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Is diversity of leisure-time sport activities associated with low back and neck–shoulder region pain? A Finnish twin cohort study

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ABSTRACT

This study investigates cross-sectional and longitudinal associations between the diversity of leisure-time sport activities and the frequencies of low back pain (LBP) and neck-shoulder region pain (NSP) in twins, including a cross-sectional within-pair design to adjust for potential familial confounding.

Finnish twins born in 1975–79 (FinnTwin16 study) reported participation in leisure-time sport activities at the mean ages of 17 (1992–96) (n = 5096, 54% females) and 34 years (2010 − 12) (n = 3731, 57% females). Diversity assessed as the number of sport activities was categorized as 1, 2, 3, 4, and ≥ 5, excluding inactive individuals. The frequencies of LBP (n = 3201) and NSP (n = 3207), reported at age 34, were categorized as never/seldom, monthly, or weekly pain. Cross-sectional and longitudinal individual-based associations between the number of sport activities and the frequency of LBP and NSP were investigated with multinomial logistic regression analyses, adjusting for multiple confounders. Cross-sectionally, participation in ≥5 sport activities, compared to 1 sport, was associated with significantly less weekly LBP (OR = 0.63, 95%CI = 0.43–0.90), but not with NSP. Longitudinally, participation in several sport activities in adolescence had no significant association with LBP or NSP in adulthood. Cross-sectional within-pair analyses were conducted among twin pairs discordant for LBP (n = 507) and NSP (n = 579). The associations between monozygotic and dizygotic twin pairs were similar in LBP-discordant pairs but differed within NSP-discordant pairs.

Participation in ≥5 sport activities in adulthood may be associated with less weekly LBP, but not with monthly LBP or the frequency of NSP. However, within-pair analyses for NSP suggest confounding due to shared familial factors.

1. Introduction

Low back pain (LBP) and neck–shoulder region pain (NSP) are important public health problems. The global one-year prevalence is around 38% for LBP (Hoy et al., 2012) and typically 30–50% for NSP (Hogg-Johnson et al., 2008). Globally, LBP and neck pain are the leading causes of disability in the working-age population (Vos et al., 2016), reducing quality of life and imposing large societal costs (Manchikanti et al., 2009; Holtermann et al., 2010).

With the prevention of LBP and NSP being highly warranted, their risk factors have been widely studied. LBP and NSP tend to be recurrent, with previous pain being a strong predictor for a new pain episode (Hartvigsen et al., 2018; Carroll et al., 2008). The prevalence of both LBP and NSP increases with age and peaks during middle age, decreasing again in later years. Women tend to report more pain in low back and neck–shoulder regions, and they also seek care more often than men do (Hoy et al., 2012; Hogg-Johnson et al., 2008). Modifiable factors related to LBP and NSP include smoking, obesity, work characteristics, mental and general health, as well as physical activity (PA) level (Ferreira et al., 2013; Hogg-Johnson et al., 2008). Despite remarkable research efforts, the level and type of PA required to prevent LBP or NSP remain under debate (Sitthipornvorakul et al., 2011).

The relationship between musculoskeletal pain (MSP) and participation in several sport activities has received little-to-no attention. Yet,

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participation in more sport activities could provide a wider range of movements and improve motor control, thus leading to adaptations preventing stress and acute injuries. Naturally, a diversity of sport activities may also predispose individuals to different types of acute injuries. Among adolescents, however, early sport specialization has been related to the risk of overuse injuries, whereas participation in different sport activities may help to avoid overuse injuries and protect against LBP and NSP (Auvinen et al., 2008; Fabricant et al., 2016). Similar studies in adult populations are scarce, yet, they could be highly relevant for making PA recommendations.

Furthermore, genetic factors significantly influence individual differences in PA traits (de Geus et al., 2014), and moderately contribute to both LBP and neck pain (Nielsen et al., 2012). Thus, analyses adjusting for unmeasured genetic and environmental influences are required to control for the possibility of underlying shared factors confounding the association between PA and LBP or NSP. However, such research is scarce.

We used the FinnTwin16 cohort study to test our hypothesis that participation in more sport activities is related to less frequent LBP and NSP. The first objective was to investigate the cross-sectional associations between the diversity of sport activities and frequency of LBP and NSP in adulthood. Secondly, we examined longitudinal associations between the diversity of sport activities in adolescence and the frequencies of LBP and NSP in adulthood. Our last and most novel objective, enabled by the unique twin sample, was to explore the cross-sectional associations between the diversity of sport activities and frequencies of LBP and NSP among discordant twin pairs to account for potential unmeasured confounding due to shared genetic and environmental factors.

2. Methods

2.1. Study design

The FinnTwin16 study is a nationwide, questionnaire-based cohort study of health behavior in Finnish twins and their families (Kaprio et al., 2002). Twin pairs born in 1975–79 were identified from the Central Population Register and the first wave of the survey took place in 1991–1995, when twins were age 16 years. The following waves took place at mean ages of 17, 18, 24, and 34. A more detailed description of the cohort can be found elsewhere (Makela et al., 2017). This study used information from the first (baseline), second (adolescence), and fifth (adulthood) waves of the FinnTwin16 study (Fig. 1), with response rates of 88%, 95%, and 72%, respectively.

The Ethics Committees of the Hospital District of Helsinki and Uusimaa and the Institutional Review Board of Indiana University, Bloomington, IN, USA approved the FinnTwin16 study. The fifth wave was accepted by the Ethics Committee of the Central Finland Hospital district. At all waves, twins gave their informed consent.

2.2. Study sample

Fig. 1 presents the formation of the study samples. For the cross-sectional analyses, we included twin individuals who participated in leisure-time physical activity (LTPA) at least once a month and reported at least one sport activity (n = 3731) in adulthood. Inactive individuals with PA participation less than once a month (n = 492), those reporting no sport activities (n = 180), pregnant women (n = 160), and those with chronic diseases or disabilities (such as depression, osteoarthritis, or visual impairments) that hinder daily activities (n = 342) were excluded (Appendix A). Information on LBP and NSP was available from 3201 and 3207 individuals (55% females), respectively.

For the longitudinal analyses, we included individuals who engaged in LTPA at least once a month and reported at least one sport activity, in both adolescence and adulthood. In addition to the previous exclusions, we excluded those with chronic diseases or disabilities (n = 155) at baseline, whereas low back or neck pain at baseline was adjusted for. Information on LBP and NSP in adulthood was available on 3005 and 3013 individuals (56% females), respectively.

Further, we identified twin pairs in which one co-twin reported more frequent and the other co-twin less frequent LBP or NSP. There were 507 twin pairs discordant for LBP (171 monozygotic (MZ), 336 dizygotic (DZ)). Similarly, 579 twin pairs discordant for NSP were identified (203 MZ, 376 DZ). Zygosity was determined using a validated questionnaire method (Sarna et al., 1978) and supplemented in some pairs by genetic marker information.

2.3. Diversity of leisure-time sport activities

As in our previous study (Makela et al., 2017), we used the number of sport activities to describe the diversity of sport activities in adolescence. Based on a similar multiple-choice question administered in adulthood, "What is your leisure-time physical activity like?" with 26 given choices and an open field with space for reporting up to three additional sport activities (Appendix B), we created a sum variable. Because the number of sport activities did not have normal distribution, a categorical variable was created as follows: 1, 2, 3, 4, and 5 or more sport activities.

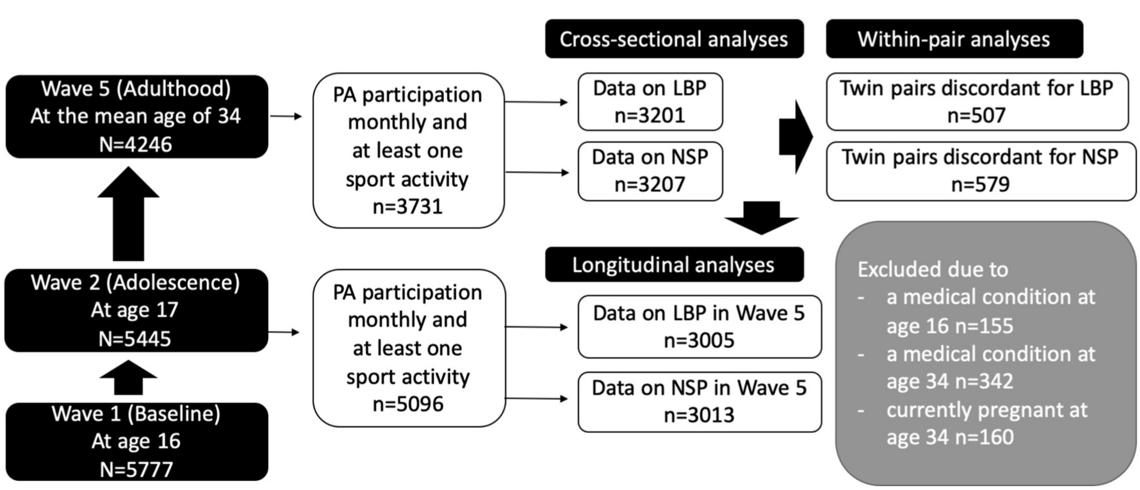

Fig. 1. Flow diagram introducing the formation of study samples (Finland, between 1991–96 and 2010–12).
PA, physical activity; LBP, low back pain; NSP neck-shoulder region pain.

2.4. Low back and neck–shoulder region pain

In follow-up, individuals answered the question "During the past 6 months, have you had any of the following symptoms, and if yes, how often?", where the symptoms included separate options for LBP and NSP (Appendix B). Those options for the frequency of pain symptoms were: never or seldom, approximately once a month, approximately once a week, and nearly every day. To distinguish between rare, occasional, and frequent pain, we re-categorized for the analyses: never/seldom (reference group), monthly (approximately once a month) and weekly (approximately once a week or nearly every day) (Guddal et al., 2017).

2.5. Covariates

Based on the literature (Hartvigsen et al., 2018; Hogg-Johnson et al., 2008), we considered the following covariates: previous LBP and/or NSP at baseline, self-rated health status, sleeping problems, mental health assessed with the 12-item General Health Questionnaire (GHQ-12) (Goldberg et al., 1997; Hu et al., 2007), smoking, body mass index (BMI), level of LTPA calculated as leisure-time Metabolic Equivalent of Task (ltMET-h/day) including active commuting (Ainsworth et al., 2011; Ainsworth and Levy, 2004), education level (highest accomplished degree), and physical demands at work in adulthood (Appendix B) (Makela et al., 2017). Most of the covariates were categorical (Table 1).

2.6. Statistical analyses

Analyses were performed with the Stata statistical package, version 15 (Stata Corp, S, 2017). After calculating the descriptive statistics, we used multinomial logistic regression analyses to estimate odds ratios (OR) with 95% confidence intervals (CI) for the frequencies of LBP and NSP in adulthood by the number of sport activities in adulthood (cross-sectional) and adolescence (longitudinal). The statistical significance level was set at $p < 0.05$.

2.7. Cross-sectional and longitudinal individual-based analyses

In individual-based analyses, we used robust estimators of variance to control for the clustering of correlated observations within a twin pair. First, we conducted cross-sectional analyses, separately for LBP and NSP. The basic model was age- and sex-adjusted and the adjusted model included potential confounders initially chosen from the literature and tested for significant associations ($p < 0.05$) with both the exposure and the outcome (LBP or NSP) in our data. Males and females were analyzed together since the likelihood ratio test comparing nested models with and without the interaction term indicated no sex interaction for LBP ($p = 0.94$) or NSP ($p = 0.57$). Similar interaction tests were conducted for all included confounders. To test the robustness of our model, cross-sectional sensitivity analyses were conducted including inactive individuals, as well as separately for those excluded due to medical condition, and for very active individuals (achieving 11 ltMET-h/day).

Second, we similarly performed longitudinal analyses including the age- and sex-adjusted basic model and the adjusted model with several

Table 1
Characteristics of the study sample, by frequency of low back and neck-shoulder region pain (Finland, between 1992–96 and 2010–12).

	Low back pain			Neck-shoulder region pain		
	Never/seldom	Monthly	Weekly	Never/seldom	Monthly	Weekly
n (%)						
Male	806 (55.4%)	433 (29.8%)	215 (14.8%)	702 (48.2%)	491 (33.7%)	263 (18.1%)
Female	959 (54.3%)	512 (29.0%)	295 (16.7%)	547 (30.9%)	609 (34.4%)	613 (34.7%)
Age (y) – mean (SD)	34.0 (1.2)	34.0 (1.2)	34.1 (1.1)	34.1 (1.2)	34.0 (1.1)	34.0 (1.2)
Number of sport activities – mean (SD)						
In adolescence (age 17)	3.5 (2.0)	3.4 (2.0)	3.3 (2.0)	3.5 (2.1)	3.4 (1.9)	3.4 (2.0)
In adulthood (age 34)	3.6 (2.0)	3.5 (2.0)	3.1 (1.8)	3.7 (2.1)	3.5 (2.0)	3.2 (1.8)
Leisure-time PA (MET-h/day) – mean (SD)	4.6 (3.8)	4.3 (3.4)	4.1 (3.4)	4.9 (3.9)	4.3 (3.3)	3.9 (3.7)
BMI (kg/m^2) – mean (SD)	24.3 (3.7)	24.8 (4.3)	25.0 (4.4)	24.4 (3.6)	24.8 (4.1)	24.4 (4.3)
GHQ-12 score – mean (SD)	9.8 (3.7)	10.8 (5.4)	11.6 (5.5)	9.8 (4.7)	10.7 (5.3)	11.6 (5.6)
Health status – n (%)						
- Very or fairly good	1587(90.5%)	796 (85.0%)	370 (73.3%)	1143(92.0%)	942 (86.4%)	674 (77.5%)
- Average	154 (8.8%)	135 (14.4%)	119 (23.6%)	92 (7.4%)	140 (12.8%)	177 (20.3%)
- Fairly or very poor	13 (0.74%)	6 (0.64%)	16 (3.2%)	7 (0.6%)	8 (0.7%)	19 (2.2%)
Sleeping problems – n (%)						
- Never or seldom	921 (52.5%)	392 (42.1%)	155 (31.0%)	496 (45.7%)	496 (45.7%)	265 (30.7%)
- Monthly	437 (24.9%)	266 (28.5%)	130 (26.0%)	331 (30.5%)	331 (30.5%)	234 (27.1%)
- Weekly	396 (22.6%)	274 (29.4%)	215 (43.0%)	262 (21.7%)	258 (23.8%)	365 (42.2%)
Smoking status – n (%)						
- Current[a]	403 (23.1%)	249 (26.7%)	165 (32.9%)	308 (24.8%)	282 (26.0%)	228 (26.3%)
- Former	364 (20.8%)	222 (23.8%)	115 (22.9%)	265 (21.4%)	243 (22.4%)	192 (22.2%)
- Never	981 (56.1%)	463 (49.6%)	222 (44.2%)	668 (53.8%)	558 (51.5%)	445 (51.5%)
Education level – n (%)						
- Compulsory	30 (1.7%)	31 (3.3%)	11 (2.2%)	23 (1.9%)	33 (3.0%)	14 (1.6%)
- Vocational secondary	497 (28.3%)	290 (31.0%)	194 (38.3%)	373 (29.9%)	334 (29.7%)	277 (31.8%)
- Academic secondary	218 (12.4%)	142 (15.2%)	69 (13.6%)	176 (14.1%)	124 (11.4%)	128 (14.7%)
- Tertiary (university or polytechnic college)	1011(57.6%)	474 (50.6%)	233 (46.0%)	674 (54.1%)	598 (54.9%)	451 (51.8%)
Work activity level – n (%)						
- Light[b]	1213 (69.2%)	605 (64.6%)	275 (54.2%)	852 (68.5%)	717 (65.9%)	535 (61.5%)
- Heavy[c]	392 (22.4%)	258 (27.6%)	171 (33.7%)	300 (24.1%)	284 (26.1%)	232 (26.7%)
- Not working or studying	147 (8.4%)	73 (7.8%)	61 (21.7%)	91 (7.3%)	87 (8.0%)	103 (11.8%)

SD, standard deviation; GHQ-12, the 12-item General Health Questionnaire; BMI, body mass index; PA, physical activity; MET, Metabolic Equivalent of Task.
[a] Including occasional smokers.
[b] Sedentary/some walking.
[c] Frequent walking/lifting/digging, etc.

confounders including pre-existing LBP and/or NSP pain. In order to detect associations contradicting our hypothesis, we performed longitudinal sensitivity analyses assessing the associations between baseline LBP and/or neck pain and the number of sport activities in adolescence and adulthood.

2.8. Within-pair analyses

We conducted cross-sectional within-pair analyses to explore the possible additional confounding due to unmeasured shared familial (genetic or environmental) factors. MZ twin pairs have the same genomic sequence, whereas DZ pairs share on average 50% of their segregating genes. Also, twin pairs reared together are exposed to a similar childhood environment. Thus, conducting analyses for MZ and DZ pairs allows full adjustment for environmental factors shared by co-twins as well as different magnitudes of shared genetic factors. If we detect an association in individual-based analysis that is clearly attenuated in MZ and DZ within-pair analyses, confounding by familial factors is suggested.

We used fixed effects multinomial logistic regression to estimate the ORs for monthly or weekly pain per difference of one sport activity participated in among the discordant twin pairs (Pforr, 2014). Thus, ORs > 1 indicate that the co-twin with the higher number of sport activities was more likely to have monthly or weekly pain than the co-twin participating in fewer sport activities, whereas ORs < 1 indicate that the co-twin with the higher number of sport activities was less likely to have monthly or weekly pain. The analyses were performed first for all twin pairs of known zygosity and then separately for MZ and DZ pairs.

3. Results

3.1. Cross-sectional associations

Descriptive statistics by the frequencies of LBP and NSP are presented in Table 1 and Appendix C. The mean follow-up time was 17.9 (standard deviation (SD) 1.1) years. Females more often reported both weekly LBP (16.7%) and weekly NSP (34.7%) compared to males (14.8% and 18.1%, respectively). At the mean ages of 17.1 and 34.0 years, individuals participated in on average 3.5 (2.0) and 3.4 (2.0) sport activities, respectively. When the frequency of LBP or NSP increased (from never/seldom to weekly), the mean number of sport activities remained nearly constant in adolescence (from 3.5 to 3.4 for both LBP and NSP) but decreased in adulthood (from 3.6 to 3.1 for LBP and from 3.7 to 3.2 for NSP, respectively).

In the basic model, participation in at least four sport activities was related to significantly less weekly LBP (Table 2). Compared to participation in one sport, the ORs were 0.70 (95%CI = 0.49–0.99) for four and 0.44 (95%CI = 0.32–0.62) for five or more sport activities. In the adjusted model, only participation in five or more sport activities had significant association with less weekly LBP (OR = 0.63, 95%CI = 0.43–0.90). In the basic model for NSP, participation in at least five sport activities was associated with less weekly NSP (OR = 0.61, 95%CI = 0.45–0.82), but after adjusting for multiple confounders, we found no significant differences (Table 2).

In sensitivity analyses, we included the inactive individuals and the results were fairly similar for both LBP and NSP (Appendix D). Additionally, we compared individuals included in the analyses to those excluded due to chronic illness or disability reported in follow-up. The excluded individuals significantly more often reported weekly LBP (42.0%) and weekly NSP (42.2%), but did not differ from the study sample in sex (females 54.9%), number of sport activities participated in (mean 3.3, SD 1.9), or LTPA level (mean 4.4 ltMET-h/d, SD 3.6). Among very active individuals achieving 11 ltMET-h/day (6.3% of study sample), we detected no significant associations (results not shown).

3.2. Longitudinal associations

Table 3 shows that participation in more sport activities during adolescence was not significantly associated with LBP or NSP in adulthood. Further, to control for the opposite association, we analyzed individuals with weekly LBP and/or neck pain at age 16 (baseline) who reported, on average, 3.1 (SD 2.1) sport activities in adolescence, which is equal to the entire sample mean 3.1 (SD 1.4). In these regression analyses, we detected no associations between the baseline pain symptoms and the number of sport activities in adolescence or adulthood.

3.3. Within-pair associations

Though the individual-based analysis indicated that participation in more sport activities was associated with less weekly LBP, the associations were of similar magnitude but non-significant among MZ and DZ pairs discordant for LBP (Table 4). Participation in more sport activities was associated with less weekly NSP, both in individual-based analysis (OR = 0.86, 95%CI = 0.80–0.91) and within all twin pairs discordant for NSP (OR = 0.83, 95%CI = 0.71–0.98). A significant association was detected among DZ pairs (OR = 0.75, 95%CI = 0.62–0.92) but not within MZ pairs.

4. Discussion

In the individual-level multiply adjusted analyses, we found that participation in ≥5 sport activities in adulthood was cross-sectionally associated with less weekly LBP, but not with monthly LBP or the frequency of NSP. Contrary to our hypothesis, no favorable longitudinal associations were detected between the diversity of sport activities in adolescence and the frequency of LBP or NSP in adulthood. Furthermore, our twin sample enabled the adjustment for unmeasured confounding due to shared familial (genetic and environmental) factors. The cross-sectional within-pair analyses indicated that the association between the diversity of sport activities and NSP may be partly confounded by shared familial factors.

To our knowledge, no previous study has investigated the association between the diversity of leisure-time sport activities and frequency of LBP and NSP in adulthood with both an individual-based and within-pair design. Evidence from adolescents suggests an association between the type of sports and MSP, as well as indicates an increased risk for MSP related to frequent participation in single risk sport (Auvinen et al., 2008; Fabricant et al., 2016; Guddal et al., 2017).

In adulthood, overall participation in PA, compared to physical inactivity, has indicated favorable associations with both LBP and NSP (Landmark et al., 2013; Palmlof et al., 2016; Shiri and Falah-Hassani, 2017), whereas participation in vigorous activities has been related to unfavorable outcomes (Heneweer et al., 2011). While the relationship of PA level with LBP and NSP has remained debatable at the population level (Sitthipornvorakul et al., 2011), it has also been suggested that instead of PA level, the improved physical fitness, both aerobic and muscular, could be beneficial in the prevention of LBP (Heneweer et al., 2012). The risks of single-sport participation in adulthood are mostly derived from studies of athletes, which have reported highly varying lifetime prevalences for LBP (Trompeter et al., 2017) and sports such as basketball, rowing, and gymnastics, as increasing the risk for LBP (Fett et al., 2017; Farahbakhsh et al., 2018). Former endurance athletes with specific back loading, however, displayed no more LBP compared with non-athletes (Foss et al., 2012; Videman et al., 1995), whereas among triathletes, sports-related injuries and overuse were two major risk factors for long-term neck pain (Villavicencio et al., 2007). Unlike previous studies, we wanted to compare participation in several sport activities to single-sport participation, simultaneously adjusting for PA level among a general population.

We found that participation in several sport activities was cross-

Table 2
Cross-sectional multinomial logistic regression results for twin individuals in (Finland, 2010–12).

Number of sport activities in adulthood		Low back pain in adulthood							
		Monthly LBP				Weekly LBP			
		Basic[a] model $n = 2694$		Adjusted[b] model $n = 2596$		Basic[a] model $n = 2264$		Adjusted[b] model $n = 2168$	
	n	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
1	452	1		1		1		1	
2	706	0.99	0.75–1.31	1.04	0.78–1.38	0.80	0.59–1.09	0.87	0.62–1.21
3	723	0.92	0.70–1.21	1.05	0.79–1.39	0.76	0.56–1.03	0.92	0.66–1.28
4	481	0.84	0.62–1.14	1.01	0.73–1.39	0.70*	0.49–0.99	0.87	0.60–1.27
≥5	839	0.97	0.74–1.26	1.25	0.94–1.66	0.44***	0.32–0.62	0.63**	0.43–0.90

Number of sport activities in adulthood		Neck-shoulder region pain in adulthood							
		Monthly NSP				Weekly NSP			
		Basic[a] model $n = 2356$		Adjusted[c] model $n = 2264$		Basic[a] model $n = 2117$		Adjusted[c] model $n = 2032$	
	n	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
1	449	1		1		1		1	
2	709	1.00	0.75–1.34	1.02	0.76–1.37	1.15	0.85–1.55	1.28	0.93–1.77
3	722	1.00	0.76–1.33	1.12	0.83–1.49	0.88	0.65–1.19	1.07	0.77–1.49
4	483	0.87	0.64–1.19	0.97	0.70–1.34	0.74	0.53–1.03	0.94	0.65–1.36
≥5	844	0.85	0.64–1.12	0.97	0.73–1.30	0.61**	0.45–0.82	0.85	0.61–1.18

LBP, low back pain; NSP, neck-shoulder region pain; OR, odds ratio; CI, confidence interval; GHQ-12, the 12-item General Health Questionnaire; MET, Metabolic Equivalent of Task; BMI, Body Mass Index.

[a] Adjusted for age and sex.
[b] Adjusted for age, sex, sleep problems, GHQ-12 score, leisure-time MET, education, work activity level, smoking, BMI.
[c] Adjusted for age, sex, sleep problems, GHQ-12 score, leisure-time MET, education, work activity level.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

sectionally related to less weekly LBP in adulthood, but detected no similar longitudinal association to support our hypothesis. However, our follow-up (on average 17.9 years) was rather long. In terms of monthly LBP, both cross-sectionally and longitudinally the association seemed to be in the opposite direction. One explanation is that irregular participation in several sport activities may cause more occasional LBP due to unusual movements and stress to the spine, compared to single-sport participation. Notably, LBP onset may significantly reduce participation in PA, and individuals with recent LBP are less likely to meet the PA guidelines (Zadro et al., 2017a). This could indicate that the relationship between MSP and PA diversity is in the opposite direction to what we hypothesized. However, our study regarded LTPA behavior and MSP symptoms over the past six months. In general, LBP has a favorable clinical course since pain levels often decrease within a few months (Hartvigsen et al., 2018). Further, we found no significant association between MSP at age 16 and the diversity of sport activities at age 17. Moreover, a recent meta-analysis found that LTPA at least 1–2 times per week possibly reduces the risk of chronic LBP by 11–16% (Shiri and Falah-Hassani, 2017).

Supporting our hypothesis, intervention studies suggest that different forms of exercise can be recommended for prevention of LBP and NSP (Shiri et al., 2018; Jensen and Harms-Ringdahl, 2007). Notably, such interventions tailored for prevention of MSP usually include selected exercise types, whereas sport activities in this study may both predispose one to and prevent one from injuries and pain. Our results suggest that after adjusting for multiple confounders, there is no robust association between more sport activities and frequency of NSP. Reviewed evidence on the association of PA with NSP is also limited (Sitthipornvorakul et al., 2011). A large cohort study, however, suggested that LTPA only protects from chronic neck pain among previously pain-free workers (Palmlof et al., 2016). Although LBP and NSP share several psychological and physical risk factors such as work characteristics, some factors might be sex- or pain area-specific (Herin et al., 2014). Unfortunately, we lacked information on such work-related factors as exposure to vibration, abnormal loading or strenuous posture. Furthermore, NSP often occurs with other or widespread pain symptoms (Sarquis et al., 2016), and previous LBP may also predispose one to NSP (Croft et al., 2001). Thus, the association of PA with NSP may be more complex than that of PA with LBP and may be more affected by other coexisting pain symptoms.

Importantly, in the within-pair analyses, we were able to adjust for unmeasured familial factors that may contribute to the variance of PA levels (de Geus et al., 2014), LBP (Ferreira et al., 2013), and NSP (Fejer et al., 2006). Our study indicated that the association between more sport activities and NSP, but not LBP, may be confounded by familial factors. Similar evidence is scarce. However, Zadro et al. (2017a, 2017b) have found that familial factors may confound the association between recent LBP and meeting the PA guidelines, whereas the association between LBP and walking or moderate-to-vigorous intensity PA seemed to be moderated by neighborhood walkability. Other recent twin studies have provided support for the hypothesis of a genetic link between depression, sleep quality, and pain (Fernandez et al., 2017; Gasperi et al., 2017). The heritability estimates — reporting the variation in a trait due to inter-individual genetic variation in a given population at a given time — for LBP range from 21% to 67% (Ferreira et al., 2013), for neck pain range from 34% in women to 52% for younger persons and males (Fejer et al., 2006) and are even higher in Finnish pre-adolescents (68%) (Stahl et al., 2013). Thus, our relatively young sample and lack of severity measure for LBP might explain part of the difference detected between the LBP and NSP when unmeasured

Table 3
Longitudinal multinomial logistic regression results for twin individuals (Finland, between 1992– 96 and 2010–12).

Number of sport activities in adolescence		Low back pain in adulthood							
		Monthly LBP				Weekly LBP			
		Basic[a] model n = 2525		Adjusted[b] model n = 2346		Basic[a] model n = 2130		Adjusted[b] model n = 1966	
	n	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
1	448	1		1		1		1	
2	708	1.13	0.85–1.48	1.07	0.80–1.43	0.97	0.70–1.35	0.95	0.66–1.36
3	650	1.03	0.78–1.36	1.05	0.78–1.41	0.85	0.60–1.20	0.87	0.60–1.28
4	464	0.99	0.73–1.33	1.06	0.77–1.46	0.81	0.56–1.18	0.92	0.62–1.38
≥5	735	0.95	0.72–1.26	1.00	0.75–1.34	0.75	0.54–1.04	0.94	0.65–1.36

Number of sport activities in adolescence		Neck-shoulder region pain in adulthood							
		Monthly NSP				Weekly NSP			
		Basic[a] model n = 2158		Adjusted[c] model n = 2013		Basic[a] model n = 2005		Adjusted[c] model n = 1833	
	n	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
1	451	1		1		1		1	
2	708	1.08	0.81–1.44	1.06	0.78–1.42	1.00	0.74–1.35	0.91	0.65–1.28
3	652	1.05	0.78–1.41	1.04	0.76–1.42	0.89	0.65–1.21	0.85	0.60–1.20
4	465	1.09	0.80–1.48	1.12	0.81–1.54	0.79	0.56–1.11	0.85	0.60–1.23
≥5	737	1.07	0.80–1.42	1.07	0.79–1.45	0.87	0.64–1.19	0.97	0.69–1.37

LBP, low back pain; NSP, neck-shoulder region pain; OR, odds ratio; CI, confidence interval; GHQ-12, the 12-item General Health Questionnaire; MET, Metabolic Equivalent of Task.

[a] Adjusted for sex and age at follow-up.

[b] Adjusted for LBP and/or NSP at age 16, sex, and age, sleep problems, GHQ-12 score, leisure-time MET, education, work activity level, and smoking at follow-up.

[c] Adjusted for LBP and/or NSP at age 16, sex, and age, sleep problems, GHQ-12 score, leisure-time MET, education, and work activity level at follow-up.

Table 4
Cross-sectional total sample and within-pair analyses for outcome discordant twin-pairs: the ORs reported for LBP and NSP per increase of one leisure-time sport activity participated in (Finland, 2010–12).

Sample	Low back pain				
	n	Monthly LBP		Weekly LBP	
		OR	95% CI	OR	95% CI
Individuals[a]	3201	0.98	0.93–1.04	0.84***	0.78–0.90
DZ & MZ pairs[b]	507	0.93	0.82–1.05	0.95	0.81–1.11
DZ pairs[b]	336	0.90	0.78–1.03	0.99	0.81–1.20
MZ pairs[b]	171	1.01	0.78–1.31	0.88	0.65–1.20

Sample	Neck-shoulder region pain				
	n	Monthly NSP		Weekly NSP	
		OR	95% CI	OR	95% CI
Individuals[a]	3207	0.95	0.95–1.07	0.86***	0.80–0.91
DZ & MZ pairs[b]	579	0.95	0.83–1.09	0.83*	0.71–0.98
DZ pairs[b]	376	0.90	0.76–1.05	0.75**	0.62–0.92
MZ pairs[b]	203	1.11	0.86–1.42	1.02	0.78–1.33

LBP, low back pain; NSP, neck-shoulder region pain; OR, odds ratio; CI, confidence interval; MZ, monozygotic; DZ, dizygotic.

[a] Multinomial regression model adjusted for age and sex.

[b] Fixed effects multinomial regression model adjusted for age and sex.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

familial factors were considered. Additionally, the change in sample size between individual and within-pair analyses may affect the results. However, our interpretation is based more on the observed change in point estimates than *p*-values. Besides the reduced sample size, a further limitation of within-pair analyses is the amplification of random measurement error which may introduce bias, which creates the suggestion of genetic confounding (McGue et al., 2010).

Considering limitations, we acknowledge that questionnaire-based studies are prone to recall bias, which in our study design was reduced by minimizing the length of the recall period. Participation in sport activities was reported in adolescence and adulthood, and MSP frequencies were reported in adulthood for the past six months. Regarding representativeness, in international comparison of questionnaire-based ltMET values, our twin individuals were at least as active as adults globally (Hallal et al., 2012). If combining monthly and weekly pain symptoms, our estimates were similar to a European study among the working population (Farioli et al., 2014). Further, self-reported musculoskeletal diseases have been shown to have a fair to good test–retest reliability (Picavet and Hazes, 2003). Patients with pain might significantly underestimate their PA level (Kremer et al., 1981), which may, however, counterbalance the common overestimation of PA participation (Klesges et al., 1990). Sensitivity analyses were conducted for excluded individuals who reported a medical condition hindering daily life. Interestingly, they reported similar PA levels to those included in the study, but higher frequencies of LBP and NSP. Overall, selection bias in this population-based cohort study with relatively high response rates is rather low.

For comparability with the literature, it would have been ideal to use standard definitions for LBP and NSP, including pain intensities, impact on life, and seeking medical care (Dionne et al., 2008; Guzman et al., 2008). However, data for these definitions are rarely available within large population-based cohorts investigating multiple health behaviors and health-related outcomes. Another issue with the pain definition was the lack of a visual means to define the pain regions. Pain reported for the entire neck-shoulder region tends to result in a higher prevalence of neck pain, whereas several pain questions as a part of a broader questionnaire relate to lower pain prevalence estimates (Hogg-Johnson et al., 2008). Although we had extensive adjustments in our analyses, some possible confounders have not been addressed.

The fluctuating and multidimensional nature of MSP remains a challenge in the research of LBP and NSP (Heneweer et al., 2011; Hogg-Johnson et al., 2008). Our follow-up time, 17 years, might have been too long for detecting longitudinal associations. Thus, intervention and cohort studies with frequent measurements and the ability to control for both modifiable and non-modifiable risk factors are essential to unravel the association of PA with MSP. Further work is required to assess the benefits of participating in a diversity of sport activities with respect to MSP prevention. Additionally, more sophisticated twin modeling is needed to estimate to what extent shared familial factors explain the association between PA and MSP.

5. Conclusions

Participation in ≥ 5 sport activities was cross-sectionally associated with less weekly LBP but not with monthly LBP in adulthood, when adjusted for confounders, including unmeasured familial factors. The association with NSP was not independent of confounders, and the cross-sectional associations for NSP may be confounded by shared familial factors. Longitudinally, participation in more sport activities in adolescence had no association with the frequency of LBP or NSP in adulthood.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2019.100933.

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References

Ainsworth, B.E., Levy, S.S., 2004. Assessment of health-enhancing physical activity-methodological issues. In: Oja, P., Broms, J. (Eds.), Health Enhancing Physical Activity. Meyer & Meyer Sport, Oxford, England, pp. 239–270.

Ainsworth, B.E., Haskell, W.L., Herrmann, S.D., Meckes, N., Jr, D.R.B., Tudor-Locke, C., Greer, J.L., Vezina, J., Whitt-Glover, M.C., Leon, A.S., 2011. 2011 compendium of physical activities: a second update of codes and MET values. Med. Sci. Sports Exerc. 43, 1575–1581. doi:https://doi.org/10.1249/MSS.0b013e31821ece12.

Auvinen, J.P., Tammelin, T.H., Taimela, S.P., Zitting, P.J., Mutanen, P.O., Karppinen, J.I., 2008. Musculoskeletal pains in relation to different sport and exercise activities in youth. Med. Sci. Sports Exerc. 40, 1890–1900. https://doi.org/10.1249/MSS.0b013e31818047a2.

Carroll, L.J., Hogg-Johnson, S., Velde, G. van der, Haldeman, S., Holm, L.W., Carragee, E.J., Hurwitz, E.L., Cote, P., Nordin, M., Peloso, P.M., Guzman, J., Cassidy, J.D., Bone, Pain, J.D. 2000-2010 T.F. on N., Disorders, I.A, 2008. Course and prognostic factors for neck pain in the general population: results of the Bone and Joint Decade 2000–2010 Task Force on Neck Pain and Its Associated Disorders. Spine 33, 75. https://doi.org/10.1097/BRS.0b013e31816445be.

Croft, P.R., Lewis, M., Papageorgiou, A.C., Thomas, E., Jayson, M.I., Macfarlane, G.J., Silman, A.J., 2001. Risk factors for neck pain: a longitudinal study in the general population. Pain 93, 317–325.

de Geus, E.J., Bartels, M., Kaprio, J., Lightfoot, J.T., Thomis, M., 2014. Genetics of regular exercise and sedentary behaviors. Twin Res. Hum. Genet. 17, 262–271. https://doi.org/10.1017/thg.2014.42.

Dionne, C.E., Dunn, K.M., Croft, P.R., Nachemson, A.L., Buchbinder, R., Walker, B.F., Wyatt, M., Cassidy, J.D., Rossignol, M., Leboeuf-Yde, C., Hartvigsen, J., Leino-Arjas, P., Latza, U., Reis, S., Gil Del Real, M.T., Kovacs, F.M., Oberg, B., Cedraschi, C., Bouter, L.M., Koes, B.W., Picavet, H.S., Tulder, M.W. van, Burton, K., Foster, N.E., Macfarlane, G.J., Thomas, E., Underwood, M., Waddell, G., Shekelle, P., Volinn, E., Korff, M.V., 2008. A consensus approach toward the standardization of back pain definitions for use in prevalence studies. Spine 33, 95–103. https://doi.org/10.1097/BRS.0b013e31815e7f94.

Fabricant, P.D., Lakomkin, N., Sugimoto, D., Tepolt, F.A., Stracciolini, A., Kocher, M.S., 2016. Youth sports specialization and musculoskeletal injury: a systematic review of the literature. Phys. Sportsmed. 44, 257–262. https://doi.org/10.1080/00913847.2016.1177476.

Farahbakhsh, F., Akbari-Fakhrabadi, M., Shariat, A., Cleland, J.A., Farahbakhsh, F., Seif-Barghi, T., Mansournia, M.A., Rostami, M., Kordi, R., 2018. Neck pain and low back pain in relation to functional disability in different sport activities. J. Exerc. Rehabil. 14, 509–515. https://doi.org/10.12965/jer.1836220.110.

Farioli, A., Mattioli, S., Quaglieri, A., Curti, S., Violante, F.S., Coggon, D., 2014. Musculoskeletal pain in Europe: the role of personal, occupational, and social risk factors. Scand. J. Work Environ. Health 40, 36–46. https://doi.org/10.5271/sjweh.3381.

Fejer, R., Hartvigsen, J., Kyvik, K.O., 2006. Heritability of neck pain: a population-based study of 33,794 Danish twins. Rheumatology (Oxford, England) 45, 589–594.

Fernandez, M., Colodro-Conde, L., Hartvigsen, J., Ferreira, M.L., Refshauge, K.M., Pinheiro, M.B., Ordoñana, J.R., Ferreira, P.H., 2017. Chronic Low Back Pain and the Risk of Depression or Anxiety Symptoms: Insights From a Longitudinal Twin Study. https://doi.org/10.1016/j.spinee.2017.02.009.

Ferreira, P.H., Beckenkamp, P., Maher, C.G., Hopper, J.L., Ferreira, M.L., 2013. Nature or nurture in low back pain? Results of a systematic review of studies based on twin samples. Eur. J. Pain 17, 957–971. https://doi.org/10.1002/j.1532-2149.2012.00277.x.

Fett, D., Trompeter, K., Platen, P., 2017. Back pain in elite sports: a cross-sectional study on 1114 athletes. PLoS One 12, e0180130. https://doi.org/10.1371/journal.pone.0180130.

Foss, I.S., Holme, I., Bahr, R., 2012. The prevalence of low back pain among former elite cross-country skiers, rowers, orienteerers, and nonathletes: a 10-year cohort study. Am. J. Sports Med. 40, 2610–2616. https://doi.org/10.1177/0363546512458413.

Gasperi, M., Herbert, M., Schur, E., Buchwald, D., Afari, N., 2017. Genetic and environmental influences on sleep, pain, and depression symptoms in a community sample of twins. Psychosom. Med. 79, 646–654. https://doi.org/10.1097/PSY.0000000000000456.

Goldberg, D.P., Gater, R., Sartorius, N., Ustun, T.B., Piccinelli, M., Gureje, O., Rutter, C., 1997. The validity of two versions of the GHQ in the WHO study of mental illness in general health care. Psychol. Med. 27, 191–197.

Guddal, M.H., Stensland, S.O., Smastuen, M.C., Johnsen, M.B., Zwart, J.A., Storheim, K., 2017. Physical activity level and sport participation in relation to musculoskeletal pain in a population-based study of adolescents: the young-HUNT study. Orthop. J.

Sports Med. 5, 2325967116685543. https://doi.org/10.1177/2325967116685543.
Guzman, J., Hurwitz, E.L., Carroll, L.J., Haldeman, S., Cote, P., Carragee, E.J., Peloso, P.M., Velde, G. van der, Holm, L.W., Hogg-Johnson, S., Nordin, M., Cassidy, J.D., Bone, Pain, J.D. 2000-2010 T.F. on N., Disorders, I.A, 2008. A new conceptual model of neck pain: linking onset, course, and care: the Bone and Joint Decade 2000–2010 Task Force on Neck Pain and Its Associated Disorders. Spine 33, 14. https://doi.org/10.1097/BRS.0b013e3181643efb.
Hallal, P.C., Andersen, L.B., Bull, F.C., Guthold, R., Haskell, W., Ekelund, U., 2012. Global physical activity levels: surveillance progress, pitfalls, and prospects. Lancet 380, 247–257. https://doi.org/10.1016/S0140-6736(12)60646-1.
Hartvigsen, J., Hancock, M.J., Kongsted, A., Louw, Q., Ferreira, M.L., Genevay, S., Hoy, D., Karppinen, J., Pransky, G., Sieper, J., Smeets, R.J., Underwood, M., Group, L.L.B.P.S.W, 2018. What low back pain is and why we need to pay attention. Lancet (London, England) 391 (10137), 2356–2367. https://doi.org/10.1016/S0140-6736(18)30480-X.
Heneweer, H., Staes, F., Aufdemkampe, G., Rijn, M. van, Vanhees, L., 2011. Physical activity and low back pain: a systematic review of recent literature. Eur. Spine J. 20, 826–845. https://doi.org/10.1007/s00586-010-1680-7.
Heneweer, H., Picavet, H.S., Staes, F., Kiers, H., Vanhees, L., 2012. Physical fitness, rather than self-reported physical activities, is more strongly associated with low back pain: evidence from a working population. Eur. Spine J. 21, 1265–1272. https://doi.org/10.1007/s00586-011-2097-7.
Herin, F., Vézina, M., Thaon, I., Soulat, J.-M., Paris, C., ESTEV group, 2014. Predictive risk factors for chronic regional and multisite musculoskeletal pain: a 5-year prospective study in a working population. Pain 155, 937–943. https://doi.org/10.1016/j.pain.2014.01.033.
Hogg-Johnson, S., Velde, G. van der, Carroll, L.J., Holm, L.W., Cassidy, J.D., Guzman, J., Cote, P., Haldeman, S., Ammendolia, C., Carragee, E., Hurwitz, E., Nordin, M., Peloso, P., Bone, Pain, J.D. 2000-2010 T.F. on N., Disorders, I.A, 2008. The burden and determinants of neck pain in the general population: results of the Bone and Joint Decade 2000–2010 Task Force on Neck Pain and Its Associated Disorders. Spine 33, 39. https://doi.org/10.1097/BRS.0b013e31816454c8.
Holtermann, A., Hansen, J.V., Burr, H., Sogaard, K., 2010. Prognostic factors for long-term sickness absence among employees with neck-shoulder and low-back pain. Scand. J. Work Environ. Health 36, 34–41.
Hoy, D., Bain, C., Williams, G., March, L., Brooks, P., Blyth, F., Woolf, A., Vos, T., Buchbinder, R., 2012. A systematic review of the global prevalence of low back pain. Arthritis Rheum. 64, 2028–2037. https://doi.org/10.1002/art.34347.
Hu, Y., Stewart-Brown, S., Twigg, L., Weich, S., 2007. Can the 12-item general health questionnaire be used to measure positive mental health? Psychol. Med. 37, 1005–1013. https://doi.org/10.1017/S0033291707009993.
Jensen, I., Harms-Ringdahl, K., 2007. Strategies for prevention and management of musculoskeletal conditions. Neck pain. Best practice & research. Clin. Rheumatol. 21, 93–108.
Kaprio, J., Pulkkinen, L., Rose, R.J., 2002. Genetic and environmental factors in health-related behaviors: studies on Finnish twins and twin families. Twin Res. 5, 366–371. https://doi.org/10.1375/136905202320906101.
Klesges, R.C., Eck, L.H., Mellon, M.W., Fulliton, W., Somes, G.W., Hanson, C.L., 1990. The accuracy of self-reports of physical activity. Med. Sci. Sports Exerc. 22, 690–697.
Kremer, E.F., Block, A., Gaylor, M.S., 1981. Behavioral approaches to treatment of chronic pain: the inaccuracy of patient self-report measures. Arch. Phys. Med. Rehabil. 62, 188–191.
Landmark, T., Romundstad, P.R., Borchgrevink, P.C., Kaasa, S., Dale, O., 2013. Longitudinal associations between exercise and pain in the general population–the HUNT pain study. PLoS One 8, e65279. https://doi.org/10.1371/journal.pone.0065279.
Makela, S., Aaltonen, S., Korhonen, T., Rose, R.J., Kaprio, J., 2017. Diversity of leisure-time sport activities in adolescence as a predictor of leisure-time physical activity in adulthood. Scand. J. Med. Sci. Sports. https://doi.org/10.1111/sms.12837.
Manchikanti, L., Singh, V., Datta, S., Cohen, S.P., Hirsch, J.A., Physicians, A.S. of I.P, 2009. Comprehensive review of epidemiology, scope, and impact of spinal pain. Pain Physician 12, 35.
McGue, M., Osler, M., Christensen, K., 2010. Causal inference and observational research: the utility of twins. Perspect. Psychol. Sci. 5, 546–556. https://doi.org/10.1177/1745691610383511.
Nielsen, C.S., Knudsen, G.P., Steingrimsdottir, O.A., 2012. Twin studies of pain. Clin. Genet. 82, 331–340. https://doi.org/10.1111/j.1399-0004.2012.01938.x.
Palmlof, L., Holm, L.W., Alfredsson, L., Magnusson, C., Vingard, E., Skillgate, E., 2016. The impact of work related physical activity and leisure physical activity on the risk and prognosis of neck pain - a population based cohort study on workers. BMC Musculoskelet. Disord. 17 (1). https://doi.org/10.1186/s12891-016-1080-1.
Pforr, K., 2014. Femlogit—Implementation of the Multinomial Logit Model with Fixed Effects. 14(4). pp. 862.
Picavet, H.S., Hazes, J.M., 2003. Prevalence of self reported musculoskeletal diseases is high. Ann. Rheum. Dis. 62, 644–650.
Sarna, S., Kaprio, J., Sistonen, P., Koskenvuo, M., 1978. Diagnosis of twin zygosity by mailed questionnaire. Hum. Hered. 28, 241–254. https://doi.org/10.1159/000152964.
Sarquis, L.M., Coggon, D., Ntani, G., Walker-Bone, K., Palmer, K.T., Felli, V.E., Harari, R., Barrero, L.H., Felknor, S.A., Gimeno, D., Cattrell, A., Vargas-Prada, S., Bonzini, M., Solidaki, E., Merisalu, E., Habib, R.R., Sadeghian, F., Kadir, M.M., Warnakulasuriya, S.S., Matsudaira, K., Nyantumbu, B., Sim, M.R., Harcombe, H., Cox, K., Marziale, M.H., Harari, F., Freire, R., Harari, N., Monroy, M.V., Quintana, L.A., Rojas, M., Harris, E.C., Serra, C., Martinez, J.M., Delclos, G., Benavides, F.G., Carugno, M., Ferrario, M.M., Pesatori, A.C., Chatzi, L., Bitsios, P., Kogevinas, M., Oha, K., Freimann, T., Sadeghian, A., Peiris-John, R.J., Sathiakumar, N., Wickremasinghe, A.R., Yoshimura, N., Kelsall, H.L., Hoe, V.C., Urquhart, D.M., Derrett, S., McBride, D., Herbison, P., Gray, A., Vega, E.J.S., 2016. Classification of neck/shoulder pain in epidemiological research: a comparison of personal and occupational characteristics, disability, and prognosis among 12,195 workers from 18 countries. Pain 157, 1028–1036. https://doi.org/10.1097/j.pain.0000000000000477.
Shiri, R., Falah-Hassani, K., 2017. Does leisure time physical activity protect against low back pain? Systematic review and meta-analysis of 36 prospective cohort studies. Br. J. Sports Med. 51 (19), 1410–1418 (doi:bjsports-2016-097352).
Shiri, R., Coggon, D., Falah-Hassani, K., 2018. Exercise for the prevention of low back pain: systematic review and meta-analysis of controlled trials. Am. J. Epidemiol. 187, 1093–1101. https://doi.org/10.1093/aje/kwx337.
Sitthipornvorakul, E., Janwantanakul, P., Purepong, N., Pensri, P., van der Beek, A.J., 2011. The association between physical activity and neck and low back pain: a systematic review. Eur. Spine J. 20, 677–689. https://doi.org/10.1007/s00586-010-1630-4.
Stahl, M.K., El-Metwally, A.A., Mikkelsson, M.K., Salminen, J.J., Pulkkinen, L.R., Rose, R.J., Kaprio, J.A., 2013. Genetic and environmental influences on non-specific neck pain in early adolescence: a classical twin study. Eur. J. Pain 17, 791–798. https://doi.org/10.1002/j.1532-2149.2012.00247.x.
Stata Corp, S, 2017. Stata Statistical Software: Release 15.
Trompeter, K., Fett, D., Platen, P., 2017. Prevalence of back pain in sports: a systematic review of the literature. Sports Med. 47, 1183–1207. https://doi.org/10.1007/s40279-016-0645-3.
Videman, T., Sarna, S., Battié, M.C., Koskinen, S., Gill, K., Paananen, H., Gibbons, L., 1995. The long-term effects of physical loading and exercise lifestyles on back-related symptoms, disability, and spinal pathology among men. Spine 20, 699–709.
Villavicencio, A.T., Hernandez, T.D., Burneikiene, S., Thramann, J., 2007. Neck pain in multisport athletes. J. Neurosurg. 7, 408–413. https://doi.org/10.3171/SPI-07/10/408.
Vos, T., et al., 2016. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 388, 1545–1602. https://doi.org/10.1016/S0140-6736(16)31678-6.
Zadro, J.R., Shirley, D., Amorim, A., Perez-Riquelme, F., Ordonana, J.R., Ferreira, P.H., 2017a. Are people with chronic low back pain meeting the physical activity guidelines? A co-twin control study. Spine J. 17, 845–854. https://doi.org/10.1016/j.spinee.2017.01.015.
Zadro, J.R., Shirley, D., Pinheiro, M.B., Bauman, A., Duncan, G.E., Ferreira, P.H., 2017b. Neighborhood walkability moderates the association between low back pain and physical activity: a co-twin control study. Prev. Med. 99, 257–263. https://doi.org/10.1016/j.ypmed.2017.03.003.