results. First, a low mean rank together with a low average VIS was observed for the physical domain, indicating that the physical domain was retained in nearly all bootstrap analyses because of a small number of important factors (having a (relatively) high VIS) besides a large number of surrogate—or unimportant—factors (with low VIS) in that domain. A conscientious selection of predictor variables thus appears to be of overriding importance not to misjudge the role that "physical factors" may play. This puts into perspective previous research concluding that psychosocial factors rather than physical or mechanical factors may be more important in spinal pain occurring in youths [e.g., 9,19,53], a view that is not supported by our results. Second, the domains' change in the order of merit between the 2 "% of reduction in total explained variance" conditions per outcome (Table 3) shows that omitting the physical domain would imply most information loss, at least for LBP and NP, whereas omitting the set of variables comprising the comorbid pain domain would imply less loss of information. This suggests that the physical variables contain unique information about the outcome while the information constituting the comorbid pain domain is captured by variables in the other domains of interest. It is thus conceivable that comorbid pain conditions themselves reflect a range of biopsychosocial processes that have emerged over time to manifest as one or more comorbid pain conditions and that, therefore, other (pain) complaints may serve to predict the risk of spinal pain. A full understanding of such factors and processes, however, requires further analysis and research. Furthermore, some caution is warranted when interpreting Nagelkerke R^2 measures since the number of factors included in a domain may influence these values. Nonetheless, in case only 1 domain (or factor) could be investigated, one might propose that future researchers in this area should choose (a variable from) the comorbid pain domain in terms of predictive ability.

This study purposefully measured a large number of variables from multiple domains, recognizing that spinal pain may be influenced by a multitude of factors. A novel multivariable analysis method was used that is well suited to deal with problems created by the number, density and correlation of data collected in this study cohort. With the aim to investigate a homogenous male and female population in terms of growth phase, research subjects were intentionally recruited according to a maturational benchmark [i.e., (predicted) APHV] and within a narrow age range. Taking a developmental age baseline as opposed to a chronological one as a base for recruitment may be a promising novel approach, indeed, as studies have indicated that IASP is associated with pubertal development rather than with chronological age [59, 60, 62]. Furthermore, we limited the study recall period for IASP to 1 month, since longer time recall periods may result in unreliable information [59, 65, 110]. Recall bias, however, cannot be excluded. The value of this study is in understanding the relative importance and predictive ability of (pre-defined groups of) factors associated with spinal pain in otherwise healthy pre-/early adolescents. It confirms that spinal pain is a complex disorder that is associated with multiple and overlapping factors, consistent with a biopsychosocial model of illness. It further underlines the importance of a broad perspective when studying, preventing and treating IASP and suggests that the specific factors behind pain might vary according to the spinal region. This information can be harnessed to delineate future research and evidence-based management of spinal pain.

Several limitations should be acknowledged. The main limitation of this study was its cross-sectional nature at this phase, which restricts us from drawing any conclusions regarding temporal or causal relationships between IASP and putative risk factors. Prospective follow-up evaluations are needed in this respect. Another concern in this study was that only 842 of the 1196 adolescents who had data on the 1-month prevalence of spinal pain (70.4 %) [64] had no missing data on any of the independent variables. A multiple imputation analysis requires modeling of the distribution of the covariates, which may result in bias if the model is misspecified, and moreover relies on a subtle missing at random assumption which essentially states that missingness may only be selective w.r.t. the observed data. We chose to use a complete case analysis instead, because this avoids modeling assumptions on the covariate distribution, and moreover allows for covariate missingness to be selective in terms of the (observed and unobserved) covariates [111]. Its main disadvantage relative to a multiple imputation analysis, however, may be a loss of information as a result of discarding partially observed records. The resulting complete-case sample was furthermore found to be similar to the complete sample with regard to pain prevalence. We therefore believe this study may be considered representative of the prevalence of spinal pain and the associations found. Because of the many examined correlates of spinal pain and the relatively low pain prevalence, we could not investigate potential differences in associations between genders. Therefore, only the results for both genders combined, albeit adjusted for gender, have been reported. Third, there was a substantial proportion of unexplained variation in all considered outcomes. Indeed, the variables included in the present models accounted only for 21, 33 and 34 % of the variance in LBP, NP, and TSP, respectively. Other factors or domains—not measured here—may thus be involved, such as inherited predisposition, dysfunction in central pain regulation, (spinopelvic) anatomy factors, movement and motor patterns, lifestyle factors other than those related to physical activity/sedentary behavior, environmental circumstances, the cognitive-evaluative component concerning spinal pain, etc. No conclusions can be drawn about potential contributions from factors or domains that were not depicted in this model of spinal pain etiology. Fourth, no questions were included focusing on duration, frequency, and severity of pain periods.

Acknowledgments We are indebted to the pupils, parents and staff of the schools and pupil guidance centers for taking part in this study and to Mr. Roel De Ridder, Ms. Gizem Îrem Güvendik, and Ms. Heidi Bauters for their assistance in data collection.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest. The authors had full control of all primary data. The authors agree to allow the journal to review our data if requested.

References

1. Vos T, Flaxman AD, Naghavi M, Lozano R, Michaud C, Ezzati M et al (2012) Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 380:2163–2196
2. Dagenais S, Caro J, Haldeman S (2008) A systematic review of low back pain cost of illness studies in the United States and internationally. Spine J 8:8–20
3. Maniadakis N, Gray A (2000) The economic burden of back pain in the UK. Pain 84:95–103

4. Borghouts JA, Koes BW, Vondeling H, Bouter LM (1999) Cost-of-illness of neck pain in The Netherlands in 1996. Pain 80:629–636
5. Roth-Isigkeit A, Thyen U, Stoven H, Schwarzenberger J, Schmucker P (2005) Pain among children and adolescents: restrictions in daily living and triggering factors. Pediatrics 115:e152–e162
6. Hestbaek L, Leboeuf-Yde C, Kyvik KO, Manniche C (2006) The course of low back pain from adolescence to adulthood: 8-year follow-up of 9600 twins. Spine 31:468–472
7. Harreby M, Neergaard K, Hesselsøe G, Kjer J (1995) Are radiologic changes in the thoracic and lumbar spine of adolescents risk factors for low back pain in adults? A 25-year prospective cohort study of 640 school children. Spine 20:2298–2302
8. Siivola SM, Levoska S, Latvala K, Hoskio E, Vanharanta H, Keinänen-Kiukaanniemi S (2004) Predictive factors for neck and shoulder pain: a longitudinal study in young adults. Spine 29:1662–1669
9. Jones GT, Watson KD, Silman AJ, Symmons DP, Macfarlane GJ (2003) Predictors of low back pain in British schoolchildren: a population-based prospective cohort study. Pediatrics 111: 822–828
10. Hanvold TN, Veiersted KB, Waersted M (2010) A prospective study of neck, shoulder, and upper back pain among technical school students entering working life. J Adolesc Health 46:488–494
11. Brattberg G (2004) Do pain problems in young school children persist into early adulthood? A 13-year follow-up. Eur J Pain 8:187–199
12. Sjolie AN (2004) Persistence and change in nonspecific low back pain among adolescents: a 3-year prospective study. Spine 29:2452–2457
13. Ståhl M, Kautiainen H, El-Metwally A, Häkkinen A, Ylinen J, Salminen JJ et al (2008) Non-specific neck pain in schoolchildren: prognosis and risk factors for occurrence and persistence. A 4-year follow-up study. Pain 137:316–322
14. Balagué F, Dudler J, Nordin M (2003) Low-back pain in children. Lancet 361:1403–1404
15. Briggs AM, Smith AJ, Straker LM, Bragge P (2009) Thoracic spine pain in the general population: prevalence, incidence and associated factors in children, adolescents and adults. A systematic review. BMC Musculoskelet Disord 10:77
16. Petersen S, Brulin C, Bergström E (2006) Recurrent pain symptoms in young schoolchildren are often multiple. Pain 121:145–150
17. Myrtveit SM, Sivertsen B, Skogen JC, Frostholm L, Stormark KM, Hysing M (2014) Adolescent neck and shoulder pain-the association with depression, physical activity, screen-based activities, and use of health care services. J Adolesc Health 55:366–372
18. Murphy S, Buckle P, Stubbs D (2007) A cross-sectional study of self-reported back and neck pain among English schoolchildren and associated physical and psychological risk factors. Appl Ergon 38:797–804
19. Watson KD, Papageorgiou AC, Jones GT, Taylor S, Symmons DP, Silman AJ et al (2003) Low back pain in schoolchildren: the role of mechanical and psychosocial factors. Arch Dis Child 88:12–17
20. Szpalski M, Gunzburg R, Balagué F, Nordin M, Mélot C (2002) A 2-year prospective longitudinal study on low back pain in primary school children. Eur Spine J 11:459–464
21. O'Sullivan PB, Smith AJ, Beales DJ, Straker LM (2011) Association of biopsychosocial factors with degree of slump in sitting posture and self-report of back pain in adolescents: a cross-sectional study. Phys Ther 91:470–483
22. Balagué F, Skovron ML, Nordin M, Dutoit G, Pol LR, Waldburger M (1995) Low back pain in schoolchildren. A study of familial and psychological factors. Spine 20:1265–1270
23. El-Metwally A, Mikkelsson M, Ståhl M, Macfarlane GJ, Jones GT, Pulkkinen L et al (2008) Genetic and environmental influences on non-specific low back pain in children: a twin study. Eur Spine J 17:502–508
24. Kovacs FM, Gestoso M, Gil del Real MT, López J, Mufraggi N, Méndez JI (2003) Risk factors for non-specific low back pain in schoolchildren and their parents: a population based study. Pain 103:259–268
25. Steele S, Grimmer K, Williams M, Gill T (2001) Vertical anthropometric measures and low back pain in adolescents. Physiother Res Int 6:94–105
26. Poussa MS, Heliövaara MM, Seitsamo JT, Könönen MH, Hurmerinta KA, Nissinen MJ (2005) Anthropometric measurements and growth as predictors of low-back pain: a cohort study of children followed up from the age of 11–22 years. Eur Spine J 14:595–598
27. Rees CS, Smith AJ, O'Sullivan PB, Kendall GE, Straker LM (2011) Back and neck pain are related to mental health problems in adolescence. BMC Public Health 11:382
28. Poussa MS, Heliövaara MM, Seitsamo JT, Könönen MH, Hurmerinta KA, Nissinen MJ (2005) Predictors of neck pain: a cohort study of children followed up from the age of 11–22 years. Eur Spine J 14:1033–1036
29. Salminen JJ (1984) The adolescent back. A field survey of 370 Finnish school children. Acta Paediatr Scand 73(Suppl 315): 1–122
30. Hertzberg A (1985) Prediction of cervical and low-back pain based on routine school health examinations. A nine- to twelve-year follow-up study. Scand J Prim Health Care 3:247–253
31. Shan Z, Deng G, Li J, Li Y, Zhang Y, Zhao Q (2014) How schooling and lifestyle factors effect neck and shoulder pain? A cross-sectional survey of adolescents in China. Spine 39:E276–E283
32. Mogensen AM, Gausel AM, Wedderkopp N, Kjaer P, Leboeuf-Yde C (2007) Is active participation in specific sport activities linked with back pain? Scand J Med Sci Sports 17:680–686
33. Lynch AM, Kashikar-Zuck S, Goldschneider KR, Jones BA (2006) Psychosocial risks for disability in children with chronic back pain. J Pain 7:244–251
34. Feldman ED, Shrier I, Rossignol M, Abenhaim L (2002) Risk factors for the development of neck and upper limb pain in adolescents. Spine 27:523–528
35. Balagué F, Troussier B, Salminen JJ (1999) Non-specific low back pain in children and adolescents: risk factors. Eur Spine J 8:429–438
36. Chen SM, Liu MF, Cook J, Bass S, Lo SK (2009) Sedentary lifestyle as a risk factor for low back pain: a systematic review. Int Arch Occup Environ Health 82:797–806
37. Dunn KM, Hestbaek L, Cassidy JD (2013) Low back pain across the life course. Best Pract Res Clin Rheumatol 27:591–600
38. Leboeuf-Yde C (2004) Back pain—individual and genetic factors. J Electromyogr Kinesiol 14:129–133
39. Hill JJ, Keating JL (2010) Risk factors for the first episode of low back pain in children are infrequently validated across samples and conditions: a systematic review. J Physiother 56:237–244
40. Prins Y, Crous L, Louw QA (2008) A systematic review of posture and psychosocial factors as contributors to upper quadrant musculoskeletal pain in children and adolescents. Physiother Theory Pract 24:221–242
41. Sitthipornvorakul E, Janwantanakul P, Purepong N, Pensri P, van der Beek AJ (2011) The association between physical activity and neck and low back pain: a systematic review. Eur Spine J 20:677–689

42. Pollock CM, Harries RL, Smith AJ, Straker LM, Kendall GE, O'Sullivan PB (2011) Neck/shoulder pain is more strongly related to depressed mood in adolescent girls than in boys. Man Ther 16:246–251
43. Gilkey DP, Keefe TJ, Peel JL, Kassab OM, Kennedy CA (2010) Risk factors associated with back pain: a cross-sectional study of 963 college students. J Manip Physiol Ther 33:88–95
44. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR (1996) A simulation study of the number of events per variable in logistic regression analysis. J Clin Epidemiol 49:1373–1379
45. Ståhl M, Mikkelsson M, Kautiainen H, Häkkinen A, Ylinen J, Salminen JJ (2004) Neck pain in adolescence. A 4-year follow-up of pain-free preadolescents. Pain 110:427–431
46. Mikkelsson M, Salminen JJ, Kautiainen H (1997) Non-specific musculoskeletal pain in preadolescents. Prevalence and 1-year persistence. Pain 73:29–35
47. Hoftun GB, Romundstad PR, Zwart JA, Rygg M (2011) Chronic idiopathic pain in adolescence—high prevalence and disability: the young HUNT Study 2008. Pain 152:2259–2266
48. Vikat A, Rimpelä M, Salminen JJ, Rimpelä A, Savolainen A, Virtanen SM (2000) Neck or shoulder pain and low back pain in Finnish adolescents. Scand J Public Health 28:164–173
49. Diepenmaat AC, van der Wal MF, de Vet HC, Hirasing RA (2006) Neck/shoulder, low back, and arm pain in relation to computer use, physical activity, stress, and depression among Dutch adolescents. Pediatrics 117:412–416
50. Hogg-Johnson S, van der Velde G, Carroll LJ, Holm LW, Cassidy JD, Guzman J et al (2008) The burden and determinants of neck pain in the general population: results of the Bone and Joint Decade 2000–2010 task force on neck pain and its associated disorders. Spine 33:S39–S51
51. Fillingim RB, Hastie BA, Ness TJ, Glover TL, Campbell CM, Staud R (2005) Sex-related psychological predictors of baseline pain perception and analgesic responses to pentazocine. Biol Psychol 69:97–112
52. Kjaer P, Wedderkopp N, Korsholm L, Leboeuf-Yde C (2011) Prevalence and tracking of back pain from childhood to adolescence. BMC Musculoskelet Disord 12:98
53. Brattberg G (1994) The incidence of back pain and headache among Swedish school children. Qual Life Res 3:S27–S31
54. Brink Y, Crous LC, Louw QA, Grimmer-Somers K, Schreve K (2009) The association between postural alignment and psychosocial factors to upper quadrant pain in high school students: a prospective study. Man Ther 14:647–653
55. Niemi SM, Levoska S, Rekola KE, Keinanen-Kiukaanniemi SM (1997) Neck and shoulder symptoms of high school students and associated psychosocial factors. J Adolesc Health 20:238–242
56. Dolphens M, Cagnie B, Vleeming A, Vanderstraeten G, Danneels L (2013) Gender differences in sagittal standing alignment before pubertal peak growth: the importance of subclassification and implications for spinopelvic loading. J Anat 223:629–640
57. Brink Y, Louw QA (2013) A systematic review of the relationship between sitting and upper quadrant musculoskeletal pain in children and adolescents. Man Ther 18:281–288
58. Dolphens M, Cagnie B, Coorevits P, Vleeming A, Vanderstraeten G, Danneels L (2014) Classification system of the sagittal standing alignment in young adolescent girls. Eur Spine J 23:216–225
59. Jeffries LJ, Milanese SF, Grimmer-Somers KA (2007) Epidemiology of adolescent spinal pain: a systematic overview of the research literature. Spine 32:2630–2637
60. LeResche L, Mancl LA, Drangsholt MT, Saunders K, Korff MV (2005) Relationship of pain and symptoms to pubertal development in adolescents. Pain 118:201–209
61. Patton GC, Viner R (2007) Pubertal transitions in health. Lancet 369:1130–1139
62. Wedderkopp N, Andersen LB, Froberg K, Leboeuf-Yde C (2005) Back pain reporting in young girls appears to be puberty-related. BMC Musculoskelet Disord 6:52
63. Malina RM, Bouchard C, Bar-Or O (2004) Growth, maturation, and physical activity. Human Kinetics, Champaign
64. Dolphens M, Cagnie B, Coorevits P, Vanderstraeten G, Cardon G, D'Hooge R et al (2012) Sagittal standing posture and its association with spinal pain: a school-based epidemiological study of 1196 Flemish adolescents before age at peak height velocity. Spine 37:1657–1666
65. Staes F, Stappaerts K, Vertommen H, Everaert D, Coppieters M (1999) Reproducibility of a survey questionnaire for the investigation of low back problems in adolescents. Acta Paediatr 88:1269–1273
66. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH (2000) Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 320:1240–1243
67. Cole TJ, Flegal KM, Nicholls D, Jackson AA (2007) Body mass index cut offs to define thinness in children and adolescents: international survey. BMJ 335:194
68. Dolphens M, Cagnie B, Coorevits P, Vleeming A, Danneels L (2013) Classification system of the normal variation in sagittal standing plane alignment: a study among young adolescent boys. Spine 38:E1003–E1012
69. Beighton PH, Grahame R, Bird HA (1999) Hypermobility of joints. Springer, London
70. Mirwald RL, Baxter-Jones AD, Bailey DA, Beunen GP (2002) An assessment of maturity from anthropometric measurements. Med Sci Sports Exerc 34:689–694
71. Saskatchewan Childhood Growth and Development (SCGD) Research group. Childhood growth utility programs. University of Saskatchewan, College of Kinesiology, Saskatoon, Saskatchewan, Canada. http://kinesiology.usask.ca/growthutility/. Accessed 30 March 2013
72. Sherar LB, Mirwald RL, Baxter-Jones AD, Thomis M (2005) Prediction of adult height using maturity-based cumulative height velocity curves. J Pediatr 147:508–514
73. Ganzeboom HBG, Treiman DJ (1996) Internationally comparable measures of occupational status for the 1988 International Standard Classification of Occupations. Soc Sci Res 25:201–239
74. Philippaerts RM, Matton L, Wijndaele K, Balduck AL, De Bourdeaudhuij I, Lefevre J (2006) Validity of a physical activity computer questionnaire in 12- to 18-year-old boys and girls. Int J Sports Med 27:131–136
75. Verstraete SJM, Cardon GM, Trost SG, De Bourdeaudhuij IMM (2006) Reliability and validity of a questionnaire to measure usual physical activity in children with and without parental assistance. In: Verstraete SJM. The effectiveness of an intervention promoting physical activity in elementary school children. Dissertation, Ghent University
76. Hildebrandt VH, Chorus AMJ, Stubbe JH (2010) Trend report of physical activity and health 2008/2009. TNO Quality of Life, Leiden
77. Biddle S, Sallis J, Cavill N (1998) Young and active? Young people and health-enhancing physical activity: evidence and implications. Health Education Authority, London
78. Harter S (1988) Manual for the Self-Perception Profile for Adolescents. University of Denver, Denver
79. Treffers PDA, Goedhart AW, Veerman JW, Van den Bergh BRH, Ackaert L, de Rycke L (2002) Handleiding Competentiebelevingsschaal voor Adolescenten (CBSA) [Manual Self-Perception Profile for Adolescents (SPPA)]. Swets and Zeitlinger, Lisse
80. Wichstrøm L (1995) Harter's Self-Perception Profile for Adolescents: reliability, validity, and evaluation of the question format. J Pers Assess 65:100–116

81. Rosenberg M (1965) Society and the adolescent self-image. Princeton University Press, Princeton
82. Franck E, De Raedt R, Barbez C, Rosseel Y (2008) Psychometric properties of the Dutch Rosenberg Self-Esteem Scale. Psychol Belg 48:25–35
83. Van Dijl H, Wilde G (1982) Handleiding bij de Amsterdamse Biografische Vragenlijst voor Kinderen, ABVK, en de Korte Amsterdamse Biografische vragenlijst voor Kinderen, KABVK [Manual Amsterdam Biographical Questionnaire for Children and Short Amsterdam Biographical Questionnaire for Children]. Van Rossen, Amsterdam
84. Watson D, Clark LA, Tellegen A (1988) Development and validation of brief measures of positive and negative affect: the PANAS scales. J Pers Soc Psychol 54:1063–1070
85. Bradburn NM (1969) The structure of psychological well-being. Aldine, Chicago
86. De Wit CAM (1987) Depressie Vragenlijst voor Kinderen, DVK en KDVK [Depression Questionnaire for Children, DQC and SDQC]. Acco, Amersfoort/Leuven
87. Diener E, Emmons RA, Larsen RJ, Griffin S (1985) The Satisfaction With Life Scale. J Pers Assess 49:71–75
88. Pavot W, Diener E, Colvin CR, Sandvik E (1991) Further validation of the Satisfaction with Life Scale: evidence for the cross-method convergence of well-being measures. J Pers Assess 57:149–161
89. Ryan RM, Frederick C (1997) On energy, personality, and health: subjective vitality as a dynamic reflection of well-being. J Pers 65:529–565
90. Armsden GC, Greenberg MT (1987) The inventory of parent and peer attachment: individual differences and their relationship to psychological well-being in adolescence. J Youth Adolesc 16:427–454
91. Noom MJ, Dekovic M, Meeus WH (1999) Autonomy, attachment and psychosocial adjustment during adolescence: a double-edged sword? J Adolesc 22:771–783
92. Victoir A (2006) DIGGing into adolescents' health behaviours: From measurement to targeting. Dissertation, Katholieke Universiteit Leuven
93. Huang J, Breheny P, Ma S (2012) A selective review of group selection in high-dimensional models. Stat Sci 27:481–499
94. Firth D (1993) Bias reduction of maximum likelihood estimates. Biometrika 80:27–38
95. Hartvigsen J, Davidsen M, Hestbaek L, Sogaard K, Roos EM (2013) Patterns of musculoskeletal pain in the population: a latent class analysis using a nationally representative interviewer-based survey of 4817 Danes. Eur J Pain 17:452–460
96. Beales DJ, Smith AJ, O'Sullivan PB, Straker LM (2012) Low back pain and comorbidity clusters at 17 years of age: a cross-sectional examination of health-related quality of life and specific low back pain impacts. J Adolesc Health 50:509–516
97. Chaléat-Valayer E, Mac-Thiong JM, Paquet J, Berthonnaud E, Siani F, Roussouly P (2011) Sagittal spino-pelvic alignment in chronic low back pain. Eur Spine J 20:634–640
98. Jackson RP, McManus AC (1994) Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. Spine 19:1611–1618
99. Egger HL, Costello EJ, Erkanli A, Angold A (1999) Somatic complaints and psychopathology in children and adolescents: stomach aches, musculoskeletal pains, and headaches. J Am Acad Child Adolesc Psychiatry 38:852–860
100. Linton SJ (2000) A review of psychological risk factors in back and neck pain. Spine 25:1148–1156
101. Pincus T, McCracken LM (2013) Psychological factors and treatment opportunities in low back pain. Best Pract Res Clin Rheumatol 27:625–635
102. Power C, Frank J, Hertzman C, Schierhout G, Li L (2001) Predictors of low back pain onset in a prospective British study. Am J Public Health 91:1671–1678
103. Marras WS, Davis KG, Heaney CA, Maronitis AB, Allread WG (2000) The influence of psychosocial stress, gender, and personality on mechanical loading of the lumbar spine. Spine 25:3045–3054
104. Hanna T (1988) Somatics: Reawakening the mind's control of movement, flexibility, and health. Addison-Wesley Publishing Company, Rochester
105. Trivedi MH (2004) The link between depression and physical symptoms. Prim Care Companion J Clin Psychiatry 6:S12–S16
106. Von Korff M, Simon G (1996) The relationship between pain and depression. Br J Psychiatry 168:101–108
107. Lu F, Huo Y, Li M, Chen H, Liu F, Wang Y et al (2014) Relationship between personality and gray matter volume in healthy young adults: a voxel-based morphometric study. PLoS One 9:e88763
108. Gatchel RJ, Peng YB, Peters ML, Fuchs PN, Turk DC (2007) The biopsychosocial approach to chronic pain: scientific advances and future directions. Psychol Bull 133:581–624
109. Bair MJ, Robinson RL, Katon W, Kroenke K (2003) Depression and pain comorbidity: a literature review. Arch Intern Med 163:2433–2445
110. Staes F, Stappaerts K, Lesaffre E, Vertommen H (2003) Low back pain in Flemish adolescents and the role of perceived social support and effect on the perception of back pain. Acta Paediatr 92:444–451
111. Bartlett JW, Carpenter JR, Tilling K, Vansteelandt S (2014) Improving upon the efficiency of complete case analysis when covariates are MNAR. Biostatistics 15:719–730