**Associations between fat mass and multi-site pain: a 5-year longitudinal study**

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**Funding sources:** National Health and Medical Research Council of Australia (302204), the Tasmanian Community Fund (D0015018), the Arthritis Foundation of Australia (MRI06161), and the University of Tasmania Grant-Institutional Research Scheme (D0015019).

**Conﬂict of interest:** None.

**Word count:** 2,908

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**Abstract**

**Objective:** Pain is common in older adults and typically involves multiple sites. Obesity is an important risk factor in the pathogenesis of pain and multi-site pain (MSP). This study aimed to examine longitudinal associations between fat mass and MSP, and to explore the potential mechanisms of any associations.

**Methods:** Data from a longitudinal population-based study of older adults (n=1099) was utilized with measurements at baseline and after 2.6 and 5.1 years. At each time-point, presence/absence of pain at the neck, back, hands, shoulders, hips, knees and feet was assessed by questionnaire. Fat mass was assessed by dual energy x-ray absorptiometry and height and weight measured.

**Results:** Participants were of mean age 63 years, mean BMI 27.9 kg/m2 and51% women. Participants reporting greater number of painful sites had greater fat mass, fat mass index (FMI) and BMI both cross-sectionally and longitudinally. In multivariable analyses, fat mass was associated with MSP (OR, 1.06 per SD; CI 1.02, 1.10) and pain at the hands, knees, hips and feet (OR=1.29 to 1.99 per SD, all P<0.05). Results were similar for FMI and BMI, although the latter was also associated with back pain (OR 1.25 per SD; 95% CI 1.02 to 1.54).

**Conclusion:** Fat mass, FMI and BMI are associated with MSP, pain at all lower limb sites and hand pain, independent of socio-demographic, physical activity and psychological factors. This suggests that both loading and systemic inflammatory factors may have an important role in the pathogenesis of fat-related MSP.

**Keywords:** Fat mass, body mass, multi-site pain, mechanism

**Significance and Innovations**

* This is the first longitudinal study to investigate the association between fat mass and multi-site pain.
* Fat mass is associated with pain at multiple sites, pain at all lower limb sites and hand pain.
* These associations are independent of demographic factors, physical activity, psychological health, education level and employment, suggesting that both loading and systemic factors may play an important role in the pathogenesis of multi-site pain.

**Introduction**

Musculoskeletal pain is common affecting people of all ages (particularly in the elderly with prevalence estimates of 10%-50%) and often occurs at multiple sites ([1-6](#_ENREF_1)). A recent study showed that three quarters of those with musculoskeletal pain have pain at multiple sites ([7](#_ENREF_7)). Evidence from previous studies demonstrated that pain at multiple sites is associated with poorer physical and psychological health, worse health-related quality of life, and disability when compared to people with pain at a single-site ([8-12](#_ENREF_8)).

Multi-site pain (MSP), often defined as number of painful sites of two or more, is complex and multi-factorial, and the underlying mechanisms remain unclear. Risk factors for MSP include older age ([2](#_ENREF_2), [13](#_ENREF_13), [14](#_ENREF_14)), female gender ([4](#_ENREF_4), [13](#_ENREF_13), [14](#_ENREF_14)), physical inactivity ([3](#_ENREF_3), [6](#_ENREF_6)), lower educational attainment ([7](#_ENREF_7), [14](#_ENREF_14)), unemployment ([15](#_ENREF_15), [16](#_ENREF_16)), psychological distress ([3](#_ENREF_3), [8](#_ENREF_8), [13](#_ENREF_13)) and genetic factors ([17](#_ENREF_17), [18](#_ENREF_18)), although the evidence is inconsistent and may vary by site. Moreover, body mass index (BMI) or weight can predict the development of pain at different sites, indicating a possible causal relationship between overweight or obesity and pain ([19](#_ENREF_19), [20](#_ENREF_20)). It has long been assumed that the mechanism by which overweight or obesity contributes to pain is due to increased physical loading; however, there is accumulating evidence to suggest a role of metabolic factors as obesity is linked to a low level of systemic chronic inflammation. Recent evidence suggests that this may be related in turn to pain ([21](#_ENREF_21)). Additionally, loading is insufficient to explaining pain occurring at non-weight bearing sites such as the hand ([6](#_ENREF_6), [22](#_ENREF_22)).

BMI is frequently used to measure and classify obesity in the majority of studies investigating the association between obesity and pain; however, it cannot adequately disaggregate the specific components of body composition which have been found to have different roles in the pathogenesis of musculoskeletal diseases ([23](#_ENREF_23)). Fat mass is associated with markers of inflammation in overweight or obese individuals. More recently, studies have reported a specific detrimental effect of fat mass for low back pain ([24](#_ENREF_24)) and foot pain ([25](#_ENREF_25), [26](#_ENREF_26)). Few studies have examined the relationship between fat mass and MSP. Only limited information is available in two cross-sectional studies ([23](#_ENREF_23), [27](#_ENREF_27)) which reported a positive association fat mass with MSP. Such cross-sectional studies cannot determine whether MSP precedes obesity or vice versa. Also, the studies did not adjust for potential confounders including socio-demographic, physical activity and psychological factors. Therefore, the aim of this study was to describe cross-sectional and longitudinal associations between fat mass and MSP in a population-based sample of older adults, and explore the mechanisms underlying this relationship.

**Patients and Methods**

**Participants**

This study utilized data from the Tasmanian Older Adult Cohort Study (TASOAC), a longitudinal, observational population-based study. A total of 1,099 participants aged 50–80 years (mean age 63 years) were randomly selected using computer generated random numbers from the electoral roll in Southern Tasmania (population 229,000), with an equal number of men and women. Baseline measures (Phase 1) were conducted in 2002. The follow-up measures were taken approximately 2.6 years (Phase 2, n=875) and 5.1 years (Phase 3, n=768) later. The study was approved by the Southern Tasmanian Health and Medical Human Research Ethics Committee, and all participants provided written informed consent.

#### Primary outcome measurement: pain at multi-sites

The location of sites at which the participants experienced pain was self-reported at baseline, phase 2 and phase 3. Participants were asked whether they had pain (yes/no) in the following sites: neck, back, hands, shoulders, hips, knees or feet. The total number of painful sites (range 0 to 7) was categorised into four groups (no pain, 1-2, 3-4 and 5-7 painful sites) according to the number of painful site groups with approximately equal numbers of participants reporting one or more painful sites ([28](#_ENREF_28)).

#### Primary exposure measurement: body composition

Body composition was measured at baseline, phase 2 and phase 3 by dual-energy X-ray absorptiometry (DXA) using a Hologic Delphi densitometer (Model: Hologic Discovery QDR; Software: Apex system software 2.4.2; Manufacturer: Hologic, Waltham, MA, USA), which is a quick, non-invasive scan and the gold standard in body composition. A DXA machine works through producing two very low dose x-ray beams, each with different energy levels. Differences in densities of each tissue type lead to different levels of absorption which allow the DXA to calculate their relative masses ([29](#_ENREF_29)). Fat mass index (FMI) was calculated as: FMI=fat mass/height2.

#### Potential covariates measurements

#### Anthropometrics

Weight was measured to the nearest 0.1 kg (with shoes, socks and bulky clothing removed) using a single pair of electronic scales (Seca Delta Model 707) calibrated using a known weight at the beginning of each clinic. Height was measured to the nearest 0.1 cm (with shoes and socks removed) using a stadiometer. Height and weight were measured at each time-point and were then used to calculate BMI (kg/m2).

#### Physical activity

Physical activity was assessed at baseline, phase 2 and phase 3 as steps/day determined by pedometer (Omron HJ –003 & HJ–102, Omron Healthcare, Kyoto, Japan), as previously described ([30](#_ENREF_30)). Briefly, participants were instructed to wear a pedometer for seven consecutive days and to record the number of steps each day and the duration and type of physical activity for any activities in which the pedometer could not be worn (for example, swimming). This was repeated six months later to account for seasonal variation. Mean steps/day was calculated as the average of the days worn at both time points.

#### Emotional problems

Emotional problems were assessed at baseline by asking the question: ‘how much have you been bothered by emotional problems during the past four weeks, such as feeling anxious, depressed or irritable?’. Responses included ‘not at all’, ‘very little’, ‘moderately’, ‘quite a lot’ and ‘extremely’. The presence of emotional problems was defined as a response of ‘very little’ or more.

#### Employment

Employment status at baseline was self-reported and collapsed into two categories: employed (full/part-time) and no paid employment (home duties, student, sole parent/disability pension, retired or unemployed).

***Education level***

Participants reported the highest education level they had completed at baseline, which was collapsed into three categories: low = school only, medium = trade/vocational certificate, high = university level or above.

**Statistical analysis**

Mean ± SD and percentages were respectively used to express the continuous and categorical variables, as noted. ANOVA and ordinal χ2 test (Kruskal-Wallis test) were used to test if there was a trend of mean of each continuous and categorical variable across pain groups. Longitudinal data were analysed using mixed-effects models that take repeated observations on participants into account and use all data on participants. To assess associations of total fat mass, FMI and BMI with MSP, mixed-effect models with random intercepts for participants were used, without and with adjustment for factors, such as age, sex, height, smoking history, physical activity, emotional problems, education level and employment. Additionally, we analysed the associations of total fat mass, FMI and BMI with pain at each site pain after adjusting for the same factors to explore the mechanisms underlying the association. We tested for interaction between each study factor (total fat mass, FMI and BMI) and follow-up time, but no significant interactions were found. To compare odds ratios (ORs), fat mass, FMI and BMI were standardised by dividing by the corresponding standard deviation (SD); therefore, all ORs represent the odds of pain associated with one SD increase in total fat mass, FMI or BMI. All statistical analyses were performed using Stata V.12.1 for windows (StataCorp, College Station, Texas, USA). P values less than 0.05 (two-tailed) were regarded as statistically significant.

**Results**

The participants were on average 63 years old, 51% female and had a mean BMI of 27.9 kg/m2 at baseline. There were 768 participants participating in follow-up over 5.1 years with three examinations contributing 2,742 person-examinations. Table 1 describes the characteristics of participants at each examination. Weight, BMI, fat mass and FMI increased by a small amount over 5.1 years, but physical activity decreased markedly.

The baseline characteristics of participants by number of painful sites are presented in Table 2. A total of 1,086 participants who had complete data on fat mass and pain were included into the analyses. 87% of participants had pain in at least one site, with 28% having pain at one or two sites, 28% having pain at three or four sites, and 31% had pain at five or more sites. Female sex, higher weight, BMI, fat mass and FMI, lower levels of physical activity, having emotional problems, being unemployed and having lower education level were associated with reporting pain at a greater number of painful sites.

Figure 1 shows the association of fat mass and BMI with number of painful sites at each examination. Fat mass and BMI increased with each category of MSP. However, there was no statistically significant increase in fat mass or BMI over 5.1 years within any pain category. Similar results were seen for FMI (data not shown).

The associations of fat mass, FMI and BMI with MSP are shown in Table 3. In univariable analysis, each SD increase in fat mass, FMI, or BMI was associated with increased odds of reporting MSP. The associations were reduced but remained statistically significant after adjusting for age, sex and height, and after further adjusting for smoking history, physical activity, emotional problems, education level and employment.

Table 4 presents the associations of fat mass, FMI and BMI with presence of pain at each site. In univariable and multivariable analysis adjusting for the same confounders as for MSP, greater fat mass was associated with greater odds of pain in lower limbs (knees, hips and feet) and hands. Results were similar with FMI and BMI as the outcome, but BMI was also associated with increased odds of back pain. There were no statistically significant associations between measures of fat mass and pain at the neck or shoulders in multivariable analysis.

**Discussion**

This study shows that fat mass, FMI and BMI are associated with MSP, pain at weight-bearing sites and hand pain. These relationships are independent of demographic factors, physical activity, psychological health, education level and employment, suggesting that fat mass may play an important independent role in the pathogenesis of MSP. This may reflect a role of systemic factors in joint pain as one would not expect to observe significant association of fat mass with hand pain.

The high prevalence of pain at multiple sites is consistent with that reported in previous studies ([3](#_ENREF_3), [7](#_ENREF_7), [13](#_ENREF_13), [23](#_ENREF_23), [31-35](#_ENREF_31)), and confirms that MSP is extremely prevalent in a community-based older population. However, some prior studies have found greater prevalence of MSP than that found in our study. These discrepancies may be attributed to the difference in the characteristics of the population studied, definition of MSP and number of painful sites assessed. Our results also showed that the proportion of people with more than two painful sites did not change much over time with slightly over half at each visit. This suggests that MSP is likely to be relatively stable once established ([2](#_ENREF_2)).

The findings that fat mass, FMI and BMI are associated with increased risk of pain at multiple sites indicates a substantial effect of fat mass or body weight on the pathogenesis of MSP. Our findings not only add further evidence to support the significant role of fat mass in pain, but extend previous cross-sectional studies to longitudinal analyses with a large dataset. Our results are consistent with previous studies in which BMI was used to examine the association between overweight/obesity and MSP. In a recent longitudinal study performed in the general population, Magnusson *et al* ([20](#_ENREF_20)) found that overweight/obesity increased the odds of reporting MSP. Kamaleri *et al* ([8](#_ENREF_8)) found a greater number of painful sites reported in those with a higher BMI. However, the specific components of body composition cannot be distinguished in these studies. Currently, there are only two cross-sectional studies investigating the relationship between body composition and MSP. Brady et al ([23](#_ENREF_23)) reported that fat mass is associated with an increased number of lower body pain sites (low back, knee and foot), and Yoo *et al* ([27](#_ENREF_27)) found fat mass to be positively associated with widespread pain.

The potential mechanisms that may link obesity-related pain are most likely physical loading and metabolic effects ([6](#_ENREF_6)). Our results showed that fat mass, FMI and BMI are associated with pain at all weight-bearing sites. This is consistent with previous studies reporting associations between fat mass and single-site pain ([25](#_ENREF_25), [26](#_ENREF_26), [36](#_ENREF_36)). These suggest a potential involvement of biomechanical mechanisms, as excess loading may result in changes in body mechanics, postures or abnormal gait, thus creating a detrimental biomechanical environment ([37](#_ENREF_37)). However, the finding of a significant association of fat mass, FMI and BMI with hand pain indicates a potential role for metabolic effects in the pathogenesis of pain, since physical loading is not adequate to explaining pain occurring at non-weight bearing sites ([19](#_ENREF_19), [38](#_ENREF_38)). It has been recognized that adipose tissue is serving as an endocrine organ to produce proinflammatory cytokines and adipokines ([39](#_ENREF_39)). An increased level of cytokines and inflammatory markers, such as C-reactive protein (CRP), Interleukins-6 (IL-6), TNF-alpha (TNF-α) and Leptin observed in obese individuals has been reported in prior studies ([40](#_ENREF_40), [41](#_ENREF_41)). Recent evidence suggests that inflammation can lead to a lowering of excitation threshold and enhanced responses to suprathreshold stimuli of peripheral nociceptors (peripheral sensitisation) ([42](#_ENREF_42)), and subsequently developing central nervous system sensitisation with pain hypersensitivity and increased vulnerability to reporting more pain sites ([43](#_ENREF_43)). It is therefore possible that individuals with greater fat mass are more likely to have peripheral or central sensitisation in relation to elevated level of systemic inflammation, thereby leading to a greater number of painful sites.

The current study was unable to detect a significant association between fat mass, FMI and BMI, and neck and shoulder pain, suggesting that neck and shoulder pain are not related to fat mass regardless of the mechanism. Consistent with this, Iizuka et al ([44](#_ENREF_44)) found no association between fat mass and neck and shoulder pain and concludes that neck and shoulder pain may be manifest through muscle dysfunction. This is supported by reported altered muscle activation patterns in patients with neck/shoulder pain with increased activation of upper trapezius and reduced activation of serratus anterior ([45](#_ENREF_45)). BMI, but not other measures of fat mass, was associated with back pain. The reasons for this remain unclear. Overall, the magnitude of the effect per SD increase for fat mass, FMI and BMI were similar for all pain sites, suggesting that DXA derived fat mass is not superior to BMI for accounting for musculoskeletal outcomes.

The current study found that the relationship between fat mass and MSP remained significant after adjusting for age, sex, height, physical activity, education level, employment, and psychological distress, suggesting that the associations with fat mass cannot be fully explained by these factors even if they were themselves associated with pain. Previous studies have demonstrated that body fat ([46](#_ENREF_46)) and pain ([47](#_ENREF_47)) are substantially influenced by underlying genetic factors, so it is possible that genetic factors may underlie these associations. This is supported by a recent meta-analysis ([48](#_ENREF_48)), in which pooling of the results from five twin studies on the relationship between obesity and low back pain showed a positive relationship between BMI or weight and low back pain, but the relationship diminished after adjusting for shared genetic factors, suggesting that genetic factor may be mediating the association.

Limitations of our study include the use of a self-reported questionnaire, which was simple (yes/no) and did not include assessment of frequency, severity, and quality of pain. We, therefore, cannot evaluate whether fat mass is associated with intensity and different types of pain. Additionally, assessments were made on only three occasions over 5.1 years – more frequent observations may allow more information on temporal patterns in fluctuations in pain. Another limitation is that the participants were recruited from one center, which may not be generalisable to other populations as previous studies have indicated that special cultural and socioeconomic conditions may determine individual perceptions affecting the report of pain ([18](#_ENREF_18), [49](#_ENREF_49)). Finally, although fat mass is often considered as a surrogate for systemic inflammation, inflammatory markers were not analysed directly in this study. Accordingly, further investigation into the role of inflammatory markers in the pathogenesis of MSP is warranted.

There are several implications raised from the findings of this study. First, overweight/obese individuals with MSP may benefit from weight loss either via exercise, diet or bariatric surgery. Therefore, the general practitioner should introduce weight management programs involving exercise and diet to overweight/obese individuals and encourage them to change their lifestyles to lose weight, although there is a considerable challenge in the maintenance of weight loss in the long-term. Second, the mechanisms by which overweight/obesity contributes to pain may be not only related to increased physical loading, but also elevated systemic inflammation; thus, facilitating potential therapeutic targets for obesity-related pain. For instance, the administration of drugs with pleiotropic actions (anti-inflammatory and those blocking cholesterol biosynthesis, such as statins) may help to attenuate pain induction in clinical setting; this would need to be tested in a future clinical trial.

To sum up, fat mass, FMI and BMI are associated with MSP, pain at all lower limb sites and hand pain, independent of socio-demographic, physical activity and psychological factors, suggesting that obesity appears to be an important factor in the pathogenesis of fat-related MSP. The potential mechanisms underlying the relationship between fat mass and MSP may be via loading and systemic inflammatory factors.

**Author contributions**

FP participated in the design of the study, analysis and interpretation of the data and manuscript preparation. LL participated in the analysis, and revising manuscript. LB participated in the analysis, interpretation of the data and revising manuscript. FC participated in the design of the study and revising manuscript. TW participated in interpretation of the data and revising manuscript. CHD participated in interpretation of the data and revising manuscript. GJ participated in the design of the study, interpretation of the data and manuscript preparation. All authors read and approved the final manuscript.

**Acknowledgements**

We thank the study participants, who made this study possible, and Catrina Boon and Pip Boon for their role in collecting the data.

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**C:\Feng\OA\Papers\Submitted\5_pain_and_mass\submission\ACR_revise_2\Figure 1.tifFigure 1** Association between fat mass/body mass index and the number of painful sites. Bar graph represents mean value of fat mass/body mass index, and error bars indicate standard deviations. P for trend determined by ANOVA test. (A) Fat mass; (B) Body mass index.

**Table 1 Characteristics of participants at each examination**\*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Characteristics | Baseline  (n=1099) | Phase 2  (n=875) |  | Phase 3  (n=768) | P value |
| Age, years | 63.0±7.5 | 65.3±7.3 |  | 67.1±7.0 | <0.001 |
| Female (%) | 51 | 49 |  | 50 | 0.648 |
| Height (cm) | 167.0±9.0 | 167.0±9.0 |  | 166.6±9.0 | 0.549 |
| Weight (kg) | 77.9±15.0 | 78.1±14.8 |  | 78.1±14.8 | 0.922 |
| Body mass index (kg/m2) | 27.9±4.8 | 28.0±4.8 |  | 28.1±4.8 | 0.594 |
| Fat mass (kg) | 28.3±8.7 | 28.2±9.0 |  | 28.4±8.7 | 0.954 |
| Fat mass index (kg/m2) | 10.3±3.6 | 10.3±3.7 |  | 10.4±3.7 | 0.854 |
| Ever smoking (%)† | 51 | NA |  | NA | NA |
| Physical activity (steps per day) | 8614.9±3354.8 | 7405.2±3358.0 |  | 6828.4±3179.8 | <0.001 |
| Emotional problems (%)† | 64 | NA |  | NA | NA |
| Employed (%)† | 39 | NA |  | NA | NA |
| Education level (%)† |  |  |  |  | NA |
| School only | 56 | NA |  | NA |  |
| Vocation training | 32 | NA |  | NA |  |
| University or higher | 11 | NA |  | NA |  |
| Multi-site joint pain (%) |  |  |  |  | 0.001 |
| No pain | 13 | 19 |  | 17 |  |
| 1-2 sites | 29 | 29 |  | 31 |  |
| 3-4 sites | 28 | 28 |  | 27 |  |
| 5-7 sites | 31 | 24 |  | 26 |  |

\*Values are the Mean±SD except for percentages;

†Variables were measured at baseline.

**Table 2 Descriptive characteristics of participants at baseline, by number of painful joints**\*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Number of painful sites | | | | P value |
|  | 0  (n=137) | 1-2  (n=310) | 3-4  (n=303) | 5-7  (n=336) |
| Age, years | 62.2±7.2 | 63.6±7.7 | 62.4±7.2 | 63.3±7.7 | 0.676 |
| Female (%) | 45 | 48 | 52 | 57 | 0.005 |
| Height (cm) | 167.4±9.0 | 167.6±9.4 | 167.4±8.6 | 165.9±8.8 | 0.028 |
| Weight (kg) | 73.5±12.7 | 77.3±15.6 | 79.2±15.3 | 79.2±14.8 | <0.001 |
| Body mass index (kg/m2) | 26.2±3.9 | 27.4±4.5 | 28.2±4.5 | 28.8±5.3 | <0.001 |
| Fat mass (kg) | 25.0±7.1 | 27.5±8.5 | 28.8±8.1 | 30.0±9.5 | <0.001 |
| Fat mass index (kg/m2) | 9.1±3.0 | 9.9±3.4 | 10.4±3.3 | 11.1±4.1 | <0.001 |
| Ever smoking (%) | 46 | 51 | 49 | 55 | 0.104 |
| Physical activity (steps/ day) | 9495.1±3579.4 | 8759.4±3274.9 | 8560.0±3258.4 | 8078.2±3341.0 | 0.001 |
| Emotional problems (%) | 53 | 56 | 62 | 70 | <0.001 |
| Employed (%) | 50 | 41 | 42 | 31 | <0.001 |
| Education level (%) |  |  |  |  | <0.001 |
| School only | 49 | 55 | 56 | 61 |  |
| Vocational training | 35 | 31 | 30 | 34 |  |
| University or higher | 16 | 14 | 13 | 5 |  |

\*Values are the Mean±SD except for percentages; ANOVA and ordinal χ2 test (Kruskal-Wallis test) were used to test if there was a trend of mean of each continuous and categorical variable (increase or decrease) across pain groups.

**Table 3 Association between fat mass, fat mass index and body mass index and multi-site pain (Number of groups=1086)**\*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Univariable | |  | Multivariable† | |  | Multivariable‡ | |
|  | OR | 95% CI |  | OR | 95% CI |  | OR | 95% CI |
| Fat mass | **1.10** | **1.06, 1.14** |  | **1.08** | **1.04, 1.12** |  | **1.06** | **1.02, 1.10** |
| Fat mass index | **1.11** | **1.07, 1.14** |  | **1.09** | **1.05, 1.13** |  | **1.07** | **1.03, 1.11** |
| Body mass index | **1.09** | **1.05, 1.12** |  | **1.08** | **1.05, 1.12** |  | **1.07** | **1.04, 1.11** |

Bold denotes statistically significant result.

\*OR (95% CI): odds ratio (95% confidence interval) representing the OR of greater number of painful sites associated with per SD increase in fat mass, fat mass index or body mass index;

†Fat mass adjusted for age, sex and height; fat mass index and body mass index adjusted for age and sex only.

‡Further adjusted for smoking history, physical activity, emotional problems, education level and employment;

**Table 4 Association between** **fat mass, fat mass index and body mass index and site-specific pain (Number of groups=1086)**\*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Pain site | Univariable | |  | Multivariable† | |  | Multivariable‡ | |
|  |  | OR | 95% CI |  | OR | 95% CI |  | OR | 95% CI |
| Fat mass |  |  |  |  |  |  |  |  |  |
|  | Neck | 1.18 | 0.97, 1.45 |  | 1.04 | 0.84, 1.29 |  | 1.00 | 0.80, 1.26 |
|  | Back | **1.24** | **1.03, 1.51** |  | 1.17 | 0.95, 1.44 |  | 1.20 | 0.97, 1.49 |
|  | Shoulders | **1.27** | **1.07, 1.51** |  | 1.15 | 0.95, 1.38 |  | 1.08 | 0.89, 1.31 |
|  | Hands | **1.54** | **1.27, 1.86** |  | **1.37** | **1.12, 1.67** |  | **1.29** | **1.04, 1.59** |
|  | Hips | **1.53** | **1.27, 1.84** |  | **1.41** | **1.16, 1.71** |  | **1.38** | **1.13, 1.70** |
|  | Knees | **1.96** | **1.61, 2.39** |  | **1.98** | **1.61, 2.44** |  | **1.99** | **1.59, 2.49** |
|  | Feet | **1.89** | **1.56, 2.28** |  | **1.79** | **1.46, 2.18** |  | **1.87** | **1.51, 2.32** |
| Fat mass index |  |  |  |  |  |  |  |  |  |
|  | Neck | **1.28** | **1.05, 1.57** |  | 1.05 | 0.83, 1.33 |  | 1.00 | 0.78, 1.28 |
|  | Back | **1.29** | **1.06, 1.57** |  | 1.20 | 0.95, 1.50 |  | 1.22 | 0.95, 1.56 |
|  | Shoulders | **1.39** | **1.16, 1.65** |  | 1.19 | 0.97, 1.46 |  | 1.10 | 0.88, 1.37 |
|  | Hands | **1.73** | **1.43, 2.11** |  | **1.47** | **1.18, 1.84** |  | **1.37** | **1.08, 1.73** |
|  | Hips | **1.62** | **1.34, 1.95** |  | **1.47** | **1.18, 1.82** |  | **1.42** | **1.13, 1.79** |
|  | Knees | **1.86** | **1.53, 2.27** |  | **2.07** | **1.64, 2.61** |  | **2.06** | **1.60, 2.64** |
|  | Feet | **1.95** | **1.61, 2.36** |  | **1.90** | **1.52, 2.37** |  | **1.99** | **1.57, 2.53** |
| Body mass index |  |  |  |  |  |  |  |  |  |
|  | Neck | 1.10 | 0.90, 1.36 |  | 1.09 | 0.89, 1.34 |  | 1.06 | 0.86, 1.31 |
|  | Back | **1.23** | **1.01, 1.50** |  | **1.23** | **1.01, 1.49** |  | **1.25** | **1.02, 1.54** |
|  | Shoulders | **1.21** | **1.02, 1.44** |  | **1.20** | **1.01, 1.42** |  | 1.14 | 0.95, 1.37 |
|  | Hands | **1.48** | **1.22, 1.79** |  | **1.46** | **1.20, 1.77** |  | **1.41** | **1.15, 1.72** |
|  | Hips | **1.49** | **1.23, 1.79** |  | **1.46** | **1.22, 1.76** |  | **1.45** | **1.20, 1.76** |
|  | Knees | **1.95** | **1.60, 2.38** |  | **1.94** | **1.59, 2.37** |  | **1.94** | **1.57, 2.40** |
|  | Feet | **1.77** | **1.46, 2.14** |  | **1.75** | **1.45, 2.12** |  | **1.84** | **1.50, 2.26** |

Bold denotes statistically significant result.

\*OR (95% CI): odds ratio (95% confidence interval) representing the OR of greater number of painful sites associated with per SD increase in fat mass, fat mass index or body mass index;

†Fat mass adjusted for age, sex and height; fat mass index and body mass index adjusted for age and sex only.

‡Further adjusted for smoking history, physical activity, emotional problems, education level and employment;