Moderating Effect of Body Height on the Association of Body Weight and Disability Caused by Non-Specific Chronic Low Back Pain in Women and Men

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Original Scientific Paper

MODERATING EFFECT OF BODY HEIGHT ON THE ASSOCIATION OF BODY WEIGHT AND DISABILITY CAUSED BY NON SPECIFIC CHRONIC LOW BACK PAIN IN WOMEN AND MEN

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SUMMARY – The aim of the study was testing the hypothesis that body height has a moderating effect on the association of weight and chronic low back pain (LBP) induced disability, and that this moderating effect is different in women and men. We performed a nested cross-sectional analysis using data collected at baseline in a prospective cohort study conducted in 2008-2009 at a special hospital for medical rehabilitation in Croatia. The outcome was the Roland-Morris Disability Questionnaire (RMDQ) score. The independent variable was body weight. The focal moderators were body height and sex. The moderation analysis was adjusted for seven sociodemographic and clinical covariates. We analyzed data on 72 patients with a median (interquartile range) age of 50 (43-55) years, 36 (50%) of whom were women, treated for nonspecific, chronic LBP. The interaction of sex, body weight and height was a significant predictor of the RMDQ score after adjustments for all covariates (increase of R2=0.13; p=0.001; false discovery rate <5%). In both sexes, the correlation between body weight and the RMDQ score was significantly moderated by body height but in opposite ways. In conclusion, the effects of body weight on physical disability are moderated by body height, but this moderation effect differs between women and men.

Key words: *Low back pain; Body weight; Body height; Physical disability; Sex*

Introduction

The extent to which body mass index, body weight, height and sex are associated with disability caused by nonspecific chronic low back pain (LBP) and the incidence of LBP itself remain controversial. Many studies have found a significant association of body mass index (BMI)[1-7], body weight or height[2,8,9] with the incidence, recurrence or severity of LBP, and consequential disability. However, many studies have shown that there is no significant association of BMI[10,11], body weight[8,11,12] or height[10-13] with LBP, and some studies have shown that the association is significant in one but not in both sexes[13,14]. Moreover, the significance and even the direction of the effects have varied substantially by the specific choice of confounders and moderators such as age, educational level, work status, physical activity, smoking status, lipid parameters or

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genetics and early environment, which were controlled as covariates or included in the model[10,13,15], and varied by the specific country or continent population[16]. These inconsistencies can partially be explained by differences in the target populations, choice of and precise definitions used for the target outcome and the selection, measurement, and control of various confounding and moderating factors. Furthermore, even height and weight can be confounding factors and can moderate the associations of the other factor with LBP. Therefore, a number of studies on the association of height with LBP have controlled for the confounding effect of BMI. However, this method may not be appropriate because height and weight do not contribute equally to BMI; their relative contribution may differ between subpopulations, e.g., between women and men, and their effects on other causal or risk and prognostic factors, moderators or confounders may be different. In a study on the association between height and LBP, it is probably better to control the confounding or moderating effect of weight, not that of BMI, and in a study on the association of weight and LBP, it is probably better to control the confounding or moderating effect of height, not that of BMI. Finally, since the etiology of LBP is not clear, observational studies on risk factors are still needed[14]. For these reasons, we decided to test the hypothesis that body height has a moderating effect on the association of body weight and LBP-induced disability in women and men. In other words, the objective was to assess the moderating effect of sex and height or the three-way interaction of sex, body height and body weight with the level of disability in patients with chronic LBP.

Patients and Methods

Study design

We performed this nested cross-sectional analysis using data collected at baseline in a prospective cohort study conducted from 2008 to 2009 in the Varaždinske Toplice Special Rehabilitation Hospital in Croatia[17]. The original study was approved by the Ethics Committees of Sestre milosrdnice University Hospital Center and Varaždinske Toplice Special Rehabilitation Hospital. All participants gave their written informed consent for participation. We protected privacy of the participants by not collecting personal information except for age and sex, by assigning them nontransparent numeric IDs for the purpose of data analysis and by keeping the informed consent forms separate from the data collected. The study and analysis were carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) of 1975. The analysis protocol was not preregistered in any public repository.

Participants

The target population included patients of both sexes, 18 to 65 years of age, with nonspecific, chronic LBP, who were hospitalized in a specialized rehabilitation institution. We defined LBP as pain, muscle tension, or stiffness localized between the low costal margin and the inferior gluteal folds, with or without sciatic nerve involvement, lasting for ≥12 weeks[18]. The non-inclusion criteria were pain irradiating in the legs, radicular pain lasting for more than three months, acute organic neurologic deficits, neoplastic or inflammatory lesions, decompensated cardiovascular disease, acute febrile infections, skin suppuration, unstable epilepsy, decompensated psychosis, incontinence, and pregnancy. We consecutively selected patients in the order of their arrival at the institution.

Sample size required

In the original cohort study, power analysis was not performed before data collection. While developing the protocol for this analysis, we were not aware of any studies analyzing the moderation effects of body height on the association of body weight and chronic LBP. Therefore, we based the power analysis on the theoretical 'medium effect size' with Cohen's $f^2=0.15$ set *a priori*. A sample size of 68 was required to achieve 80% power at $p<0.05$ in detecting a standardized effect of this size or larger.

Outcomes

The outcome was the result of the Roland-Morris Disability Questionnaire (RMDQ)[19]. The RMDQ is a self-administered, paper-and-pencil instrument that is used to assess everyday physical functioning or physical disability perceived to be associated with LBP. We used its original form with 24 binary (yes/no) items. The majority of studies have found it to be unidimensional[20], although some studies have reported different results[21]. The sample size prevented us from properly checking the dimensionality of the RMDQ, and the results for each item were not available. The assumption of unidimensionality was assumed to have been met, and the RMDQ was scored by summing answers to all questions, as in the original study. The score can range from 0 to 24, where a higher score indicates worse physical functioning or higher disability. RMDQ has well documented and acceptable psychometric properties[22].

Possible confounders controlled as covariates

We controlled the effects of only possible confounders that have been well documented in the literature, including age; sex; educational level dichotomized into (a) primary school or (b) secondary school or higher; type of work categorized into (a) hard physical work, (b) moderate physical work, (c) sedentary work or unemployed; family history of low back pain; diagnosis: (a) lumbar syndrome, (b) lumboischialgia, locomotor comorbidities and other chronic diseases. We considered locomotor comorbidities to be either (a) not present or (b) present because we had to group degenerative and inflammatory comorbidities due to the low frequency of the latter type of comorbidities.

Other variables

The other variables that we used only to describe the study population were pain self-assessed on the visual analog scale (VAS), the modified Schober test, left and right lateral flexion, trunk flexion measured by the fingertips-to-floor test, and the physical disability index. The pain VAS that we used is a self-assessment tool with a 100 centimeter long unidimensional, single-item scale the extreme points of which are anchored by descriptions of "no pain at all" at the bottom and "the highest pain imaginable" at the top. The modified Schober test measures the spinal range of motion by a tape that is held over the spine between 5 cm below and 10 cm above the lumbosacral junction. The physical disability index is a physician-assessed 54-item measure of four domains of physical disability, i.e., motion, strength, balance and mobility. We used only the summary score, which was computed as the sum of the scores for individual items. We did not adjust the analysis for any of these variables because all of them may be mediators of the causal path between body weight, body height, sex, pain and LBP-induced disability as measured by the RMDQ.

Statistical analysis

In the primary analysis, we used Hayes's PROCESS macro 'Model 3' ('moderated moderation') with linear regressions of body weight with the RMDQ score conditioned by body height, which was conditioned by sex[23] (Fig. 1). First, we performed unadjusted primary

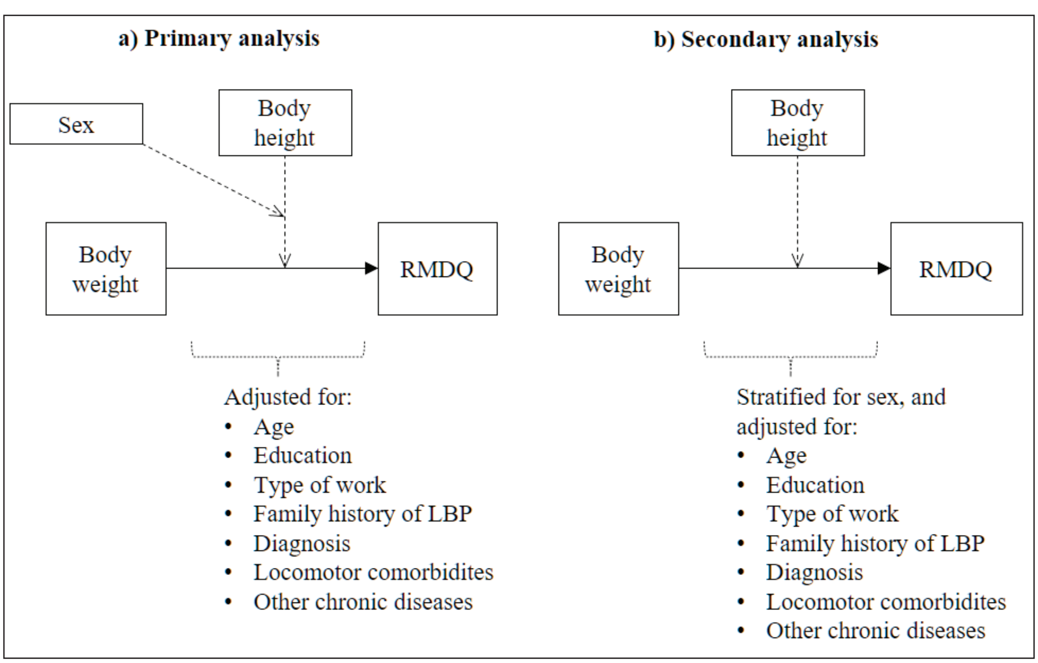

Fig. 1. Conceptual diagrams of primary and secondary analyses.

analysis and then adjusted for all preplanned covariates. We planned in advance to perform a sex-stratified adjusted secondary analysis if the primary adjusted analysis showed that the effect of body weight was significantly moderated by body height in both women and men. In secondary analysis, we analyzed the simple, two-way, moderating effects of body height on the effect of body weight on the RMDQ result using Hayes's PROCESS macro 'Model 1' ('simple moderation') with linear regressions, separately in women and men (Fig. 1). We did this using the Johnson-Neyman technique[23,24]. The Johnson-Neyman technique finds the values of the moderator (body height) at which the conditional effects of the independent variable (body weight) on the outcome (RMDQ score) changed from statistically nonsignificant to statistically significant and therefore defined the 'region of significance' of the effect of the independent variable (body weight) on the outcome (RMDQ score) along the values of the moderator (body height). In more technical terms, the Johnson-Neyman technique finds the values of the moderator, where the ratio of the conditional effect of the independent variable to its standard error is equal to the critical t-value, that is, where it is significant at the chosen level. Before the analysis, we screened for outliers and influential cases and determined the linearity of the correlation between body weight, height and the RMDQ score. We did this by inspecting the scatter plots and comparing the linear fit with the locally weighted scatter plot smoothing lines of the RMDQ results regressed on body weight and height. For the adjusted analysis, we inspected scatter plots of the standardized residuals and body weight and height. We assessed the level of homoscedasticity by inspecting the scatter plots of the standardized residuals against the standardized predicted values and using the Breusch-Pagan/Cook-Weisberg test. We tested the normality of the residuals using the Shapiro-Wilk test. In both analyses, we presented unstandardized regression coefficients with their 95% confidence intervals (CIs). To aid the interpretation and understanding of the results, we presented the expected change in the RMDQ *per* unit change in body weight (unstandardized beta coefficients) at three different values of body height: one standard deviation (SD) below the mean body height and one mean and one SD above the mean body height (Table 3, Fig. 2). Before performing the moderation analysis, we centered body weight and height at the means because a body weight of 0 kg and body height of 0 cm are meaningless. For this reason, their beta coefficients are not meaningful when the interaction is included in the equation. With centering, they became meaningful, but they were not of importance to this analysis. We did not center sex. There were no missing data in the variables we used. Therefore, the sample sizes for the unadjusted and adjusted analyses were the same. We set two-tailed statistical significance level to be $p<0.05$ and calculated all CIs at the 95% level. We categorized BMI only for descriptive purposes, and we analyzed only the original, continuous data. We controlled the false positive rate using the Benjamini-Hochberg procedure with the false discovery rate (FDR) set in advance at FDR <5%. We performed the correction counting all primary and secondary analysis p-values, but we did not include p-values for correlations between body height, weight and BMI because we used them only for descriptive and not inferential purposes. We performed the statistical data analysis using StataCorp 2019 (Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC) and the moderation analysis using the Process macro program written by Andrew F. Hayes[23].

Results

Description of the participants

We analyzed data on 72 patients with a median (IQR) age of 50 (43-55) years, 36 (50%) of whom were women (Table 1). The total range of age was from 27 to 65 years. The participants of different sexes were comparable with regard to the median age, frequency of hard physical work, severity of pain self-assessed using the VAS, the results of the modified Schober test, left and right lateral flexion, trunk flexion, physical disability index result and RMDQ score. The female participants had a lower level of education, a somewhat higher prevalence of moderate physical work, and a lower prevalence of sedentary work or unemployment. They were more often obese (BMI ≥30 kg/m^2) and more often had a normal BMI than did the men, who were more often overweight (BMI 25-29.9 kg/m^2). The women were more often diagnosed with lumbar syndrome and other extraskeletal chronic comorbidities and less often diagnosed with pain irradiating below the knee (lumboischialgia) and loco-

Table 1. Participant characteristics (N=72)

	Whole sample (N=72)		Women (n=36)		Men (n=36)	
Age (years), median (IQR)	50	(43-55)	50	(44-54)	51	(41-56)
Education:						
primary school	20	(28)	15	(42)	5	(14)
secondary or higher	52	(72)	21	(58)	31	(86)
Type of work:						
hard physical work	29	(40)	14	(39)	15	(42)
moderate physical work	25	(35)	14	(39)	11	(31)
sedentary work or unemployed	18	(25)	8	(22)	10	(28)
Body height (cm), mean (SD)	170	(8.0)	166	(6.7)	175	(6.4)
Body weight (kg), mean (SD)	80	(12.4)	75	(12.6)	84	(10.7)
Body mass index (kg/m^2), mean (SD)	27	(3.8)	28	(4.5)	27	(3.1)
Categorized body mass index (kg/m^2):						
normal (<25)	17	(24)	11	(31)	6	(17)
overweight (25-29.9)	37	(51)	13	(36)	24	(67)
obese (≥30)	18	(25)	12	(33)	6	(17)
Family history of low back pain	40	(56)	19	(53)	21	(58)
Diagnosis:						
lumbar syndrome	46	(64)	25	(69)	21	(58)
lumboischialgia	26	(36)	11	(31)	15	(42)
Locomotor comorbidities:						
none	30	(42)	11	(31)	19	(53)
degenerative	37	(51)	22	(61)	15	(42)
inflammatory	5	(7)	3	(8)	2	(6)
Other chronic diseases	35	(49)	20	(56)	15	(42)
Pharmacotherapy:						
NSAID	49	(68)	23	(64)	26	(72)
analgesic and weak opioids	19	(26)	11	(31)	8	(22)
analgesic only	1	(1)	1	(3)	0	(0)
weak opioids only	2	(3)	1	(3)	1	(3)
other	1	(1)	0	(0)	1	(3)
Pain (VAS), mean (SD)	73	(11.5)	75	(10.0)	72	(12.8)
Modified Schober test (mm), mean (SD)	25	(7.1)	24	(6.9)	26	(7.4)
Left lateral flexion (mm), mean (SD)	590	(48.1)	580	(41.4)	600	(52.6)
Right lateral flexion (mm), mean (SD)	586	(45.7)	579	(40.6)	592	(50.1)
Trunk flexion/fingertips-floor distance (mm), mean (SD)	397	(118.0)	401	(132.0)	394	(104.0)
Physical Disability Index, mean (SD)	6.2	(1.37)	6.4	(1.48)	6.1	(1.26)
RMDQ, mean (SD)	18	(4.5)	18	(4.7)	18	(4.3)

Data are presented as number (percentage) of participants if not stated otherwise; IQR = interquartile range; SD = standard deviation; NSAID = nonsteroidal anti-inflammatory drugs; VAS = visual analog scale; RMDQ = Roland Morris Disability Questionnaire motor comorbidities. Body weight and height were significantly correlated in the men (Pearson's r=0.47; r^2=0.22; p=0.004) but not in the women (Pearson's r=0.28; r^2=0.08; p=0.102). BMI was significantly correlated with body weight in both sexes (women: Pearson's r=0.87; r^2=0.75; p<0.001; men: Pearson's r=0.82; r^2=0.67; p<0.001). BMI was not significantly correlated with body height in either sex (women: Pearson's r=-0.23; r^2=0.05; p=0.172; men: Pearson's r=-0.13; r^2=0.02; p=0.458).

Primary analysis

In the unadjusted analysis, the result of the three-way interaction of sex, body height and body weight with the RMDQ score was not significant and it was above the acceptable limit with the FDR (F(1,64)=3.97; p=0.051; FDR >5%; change of R^2=0.05) (Table 2). After adjustments for age, educational level, type of work, family history of LBK, diagnosis, locomotor comorbidities and other chronic diseases, the complex moderating effects of sex and body height on the relation

Table 2. Moderation effects of body height and sex on the effect of body weight on RMDQ score (N=72)

	b	($CI_{95\%}$)	p
Unadjusted analysis			
Body weight	-0.01	(-0.25; 0.22)	0.914
Body height	-0.24	(-0.53; 0.05)	0.109
Sex (women)	0.42	(-2.17; 3.01)	0.746
Interaction of body weight and body height	0.01	(-0.02; 0.04)	0.355
Interaction of body weight and sex (women)	0.05	(-0.22; 0.31)	0.736
Interaction of body height and sex (women)	0.30	(-0.67; 0.68)	0.106
Interaction of body height, body weight and sex (women)	-0.03	(-0.06; 0.00)	0.051
Adjusted analysis†			
Body weight	-0.16	(-0.40; 0.07)	0.164
Body height	-0.32	(-0.60; -0.03)	0.028*
Sex (women)	0.20	(-2.29; 2.69)	0.872
Interaction of body weight and body height	0.03	(0.00; 0.06)	0.022*
Interaction of body weight and sex (women)	0.19	(-0.06; 0.45)	0.139
Interaction of body height and sex (women)	0.43	(0.07; 0.79)	0.020*
Interaction of body height, body weight and sex (women)	-0.06	(-0.09; -0.02)	0.001*
Covariates:			
Age (years)	0.17	(0.02; 0.32)	0.031
Secondary or higher education (compared to primary)	-2.13	(-4.72; 0.47)	0.106
Moderate physical work (compared to hard)	0.87	(-1.59; 3.33)	0.482
Sedentary work or unemployed (compared to hard)	-1.17	(-3.81; 1.47)	0.379
Family history of low back pain	1.04	(-1.05; 3.14)	0.323
Diagnosis: Lumboischialgia (compared to lumbar syndrome)	2.89	(0.89; 4.88)	0.005*
Locomotor comorbidities	0.02	(-2.06; 2.10)	0.986
Other chronic diseases	1.13	(-0.88; 3.15)	0.265

Values of body weight and body height were centered at their means before analysis; in sex, men were reference, and women targeted category; RMDQ = Roland Morris Disability Questionnaire; b = crude, unstandardized regression coefficient; CI = confidence interval; p = statistical significance calculated using linear regression

†Analysis was adjusted for age, education, type of work, family history of low back pain, diagnosis, locomotor comorbidities and other chronic diseases

*False discovery rate <5%

Table 3. Adjusted expected changes of RMDQ score at unit change in body weight (kg) at three different levels of body height (cm) in women and men

	Expected change in RMDQ score at unit change of body weight (kg)	($CI_{95\%}$)	p
Women (n=36)			
Body height			
1 SD below mean (159 cm)	0.29	(0.12; 0.46)	0.002*
Mean (166 cm)	0.06	(0.02; 0.26)	0.021*
1 SD above mean (172 cm)	-0.01	(-0.14; 0.12)	0.934
Men (n=36)			
Body height			
1 SD below mean (169 cm)	-0.17	(-0.48; 0.14)	0.266
Mean (175 cm)	0.02	(-0.16; 0.20)	0.848
1 SD above mean (181 cm)	0.21	(-0.02; 0.44)	0.078

RMDQ = Roland Morris Disability Questionnaire; CI = confidence interval; p = statistical significance; SD = standard deviation
Analyses were adjusted for age, education, type of work, family history of low back pain, diagnosis, locomotor comorbidities and other chronic diseases
*false discovery rate <5%

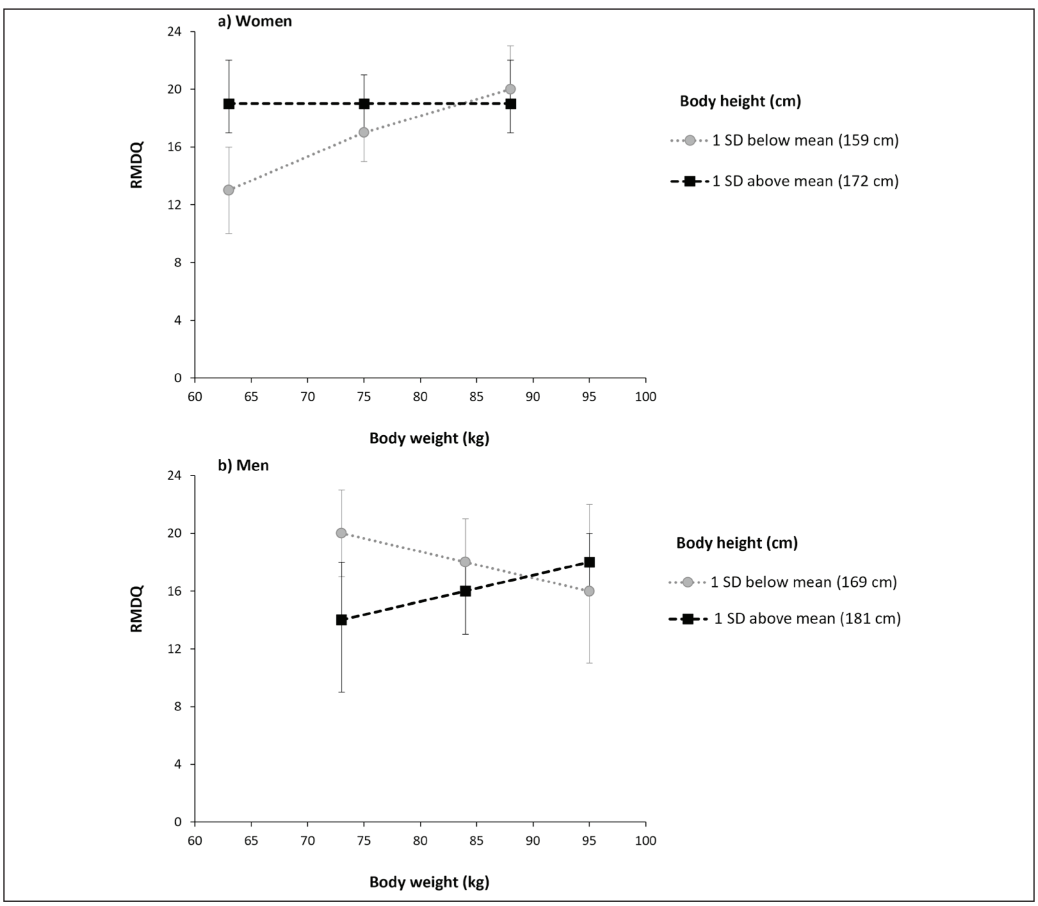

Fig. 2. Adjusted expected changes of Roland Morris Disability Questionnaire score at unit change in body weight (kg) at two different levels of body height (1 standard deviation below and above the mean) in women (n=36) and men (n=36); values of all covariates were set at their sample means.

between body weight and the RMDQ score was significant and of moderate magnitude (F(1,57)=12.29; p=0.001; FDR <5%; change of R^2=0.13) (Table 2). The moderating effect of body height on the correlation of body weight and the RMDQ score was significant in both the women and men, but the directions of the effects were opposite (women: b=-0.02; F(1,57)=10.25; p=0.002; FDR <5%; men: b=0.03; F(1,57)=5.18; p=0.027; FDR <5%).

Secondary analysis

Therefore, in the secondary analysis, we performed a simple moderator analysis of the interaction of body weight and height separately in women and men (Table 3, Fig. 2). Using the Johnson-Neyman technique, in women, we discovered two regions of significant effects of body weight on the RMDQ score. The first region was in the women who were shorter than 167 cm. In our sample, 58% of the women were shorter than 167 cm, and 42% were taller. Within this range of body height, the correlation of body weight with the RMDQ score was positive. At the body height one standard deviation below the mean, a woman who weighed 1 kg more than another randomly selected woman was expected to have a RMDQ score higher by 0.29 points (95% CI 0.12; 0.46; p=0.002; FDR <5%) if their other characteristics were the same (Table 3, Fig. 2). Between two randomly selected women whose body height was at the mean of all women (166 cm), the one who weighed 1 kg more was expected to have a RMDQ score higher by 0.06 (95% CI 0.02; 0.26; p=0.021; FDR <5%) points (Table 3, Fig. 2). If two randomly selected women whose body height was above 167 cm had different body weights, it was not expected that their RMDQ scores would be different. We detected another region of significance at the value of 183 cm of body height, but in our study population, there were only 3% of such women; therefore, this finding is overly unreliable and should not be interpreted. The correlation between body weight and the RMDQ score in the women changed from positive to negative at a body height of 173 cm, but this inverse correlation was not significant or satisfactorily reproducible. In the men, we did not detect any specific significance regions.

Discussion

We found a complex relationship among sex, body weight, body height and everyday physical functioning or physical disability associated with chronic LBP. The effect of body weight on LBP-induced disability is modified by body height, and this moderating effect of body height on the correlation of body weight and disability differs between women and men. Body weight and disability are positively correlated in women of an average height or shorter. The moderating effect of height in men is reversed compared with that in women.

The causal mechanisms or the nature of the observed moderating effects is not clear, just as the nature of the association between height and LBP is not clear[14]. A taller person may have a higher risk of various anatomy-related LBP-induced disability risk factors, and different endocrine and stress-related risk factors may be associated with body height[14], but it is not clear why these effects would be sex-specific. In adolescence, the interaction of rapid growth with different anthropometric parameters is associated with LBP[25]. It is possible that anatomical and mechanical causal foundations for a future association between body height and LBP and LBP-induced disability are created during this period of accelerated growth in adolescence. In other words, it is possible that the cause of the association between height and LBP and the effect of body height on the association of body weight and LBP are anatomical and related to mechanical disorders occurring during accelerated growth or adolescence. Overweight and obesity are associated with structural modifications and degeneration of intervertebral discs in the lumbar spine caused by chronic biomechanical loading on the disc[3,26]. A taller person may have higher discs and therefore be more prone to instability under external loading and a higher risk of failure, but it is possible that the effects of chronic biomechanical loading caused by body weight differ by disc height. Several studies have observed an association between body height and the asymmetry of facet joints[27]. This asymmetry is a proven risk factor for LBP, and again, this asymmetry may modify the effects of chronically high biomechanical loads caused by high body weight. If body fat mass is a better predictor of LBP than BMI[3,28] and if body height is associated with the distribution of body fat mass but not with BMI, body fat mass may be the cause of the observed body height moderating effect. Furthermore, if the android-to-gynoid fat mass ratio is associated with LBP and thus causes disability, this association may partially explain the observed effect of sex[29]. Height can be associated with the type and intensity of leisure activities. It can also moderate the association of weight with activity, and of that activity with LBP and LBP-induced disability. Body height above some threshold, particularly at an older age, may be associated with an increased risk of injuries. Self-efficacy, psychological distress and fear have been shown to be mediators between LBP and disability, but the methodological quality of the study was poor[30]. In women, we detected a second region of significance but an inverse effect of body weight on the RMDQ score at body height ≥183 cm. We could not interpret this result because of its insufficient reliability. Future studies should be performed to test the hypothesis that in very tall women (≥183 cm), the relation between body weight and LBP-induced disability is inverse. As body height and weight in women were only weakly and not significantly correlated, this inverse effect, if it exists in the population, may not be associated with the increased body weight in very tall women. Different causal mechanisms remain to be discovered if this finding is observed in future studies.

Limitations of the study

In 2015, Heuch *et al.* pointed out that LBP was unlikely to cause a decrease in height and therefore that a cross-sectional study had an acceptable level of rigor[14]. The authors meant that there was no risk of reverse causation after at least the age of 30[1]. However, this still does not protect against different confounders, such as degenerative changes or osteoporosis and vertebral fractures[31], which may cause both a decrease in height and LBP or disability, especially after the age of 30. Furthermore, LBP can cause weight gain and disability, and weight gain can cause LBP and disability as well; one in four of the participants in our study and analysis were obese. For these reasons, the main limitation of our study was its cross-sectional design, which prevented us from controlling for many unmeasured yet measurable confounders and from testing causal hypotheses. Even though the outcome was the severity of disability and not the incidence, a prospective cohort study would be a better methodological choice. The external validity of our findings is limited. Since the study was conducted at a single institution, our results should be generalized cautiously to a broader population of patients treated in different settings. The original RMDQ item scores were not available for this analysis, and only the summary score was available. However, even if they were available, the sample size was not large enough to allow us to check the dimensionality of the scale applied to this study population properly or to determine the measurement invariance between women and men. In the original study, consecutively rather than randomly selected patients were included. This may increase the risk of a selection bias. In several countries, the ceiling effect was detected in the RMDQ[32]. Some signs of the ceiling effect in our study population were larger in the women than in the men, although the difference was small. We cannot speculate about the possible consequences of this source of bias, but future studies should use several outcomes to prevent it. Most likely, both the RMDQ score, with a risk of a ceiling effect, and the Oswestry disability index, with the risk of the floor effect, is the best choice[33]. The results of the imaging diagnostic tests were not available to assess the severity of degenerative changes as the most prevalent cause of chronic LBP.

Conclusions

It seems that the relationship among sex, body weight and body height and physical disabilities perceived to be associated with a nonspecific, chronic LBP is complex. The effect of body weight on physical disability is moderated by body height, but this effect is different between women and men. In other words, the effect of body weight and disability caused by LBP is different in people of different body heights. Furthermore, this difference in body weight effect associated with body height is reversed in women and men. Therefore, clinical assessments and research should not approach body weight, body height and sex independently of each other or adjust the analysis of one of these factors for others. Instead, the interaction of the three should always be included. To avoid apparently controversial results, future studies should analyze the interaction effects of body weight with body height, and the analysis should be stratified by sex.

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References

1. Heuch I, Heuch I, Hagen K, Zwart J-A. Body mass index as a risk factor for developing chronic low back pain. Spine (Phila Pa 1976). 2013;38(2):133-9. doi: 10.1097/BRS.0b013e3182647af2
2. Hershkovich O, Friedlander A, Gordon B, *et al*. Associations of body mass index and body height with low back pain in 829,791 adolescents. Am J Epidemiol. 2013;178(4):603-9. doi: 10.1093/aje/kwt019
3. Hussain SM, Urquhart DM, Wang Y, *et al*. Fat mass and fat distribution are associated with low back pain intensity and disability: results from a cohort study. Arthritis Res Ther. 2017;19(1):26. doi: 10.1186/s13075-017-1242-z
4. Shiri R, Lallukka T, Karppinen J, Viikari-Juntura E. Obesity as a risk factor for sciatica: a meta-analysis. Am J Epidemiol. 2014;179(8):929-37. doi: 10.1093/aje/kwu007
5. Zhang T-T, Liu Z, Liu Y-L, Zhao J-J, Liu D-W, Tian Q-B. Obesity as a risk factor for low back pain. Clin Spine Surg A Spine Publ. 2018;31(1):22-7. doi: 10.1097/BSD.0000000000000468
6. Muthuri S, Cooper R, Kuh D, Hardy R. Do the associations of body mass index and waist circumference with back pain change as people age? 32 years of follow-up in a British birth cohort. BMJ Open. 2020;10(12):e039197. doi: 10.1136/bmjopen-2020-039197
7. Shiri R, Karppinen J, Leino-Arjas P, Solovieva S, Viikari-Juntura E. The association between obesity and low back pain: a meta-analysis. Am J Epidemiol. 2010;171(2):135-54. doi: 10.1093/aje/kwp356
8. Ferrari S, Vanti C, Pellizzer M, Dozza L, Monticone M, Pillastrini P. Is there a relationship between self-efficacy, disability, pain and sociodemographic characteristics in chronic low back pain? A multicenter retrospective analysis. Arch Physiother. 2019;9(1):9. doi: 10.1186/s40945-019-0061-8
9. Coeuret-Pellicer M, Descatha A, Leclerc A, Zins M. Are tall people at higher risk of low back pain surgery? A discussion on the results of a multipurpose cohort. Arthritis Care Res (Hoboken). 2010;62(1):125-7. doi: 10.1002/acr.20023
10. Dario AB, Loureiro Ferreira M, Refshauge K, Luque-Suarez A, Ordoñana JR, Ferreira PH. Obesity does not increase the risk of chronic low back pain when genetics are considered. A prospective study of Spanish adult twins. Spine J. 2017;17(2):282-90. doi: 10.1016/j.spinee.2016.10.006
11. Taylor JB, Goode AP, George SZ, Cook CE. Incidence and risk factors for first-time incident low back pain: a systematic review and meta-analysis. Spine J. 2014;14(10):2299-319. doi: 10.1016/j.spinee.2014.01.026
12. Endo T, Abe T, Akai K, *et al*. Height loss but not body composition is related to low back pain in community-dwelling elderlies: Shimane CoHRE study. BMC Musculoskelet Disord. 2019;20(1):207. doi: 10.1186/s12891-019-2580-6
13. Inoue G, Miyagi M, Uchida K, *et al*. The prevalence and characteristics of low back pain among sitting workers in a Japanese manufacturing company. J Orthop Sci. 2015;20(1):23-30. doi: 10.1007/s00776-014-0644-x
14. Heuch I, Heuch I, Hagen K, Zwart J-A. Association between body height and chronic low back pain: a follow-up in the Nord-Trondelag Health Study. BMJ Open. 2015;5(6):e006983-e006983. doi: 10.1136/bmjopen-2014-006983
15. Dario AB, Ferreira ML, Refshauge K, *et al*. Are obesity and body fat distribution associated with low back pain in women? A population-based study of 1128 Spanish twins. Eur Spine J. 2016;25(4):1188-95. doi: 10.1007/s00586-015-4055-2
16. Koyanagi A, Stickley A, Garin N, *et al*. The association between obesity and back pain in nine countries: a cross-sectional study. BMC Public Health. 2015;15(1):123. doi: 10.1186/s12889-015-1362-9
17. Nemčić T, Budišin V, Vrabec-Matković D, Grazio S. Comparison of the effects of land-based and water-based therapeutic exercises on the range of motion and physical disability in patients with chronic low-back pain: single-blinded randomized study. Acta Clin Croat. 2013;52(3):321-7.
18. Koes BW, van Tulder MW, Thomas S. Diagnosis and treatment of low back pain. BMJ. 2006;332(7555):1430-4. doi: 10.1136/bmj.332.7555.1430
19. Roland M, Morris R. A study of the natural history of back pain. Spine (Phila Pa 1976). 1983;8(2):141-4. doi: 10.1097/00007632-198303000-00004
20. Yamato TP, Maher CG, Saragiotto BT, Catley MJ, McAuley JH. The Roland-Morris Disability Questionnaire: one or more dimensions? Eur Spine J. 2017;26(2):301-8. doi: 10.1007/s00586-016-4890-9
21. Magnussen L, Lygren H, Strand L. Reconsidering the Roland-Morris Disability Questionnaire: time for a multidimensional framework? Spine (Phila Pa 1976). 2015;40(4):257-63.
22. Roland M, Fairbank J. The Roland-Morris Disability Questionnaire and the Oswestry Disability Questionnaire. Spine (Phila Pa 1976). 2000;25(24):3115-24. doi: 10.1097/00007632-200012150-00006
23. Hayes AF. Introduction to Mediation, Moderation, and Conditional Process Analysis. A Regression-Based Approach. 2nd edn. The Guilford Press; 2018.
24. Johnson PO, Neyman J. Tests of certain linear hypotheses and their applicaiton to some educational problems. Stat Res Mem. 1936;1:57-93.
25. Poussa MS, Heliövaara MM, Seitsamo JT, Könönen MH, Hurmerinta KA, Nissinen MJ. Anthropometric measurements and growth as predictors of low-back pain: a cohort study of children followed up from the age of 11 to 22 years. Eur Spine J. 2005;14(6):595-8. doi: 10.1007/s00586-004-0872-4
26. Liuke M, Solovieva S, Lamminen A, *et al*. Disc degeneration of the lumbar spine in relation to overweight. Int J Obes. 2005;29(8):903-8. doi: 10.1038/sj.ijo.0802974
27. Karacan I, Aydin T, Sahin Z, *et al*. Facet angles in lumbar disc herniation: their relation to anthropometric features. Spine (Phila Pa 1976). 2004;29(10):1132-6. doi: 10.1097/00007632-200405150-00016
28. Urquhart DM, Berry P, Wluka AE, *et al*. 2011 Young Investigator Award Winner. Spine (Phila Pa 1976). 2011;36(16):1320-5. doi: 10.1097/BRS.0b013e3181f9fb66
29. Brady SRE, Urquhart DM, Hussain SM, *et al*. High baseline fat mass, but not lean tissue mass, is associated with high intensity low back pain and disability in community-based

adults. Arthritis Res Ther. 2019;21(1):165. doi: 10.1186/s13075-019-1953-4

30. Lee H, Hübscher M, Moseley GL, *et al*. How does pain lead to disability? A systematic review and meta-analysis of mediation studies in people with back and neck pain. Pain. 2015;156(6):988-97. doi: 10.1097/j.pain.0000000000000146
31. Nakano M, Nakamura Y, Suzuki T, Kobayashi T, Takahashi J, Shiraki M. Implications of historical height loss for prevalent vertebral fracture, spinal osteoarthritis, and gastroesophageal reflux disease. Sci Rep. 2020;10(1):19036. doi: 10.1038/s41598-020-76074-6
32. Yao M, Zhu S, Tian Z, *et al*. Cross-cultural adaptation of Roland-Morris Disability Questionnaire needs to assess the measurement properties: a systematic review. J Clin Epidemiol. 2018;99:113-22. doi: 10.1016/j.jclinepi.2018.03.011
33. Chiarotto A, Maxwell L, Terwee C, Wells G, Tugwell P, Ostelo R. Roland-Morris Disability Questionnaire and Oswestry Disability Index: which has better measurement properties for measuring physical functioning in nonspecific low back pain? Systematic review and meta-analysis. Phys Ther. 2016;96(10):1620-37. doi: 10.2522/ptj.20150420

Sažetak

MODERATORSKI UČINAK TJELESNE VISINE NA POVEZANOST TJELESNE MASE I ONESPOSOBLJENOSTI UZROKOVANE KRONIČNOM NESPECIFIČNOM KRIŽOBOLJOM U ŽENA I MUŠKARACA

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Cilj je bio testirati hipotezu da tjelesna visina ima moderatorski učinak na povezanost težine i onesposobljenosti uzrokovane kroničnim bolovima u križima (KBK) te da se taj moderatorski učinak razlikuje kod žena i muškaraca. Proveli smo ugniježđenu presječnu analizu koristeći podatke prikupljene na početku prospektivne kohortne studije provedene 2008.-2009. godine u specijalnoj bolnici za medicinsku rehabilitaciju u Hrvatskoj. Ishod je bio rezultat Roland-Morrisova upitnika onesposobljenosti (RMDQ). Neovisna varijabla bila je tjelesna masa. Ciljani moderatori bili su tjelesna visina i spol. Analiza moderacije prilagođena je za sedam sociodemografskih i kliničkih kovarijata. Analizirali smo podatke za 72 bolesnika s medijanom (IQR) dobi 50 (43-55) godina, od kojih su 36 (50%) bile žene, liječenih zbog nespecifične KBK. Interakcija spola, tjelesne mase i visine bila je značajan prediktor rezultata RMDQ nakon prilagodbi za sve kovarijate (porast R^2=0,13; p=0,001; stopa lažnih otkrića <5%). U oba spola je korelacija između tjelesne mase i rezultata RMDQ značajno moderirana tjelesnom visinom, ali u suprotnim smjerovima. U zaključku, učinci tjelesne mase na tjelesnu onesposobljenost moderirani su tjelesnom visinom, ali taj se moderatorski učinak razlikuje kod žena i muškaraca.

Ključne riječi: *Bolovi u križima; Tjelesna težina; Tjelesna visina; Tjelesna onesposobljenost; Spol*