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Original Contribution

Associations of Body Mass Index and Body Height With Low Back Pain in 829,791 Adolescents

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Body mass index (BMI) (calculated as weight (kg)/height $(m)^2$) and height are linked to the pathogenesis of low back pain, but evidence-based confirmation is lacking. We examined the prevalence of low back pain in adolescents and its association with BMI and height. Disability clauses (official military limitations related to a person's health status) indicating low back pain severity were divided according to symptoms of low back pain alone and symptoms of low back pain with objective corroborating findings. All 829,791 males and females undergoing mandatory premilitary recruitment examinations since 1998 were included. Logistic regression models assessed the relationships of BMI and height with low back pain. Prevalence of low back pain was 0.2% for both males and females with objective findings and 5.2% for males and 2.7% for females without objective findings. Higher BMI was significantly associated with low back pain in males (for overweight, odds ratio = 1.097, $P < 0.001$; for obese, odds ratio = 1.163, $P < 0.001$) and in females (for overweight, odds ratio = 1.174, $P < 0.001$; for obese, odds ratio = 1.211, $P < 0.001$). Height was associated with increased risk of low back pain in both genders. Odds ratios for low back pain in the tallest group compared with the shortest group were 1.438 ($P < 0.001$) for males and 1.224 ($P < 0.001$) for females. Low back pain with or without objective findings was associated with overweight and obesity as well as with height.

adolescents; body mass index; height; low back pain; obesity; weight

Abbreviation: BMI, body mass index.

Low back pain is one of the most common medical diagnoses in children and adolescents as well as in adults. The actual prevalence of low back pain for children, adolescents, and young adults is still a controversial issue (1). The diagnosis of low back pain relies mainly on the patient's reported symptoms, because the results of physical examinations and imaging studies are often normal. The etiology of low back pain often remains unknown (2, 3). Body mass index (BMI) (measured as weight (kg)/height $(m)^2$) and body height have been suggested as contributing to the pathogenesis of low back pain, but evidence-based confirmation of their possible roles is lacking. Increased mechanical demands resulting from obesity have also been suspected of causing low back pain through excessive load bearing (4–10), and it has also been suggested that metabolic factors associated with obesity may be detrimental to the low back (4). Thus, some authors consider obesity as being a possible, but not dominant, contributing factor to low back pain (11), whereas others find it to be a risk factor for low back pain (12, 13). It has also been postulated that obesity may be a marker or a confounder for other factors that are the true causes of low back pain (4, 6, 7).

With obesity becoming a worldwide problem over recent years, its possible connection to the development of low back pain is becoming increasingly important, with some considering that it could explain the concomitantly growing prevalence of low back pain in young adults (14). Although there is some evidence that children and adolescents with low back pain may be heavier, there is little evidence to suggest that height, growth, weight, or BMI is actually associated with the onset of low back pain symptoms (1).

In this study, we examined the prevalence of low back pain in a large cohort of adolescents and looked into the possible associations of BMI and height with low back pain in this group.

MATERIALS AND METHODS

Source of data

At the age of 17 years, most male and female Israelis are required by law to report to the military recruiting center to undergo a rigorous medical evaluation for the purpose of medical classification. The evaluation includes a medical questionnaire filled in by the candidate and a medical report signed by his or her primary care physician. Height and weight are measured by a trained medical technician. The candidates then undergo complete histories and physical examinations by physicians on the medical board and are referred to specialists or for auxiliary tests if needed.

After completing the medical evaluation, each subject is assigned a global medical profile as well as numerical codes that represent the subject's medical status and diagnoses. These codes are defined according to the Israeli Regulations of Medical Fitness Determination, and they represent specific medical conditions.

The subject's height and weight measurements, medical profiles, and numerical code(s) for an existing disability are stored in a central computerized database. All of the data in our study were extracted from this database with approval of the Israel Defense Forces Medical Corps institutional review board and with strict observation of patient anonymity.

Study population

The study population included 829,791 adolescents who were evaluated by the regional recruitment centers between 1998 and 2010 and whose height and weight measurements were on file.

Definitions for group assignment

BMI groups were classified according to the US Centers for Disease Control and Prevention's age- and sex-matched percentile grading: underweight (<5%), normal weight (5%–<85%), overweight (85%–<95%), and obese (≥95%). The study population was further divided into 5 groups according to height quintiles separately for males and females. All subjects diagnosed as having low back pain were classified into 1 of 2 severity groups. Group A had no corroborative objective findings (e.g., dropfoot, weakness, urinary incontinence) in the physical examination or on imaging studies (i.e., computerized tomography, magnetic resonance imaging, myelography). Group B did have objective findings that correlated with the patient's diagnosis (e.g., herniated disk, spinal stenosis).

Data analysis

The associations of BMI and height with low back pain were assessed by logistic regression analysis that applied the following models: binary models when low back pain was considered as a dichotomous variable and multinomial models with no low back pain as the base category for comparison when low back pain was classified into groups A and B. BMI and body height were considered as ordinal variables according to the aforementioned groups and as continuous variables. Results from logistic regression analyses were presented as odds ratios, 95% confidence intervals, and *P* values.

Linear regression models were performed to examine trends in obesity and overweight during the study period and to examine the trend in low back pain prevalence. We found a significant trend in obesity and overweight prevalence but not in low back pain prevalence (data not shown).

A multivariable analysis including various sociodemographic factors such as socioeconomic status, country of origin, immigration status, and intelligence quotient was also performed. The results were similar to those presented in this study, and we did not include them here.

All statistical analyses were performed by using SPSS, version 19.0, software (SPSS, Inc., Chicago, Illinois).

RESULTS

This study included 470,125 adolescent males and 359,666 adolescent females. Characteristics of the study population are presented in Tables 1 and 2. The mean BMI was 22.04 (standard deviation (SD), 3.8) for males and 21.8 (SD, 3.7) for females, and the mean height was 174.1 (SD, 6.8) cm for males and 162.1 (SD, 6.25) cm for females. Of the total population of 829,791 participants, 25,416 (5.4%) males and 10,442 (2.9%) females had low back pain. For the males, the prevalence of low back pain was 5.2% for group A and 0.2% for group B. For the females, the prevalence of low back pain was 2.7% for group A and 0.2% for group B.

Association between low back pain and BMI

The prevalence of low back pain was lowest for the underweight adolescents in group A (4.8% of males and 2.6% of females) as well as for those in group B (0.1% of males and 0.2% of females). Higher BMI was associated with low back pain (Tables 3 and 4). There was a dose-response curve between BMI and the odds ratio for low back pain among both males and females. An association between BMI and low back pain was also found when low back pain with and without objective findings on imaging studies or physical examination was analyzed separately (Tables 3 and 4). The highest odds ratios were measured for obese females in group B (odds ratio = 1.492, 95% confidence interval: 1.109, 2.009; $P = 0.008$).

Association between low back pain and height

Height was also positively associated with the prevalence of low back pain in both males and females. The odds ratio for low back pain in the highest quintile of height was 1.438 (95% confidence interval: 1.380, 1.499; $P < 0.001$) for males and 1.224 (95% confidence interval: 1.154, 1.300; $P < 0.001$) for females compared with the lowest quintile. There were also linear trends in the odds ratios for the height quintiles in both males and females (Tables 3 and 4). The same trends emerged when the low back pain population

Table 1. Body Mass Index and Height Categories and the Prevalence of Low Back Pain by Severity in Adolescent Males, Israel, 1998–2010

	Total No.	No Low Back Pain		Low Back Pain		Low Back Pain (Less Severe)[a]		Low Back Pain (More Severe)[b]	
		No.	%	No.	%	No.	%	No.	%
Body mass index[c] category[d]									
Underweight	31,301	28,211	6.73	1,545	6.08	1,505	6.18	40	3.75
Normal weight	357,341	319,285	76.15	19,028	74.87	18,229	74.86	799	74.95
Overweight	48,301	42,689	10.18	2,806	11.04	2,662	10.93	144	13.51
Obese	33,187	29,113	6.94	2,037	8.01	1,954	8.02	83	7.79
Total	470,125	419,293	100	25,416	100	24,350	100	1,066	100
Height category									
Quintile 1 (130–168 cm)	96,034	91,558	20.59	4,476	17.61	4,329	17.78	147	13.79
Quintile 2 (169–172 cm)	97,648	92,672	20.84	4,976	19.58	4,802	19.72	174	16.32
Quintile 3 (173–176 cm)	109,424	103,592	23.29	5,832	22.95	5,606	23.02	226	21.20
Quintile 4 (177–180 cm)	89,367	84,337	18.96	5,030	19.79	4,774	19.61	256	24.02
Quintile 5 (181–210 cm)	77,652	72,550	16.31	5,102	20.07	4,839	19.87	263	24.67
Total	470,125	444,709	100.00	25,416	100	24,350	100	1,066	100

[a] Low back pain without clinical or imaging corroboration.
[b] Low back pain with clinical or imaging corroboration.
[c] Body mass index is weight (kg)/height (m)^2.
[d] Body mass index groups were classified according to the age- and sex-matched percentile grading of the US Centers for Disease Control and Prevention (Atlanta, Georgia): <5%, underweight; 5%–<85%, normal weight; 85%–<95%, overweight; ≥95%, obese.

was divided into groups A and B (Tables 3 and 4). The odds ratios for low back pain were positively associated with height and were even higher in group B compared with group A in all height quintiles. That is, the likelihood of experiencing low back pain with objective findings was higher among tall participants of both genders.

Table 2. Body Mass Index and Height Categories and the Prevalence of Low Back Pain by Severity in Adolescent Females, Israel, 1998–2010

	No Low Back Pain		Low Back Pain		Low Back Pain (Less Severe)[a]		Low Back Pain (More Severe)[b]		
	Total No.	No.	%	No.	%	No.	%	No.	%
Body mass index[c] category[d]									
Underweight	16,137	15,696	4.49	441	4.22	401	4.16	40	4.98
Normal weight	290,558	282,326	80.84	8,232	78.84	7,621	79.07	611	76.00
Overweight	37,903	36,648	10.49	1,255	12.02	1,149	11.92	106	13.18
Obese	15,068	14,554	4.17	514	4.92	467	4.85	47	5.85
Total	359,666	349,224	100	10,442	100	9,638	100	804	100
Height category									
Quintile 1 (130–157 cm)	82,884	80,666	23.10	2,222	21.28	2,077	21.55	145	18.03
Quintile 2 (158–160 cm)	64,410	62,629	17.93	1,781	17.06	1,670	17.33	111	13.81
Quintile 3 (161–164 cm)	87,120	84,642	24.24	2,478	23.73	2,297	23.83	181	22.51
Quintile 4 (165–167 cm)	56,599	54,878	15.71	1,721	16.48	1,580	16.39	141	17.54
Quintile 5 (168–215 cm)	68,653	66,413	19.02	2,240	21.45	2,014	20.90	226	28.11
Total	359,666	349,224	100	10,442	100	9,638	100	804	100

[a] Low back pain without clinical or imaging corroboration.
[b] Low back pain with clinical or imaging corroboration.
[c] Body mass index is weight (kg)/height (m)^2.
[d] Body mass index groups were classified according to the age- and sex-matched percentile grading of the US Centers for Disease Control and Prevention (Atlanta, Georgia): <5%, underweight; 5%–<85%, normal weight; 85%–<95%, overweight; ≥95%, obese.

Table 3. Odds Ratios for Low Back Pain in Relationship to Body Mass Index and Height Category by Severity in Adolescent Males, Israel, 1998–2010

	Low Back Pain			Low Back Pain (Less Severe)[a]			Low Back Pain (More Severe)[b]		
	OR[c]	95% CI	*P* Value	OR[d]	95% CI	*P* Value	OR[d]	95% CI	*P* Value
Body mass index[e] category[f]									
Underweight	0.923	0.875, 0.974	0.003	0.939	0.889, 0.991	0.021	0.569	0.414, 0.782	0.001
Normal weight	1.000	Referent		1.000	Referent		1.000	Referent	
Overweight	1.097	1.053, 1.142	<0.001	1.086	1.041, 1.132	<0.001	1.340	1.122, 1.601	0.001
Obese	1.163	1.109, 1.219	<0.001	1.164	1.110, 1.222	<0.001	1.128	0.900, 1.415	0.296
Body mass index[g]	1.016	1.013, 1.2	<0.001	1.015	1.012, 1.018	<0.001	1.042	1.027, 1.057	<0.001
Height category									
Quintile 1 (130–168 cm)	1.000	Referent		1.000	Referent		1.000	Referent	
Quintile 2 (169–172 cm)	1.098	1.054, 1.145	<0.001	1.12	1.073, 1.17	<0.001	1.155	0.924, 1.446	0.206
Quintile 3 (173–176 cm)	1.152	1.106, 1.199	<0.001	1.189	1.141, 1.24	<0.001	1.318	1.066, 1.63	0.011
Quintile 4 (177–180 cm)	1.220	1.171, 1.271	<0.001	1.267	1.213, 1.324	<0.001	1.837	1.492, 2.261	<0.001
Quintile 5 (181–210 cm)	1.438	1.380, 1.499	<0.001	1.508	1.443, 1.575	<0.001	2.094	1.7, 2.579	<0.001
Height[h]	1.019	1.017,1.022	<0.001	1.018	1.016, 1.020	<0.001	1.045	1.036, 1.054	<0.001

Abbreviations: CI, confidence interval; OR, odds ratio.

[a] Low back pain without clinical or imaging corroboration.

[b] Low back pain with clinical or imaging corroboration.

[c] Odds ratios from binary logistic regression.

[d] Odds ratios from multinomial logistic regression with no low back pain as the base category.

[e] Body mass index is weight (kg)/height (m)^2.

[f] Body mass index groups were classified according to the age- and sex-matched percentile grading of the US Centers for Disease Control and Prevention (Atlanta, Georgia): <5%, underweight; 5%–<85%, normal weight; 85%–<95%, overweight; ≥95%, obese.

[g] Body mass index analyzed as a continuous variable; each increase in 1 body mass index unit was associated with increased odds of low back pain.

[h] Height analyzed as a continuous variable; each increase of 1 cm was associated with increased odds of low back pain.

DISCUSSION

Understanding the complicated nature of low back pain is a daunting challenge. Although low back pain is considered a common and disabling medical condition, its etiology is still not fully understood and its true prevalence throughout life and, in particular, during the first decades of life, is unknown. Possible associations of weight and height with low back pain have intrigued researchers for many years. Although low back pain pathophysiology has been associated with body measures by some experts, there is no consensus on this subject in the literature. Today, with obesity becoming a rapidly growing problem worldwide, its possible association with the development of low back pain has gained even greater importance. It has been postulated that, among other serious medical conditions, obesity could explain the concomitantly growing prevalence of low back pain among young adults (14).

Our analysis provides a detailed summary of the prevalence of low back pain in a large Israeli adolescent population (i.e., boys and girls aged 17 years) and pertinent information about its associations with BMI and height. The most intriguing findings of our study are the dose-dependent curves between low back pain and BMI or height. The odds ratios for low back pain with and without correlating objective findings increased with increasing BMI values (BMI ranging from less than 19 to more than 35) and also with increasing height (ranging from 130 to 215 cm) for both males and females (Tables 1 and 2). Our findings indicate that the prevalence of substantial low back pain might be less common than would be expected on the basis of previously published research (1). Indeed, there is a wide range of reported prevalence in the literature because of the inherent limitations of self-reporting and also because the symptoms rarely result in consultation (1).

The diagnosis of low back pain was 2.14 times as common in the young males as in the young females of our study population, although the prevalence of low back pain with objective findings was equal for both genders and rare (only 0.2% of the population). Specifically, when we refined our results by adding an objective finding to the diagnosis of low back pain, only a small fraction of our study population had objective physical examination or imaging findings that correlated with their symptoms of low back pain. Comparisons of our findings with the prevalence of low back pain in children, adolescents, and young adults as reported in the literature revealed that the reported prevalence of low back pain is slightly higher. Estimates of low back pain prevalence in children and adolescents vary widely among studies depending on the age of study participants and on methodological differences, particularly in terms of how low back pain is defined. Watson et al. (15) reported a prevalence of

Table 4. Odds Ratios for Low Back Pain in Relationship to Body Mass Index and Height Category by Severity in Adolescent Females, Israel, 1998–2010

	Low Back Pain			Low Back Pain (Less Severe)[a]			Low Back Pain (More Severe)[b]		
	OR[c]	95% CI	*P* Value	OR[d]	95% CI	*P* Value	OR[d]	95% CI	*P* Value
Body mass index[e] category[f]									
Underweight	0.964	0.874, 1.062	0.454	0.946	0.855, 1.048	0.289	1.178	0.855, 1.622	0.317
Normal weight	1.000	Referent		1.000	Referent		1.000	Referent	
Overweight	1.174	1.106, 1.248	<0.001	1.161	1.091, 1.237	<0.001	1.336	1.087, 1.643	0.006
Obese	1.211	1.106, 1.326	<0.001	1.189	1.081, 1.307	<0.001	1.492	1.109, 2.009	0.008
Body mass index[g]	1.018	1.013, 1.023	<0.001	1.017	1.012, 1.022	<0.001	1.026	1.009, 1.045	0.003
Height category									
Quintile 1 (130–157 cm)	1.000	Referent		1.000	Referent		1.000	Referent	
Quintile 2 (158–160 cm)	1.032	0.969, 1.100	0.324	1.042	0.975, 1.113	0.229	1	0.778, 1.286	0.998
Quintile 3 (161–164 cm)	1.063	1.003, 1.126	0.040	1.061	0.997, 1.128	0.061	1.178	0.942, 1.473	0.151
Quintile 4 (165–167 cm)	1.138	1.068, 1.214	<0.001	1.116	1.042, 1.194	0.002	1.436	1.134, 1.818	0.003
Quintile 5 (168–215 cm)	1.224	1.154, 1.300	<0.001	1.163	1.09, 1.24	<0.001	1.783	1.437, 2.212	<0.001
Height[h]	1.013	1.01, 1.016	<0.001	1.01	1.007, 1.14	<0.001	1.040	1.028, 1.051	<0.001

Abbreviations: CI, confidence interval; OR, odds ratio.
[a] Low back pain without clinical or imaging corroboration.
[b] Low back pain with clinical or imaging corroboration.
[c] Odds ratios from binary logistic regression.
[d] Odds ratios from multinomial logistic regression with no low back pain as the base category.
[e] Body mass index is weight (kg)/height (m)^2.
[f] Body mass index groups were classified according to the age- and sex-matched percentile grading of the US Centers for Disease Control and Prevention (Atlanta, Georgia): <5%, underweight; 5%–<85%, normal weight; 85%–<95%, overweight; ≥95%, obese.
[g] Body mass index analyzed as a continuous variable; each increase in 1 body mass index unit was associated with increased odds of low back pain.
[h] Height analyzed as a continuous variable; each increase of 1 cm was associated with increased odds of low back pain.

24% in schoolchildren aged 11–14 years in northwest England, whereas Balagué et al. (16) reported a prevalence of 26% in schoolchildren aged 12–17 years in Switzerland. Even studies that recorded pain over a very short time interval (e.g., point prevalence) revealed that as many as 1 child in 20 may be experiencing low back pain at any given time (17–19). Some authors have reported that self-reported low back pain–related disability in childhood is common. Watson et al. (15) conducted a large community study and reported that 94% of symptomatic children aged 11–14 years reported difficulty with 1 or more of the activities listed in a modified version of the Hannover Functional Ability Questionnaire (20). However, when using a similar disability instrument, Salminen et al. (21) reported limitations in only 18% of subjects. Despite being reported as a common and often limiting experience, few children report the severity of low back pain as sufficient to prevent them from attending school or playing sports (18, 22, 23).

A comparison of the above-cited reports with our study reveals both common ground and differences. The first, and what we believe to be the most important, difference is the method used to gather information in our study, which was based on a thorough medical assessment by a physician and not on self-reported information. Our data were also supported by imaging findings and expert consultations for all subjects for whom there were objective findings. This could explain our relatively lower prevalence compared with other studies. On the other hand, only a fraction of the low back pain reported by our study participants had correlating objective findings to explain the pain, which was similar to the data in other reports. We also found more males than females to be experiencing low back pain, but the numbers were equal when we refined their low back pain symptoms with objective findings. This is in contrast to most reports, which found higher rates of low back pain among females (15, 17, 19).

The prevalence of low back pain extrapolated from the data accumulated for this article is based on a large population of adolescents, and low back pain was found to be a fairly common condition among them. Although low back pain can be associated with serious pathology, such a presentation is actually rare and symptoms are usually mild, nonspecific, and self-limiting. When we looked into the association between BMI and low back pain with and without objective findings, our main finding was a direct link between BMI and the odds ratios for low back pain symptoms among both males and females. Specifically, subjects with higher BMIs had higher odds ratios for low back pain.

An association between low back pain symptoms and increased BMI has been considered before (24), and several theories about its pathophysiology through mechanical loading have been suggested (4–10). Theories based on metabolic activity, such as adipose tissue that is metabolically active releasing a multitude of proinflammatory cytokines, and key mediators of metabolism termed the "adipokines" have also been proposed (25). In a systematic literature review, Leboeuf-Yde (26) studied the relationships of body weight and BMI with low back pain symptoms. That author did not find a strong association between low back pain and body weight or BMI. Deere et al. (27) reported that obese adolescents were more likely to report musculoskeletal pain. In a meta-analysis from 2009, Shiri et al. (28) reported that, in a more heterogenic population group, overweight and obesity similarly increased the risk of low back pain. In a review from 1999, Balagué et al. (29) stated that height but not body weight has been found to be significantly associated with low back pain.

Other publications further emphasize the association between BMI and low back pain symptoms and attempt to uncover its pathophysiology. Arana et al. (30) described the association between the magnetic resonance imaging findings (Modic changes and associated features) of patients with low back pain symptoms and above-normal BMI. Webb et al. (31) found BMI to be an important independent predictor of back pain and its severity. Although low back pain is discussed extensively in the literature, few studies have addressed its pathophysiology, and our understanding of the causative relationships between increased BMI or body height and low back pain remains poor.

Our study has several limitations. The main one lies in its being cross-sectional and unable to explain the pathophysiology behind the findings or to definitely establish a temporal relationship between anthropometric variables and low back pain. The second weakness is that we studied a single age group (those 17 years of age). We also report a higher rate of low back pain in males compared with females, which is the opposite finding of most published reports. The higher rates in males were in the subjective group only; the rates in males and females were equal in the objective groups. This difference might be related to the situation at the diagnosis point—a prerecruitment examination. Males might tend to report more in this situation, which might explain the difference of the subjective group but not in the objective group.

To the best of our knowledge, the current work is the largest study of its kind, and its strength lies in our access to a uniquely extensive database in which all the relevant information on a large study population is stored. We believe that the results validate the relationship between BMI and low back pain that has been suggested in the past but has not been established by such large numbers before. One explanation for this finding is that, although an elevated BMI is probably not a strong risk factor for low back pain, it is nevertheless an important one because of its growing prevalence in Western populations. The evidence of an association between low back pain and increased height or weight suggests a possible role for those body measures in the pathophysiology of low back pain. The exact mechanism leading to the relationship between body measures and low back pain symptoms has yet to be elucidated by further studies to connect our epidemiologic findings to the processes leading to the development of low back pain. We also believe that further study of the mechanism behind this relationship would help us understand the impact of weight loss as well as better ways to address taller patients with back pain.

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O. H. and A. F. contributed equally to this study, and each should be considered as first author.

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