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Hand nerve function after mountain bike cycling

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Abstract: Hand-arm vibrations can cause permanent injuries and temporary changes affecting the sensory and circulatory systems in the hands. Vibrational effects have been thoroughly studied within the occupational context concerning work with handheld vibrating tools. Less is known about vibrational exposure and risk of effects during cycling. In the present study, 10 cyclists were recruited for exposure measurements of hand-arm vibrations during mountain bike cycling on the trail, and the effects on the nerve function were examined with quantitative sensory testing (QST) before and after the ride. The intervention group was compared to a control group that consisted of men exposed to hand-arm vibrations from a polishing machine. The results of the QST did not statistically significantly differ between the intervention and study groups. The intervention group showed a lesser decrease in vibration perception in digitorum II, digitorum V, and hand grip strength than the control group. It was concluded that no acute effects on nerve function in the dominant hand were measured after mountain bike cycling on the trail, despite high vibration doses through the handlebars.

Keywords: mountain bike, trail, cycling, hand-arm vibration syndrome, quantitative sensory testing

1. Introduction

During cycling, so-called hand-arm vibrations (HAV) are transmitted via the handlebar to the rider. The exposure to vibrations during cycling are similar in appearance to that acquired during work with handheld vibrating tools. The physiological effects of HAV have primarily been described in the literature concerning occupational exposures, thoroughly reviewed in 2016 by Nilsson et al. [1]. In this context, it is well known that prolonged exposure to hand-arm vibrations (HAV) can result in a permanent symptom complex, known as hand-arm vibration syndrome (HAVS), affecting peripheral neurological, musculoskeletal, and/or vascular systems [2,3]. HAVS is clinically presented by neurosensory symptoms. Symptoms of HAVS may initially include paresthesia and impaired sensation of touch, vibration, and temperature. Vascular symptoms present as attacks of paleness and discomfort in affected fingers when exposed to cold and are called secondary Raynaud’s phenomenon [3]. With increased exposure to HAV, patients can worsen their fine motor skills, which can be a disabling factor in work and reduce the quality of life [3]. Diagnostic information of

HAVS is commonly collected through quantitative sensory testing (QST), involving examinations of thermal and vibrotactile perception; furthermore, a test of motor functions of the hands, i.e. grip strength for whole hand, or pinch and key grip [1].

In addition to the potential influence of vibrations during cycling, pressure via the handlebar over the hypothenar eminence has been proposed to be of sufficient magnitude to cause damage of the ulnar nerve, resulting in so-called "cyclist's palsy" [4]. Typical symptoms for cyclist's palsy are sensory deficits of the palmar aspect of the fourth and fifth digits, followed by motor symptoms including decreased pinch strength and difficulties with fine motor tasks [5]. High incidence of motor and/or sensory symptoms have been reported in prospective studies of cyclists after long duration rides [6,7] in concordance with observations in several previous case studies (e.g. [8,9,10]). Symptoms may level off after sufficient time resting after exposure. Entrapment of the median nerve causing carpal tunnel syndrome can also occur during cycling, but less commonly than ulnar neuropathy [11,12]. Symptoms from pressure on the nerves in the hands or nerve entrapment in cyclists may overlap with symptoms related to HAVS. Therefore, the potential contribution of HAV to development of such symptoms from cycling may be of additional relevance in order to determine causality.

The nervous system in the hands has four different types of mechanoreceptors, i.e., two fast adapting and two slowly adapting (FAI and FAII, SAI and SAII, respectively), which all mediate different sensations. The FAII receptors are the most dominant in mediating the sense of vibrations, while the SAI receptors are most sensitive to detecting surface topography [13,14]. During and after exposure to HAV, temporary changes in the hand occur, which are not always perceived consciously [15,16]. Examples of acute effects that have been exhibited in other studies are impaired tactile acuity, a shift in the thermal and vibration perception threshold, and an increase in forearm muscle activity [17-20]. The acute effects often fade away within one hour after the HAV has ceased [21].

To reduce the incidence of injuries caused by HAV in work environments, the Swedish Work Environment Authority regulates the HAV dose that an employee is allowed to be exposed to at work. The daily occupational eight-hour HAV exposure, known as A(8) value, must not exceed 5.0 ms^{-2} (limit value). In addition, if the A(8) value exceeds 2.5 ms^{-2} (action value), the affected worker must be offered a medical examination [22,23].

Similarly to exposure to HAV from work with vibrating tools, mountain bike cycling implies a high potential for vibration exposure, particularly in off-terrain conditions. A recent technical report suggested that mountain bike cycling on trails could lead to HAV exposure exceeding 2.5 ms^{-2} after only 24 minutes [24]. With this in mind, vibrations from mountain bike cycling could possibly increase the risk of being affected by HAVS. From the literature, little is known about HAV exposure during mountain bike cycling and related effects on the nerve function in the hands. The HAV exposure during cycling has been evaluated in other studies [25-30]. However, to our knowledge, there is no literature data on HAV exposure during mountain bike cycling on trails or cycling at all, combined with examination of effects on the nerve function of the cyclists.

In this study, we sought to examine the exposure to HAV during mountain bike cycling on the trail and subsequent effects on nerve function in the hands of the cyclists with quantitative sensory testing, QST.

2. Materials and Methods

2.1. Study design and population

The present study was conducted in a non-randomized interventional manner in Örebro County, Sweden, in 2020. An invitation to participate in the intervention group of this study was made through a local amateur mountain bike group. The individuals were orally informed about the study and had access to the research plan. Individuals could be included if exercising by cycling actively outdoors one or more times per week. The only exclusion criteria were impaired general condition and previously known HAV-induced injuries.

A control group was obtained from Löfgren et al. [31], which consisted of male workers from the Department of Occupational and Environmental Medicine, Örebro University Hospital. Eight values and results from Quantitative Sensory Testing (QST) could be extracted from their study baseline characteristics. They were previously unexposed to vibration in their occupation. Only men were selected because of a minority of women in the intervention group. The control group underwent a vibration exposure using a COTECH Polishing Machine, 120 W (Clas Ohlsson, Sweden).

2.2. Questionnaire

Baseline characteristics for the intervention group were collected through a questionnaire. The questionnaire used in this study was adjusted from a validated questionnaire used routinely for patients at the Department of Occupational and Environmental Medicine, Örebro University Hospital, to better match vibration exposure from cycling. The questionnaire collected information about sex, age, weight, height, dominant hand, nicotine habits, work with vibrating tools, cycling habits, and hand symptoms prior to intervention. The answers to the questionnaire were collected through, and dealt with by, the web-based tool esMaker.

2.3. Exposure assessment

The intervention group underwent a predetermined ride on the trail with their own mountain bikes. The ride on the trail lasted for about one hour, with additional time (10–15 minutes) for transport on asphalt to and from the trail. The trail was characterized by flat, singletrack terrain with natural obstacles composed of abundant tree-roots and cobblestone-sized rocks, no drops or jumps. The mountain bikes in the study were of cross country/XC type (nine bikes) or trail type (one bike) equipped with front suspension (travel 100 mm and 120 mm, respectively). Most of the bikes had a wheel size of 29′ (eight bikes) and two bikes had smaller wheels (27.5′ and 26′, respectively). All riders wore padded gloves. The vibration measurement during the cycling was performed with a primary vibration meter (SVANTEK 106) which consisted of a three-axis accelerometer and a data logger. A secondary vibration meter (AX3, Axivity) was also used in case of damage or interrupted sampling of data. It had a three-axis accelerometer and data logger in the same object. Both vibration meters registered vibrations according to the standard (SS-EN ISO 5349).

The primary vibration meter was default set for HAV, logged peak value, and root-mean-square (RMS) every 0.5 seconds, and was calibrated by the Instrument Pool of the Department of Occupational and Environmental Medicine according to the recommendation of the manufacturer. The accelerometer of the vibration meter was attached to the handlebars, two centimeters from the steering column, and had a cord to the data logger placed in a waist bag attached to the cyclists' body. The secondary accelerometer was attached to the handlebars two centimeters from the steering column on the other side.

The exposure time was determined from the vibration meter and defined as the logged time between elevation and drop from the baseline of the vibration signal. The acquired exposure time was cross-checked by data from a tracking application (STRAVA) in case of unforeseen events that would impede the collection of vibration data.

2.4. Medical examination

QST was performed immediately before and after cycling. The method has routinely been utilized in patient examinations at the Department of Occupational and Environmental Medicine, Örebro. A single examiner examined all individuals. Only the dominant hand of each individual was examined. If an individual's finger was below 28 °C after cycling, their hand was heated by a heating pad and placed palmar on their wrist to adjust for the impact of cold weather.

The sensory and motor functions were examined in the following order. Vibration sense was examined using VibroSense-meter (VibroSense Dynamics AB, Malmö, Sweden). It recorded vibration thresholds for frequencies of 8, 16, 32, 64, 125, 250, and 500 Hz and the average perceptual vibration threshold of all frequencies, measured as a sensory index (SI). Touch sense was examined using five different sizes of monofilament (0.07, 0.4, 2.0, 4.0, 300 g) (Touch Test Sensory Evaluators, North Coast Medical, CA, USA). Grip strength was examined using Jamar dynamometer (Sammons Preston, NY, USA) and pinch gauge (B&L Engineering, NY, USA) for whole hand grip, and pinch and key grip, respectively. Each grip was examined three times, and a mean was extracted.

2.5. Statistics

The background information is presented using descriptive statistics and is reported in number (n) of individuals. For age, median and range are reported. RMS and exposure time were extracted from the logged data of the vibration meter. The A(8) value was calculated with these variables according to the standards of the Swedish Work Environment Authority [32]. After that, the mean with the coefficient of variation (CV) and median with range for A(8) value was calculated. The intervention group was divided into two equally large groups of five individuals by the median to dichotomize. Mann-Whitney test was then used to compare the dichotomized groups to each other regarding QST results before and after vibration exposure, respectively. After that, Wilcoxon signed ranks test was used to compare QST results before and after vibration exposure within the two dichotomized groups. The Shapiro-Wilk test was used to test if the intervention group had a normal distribution of QST results before and after vibration exposure. A T-test was then performed to compare the male population of the intervention group to the control group regarding QST results before vibration exposure. Multiple linear regression analysis, adjusted for A(8) value, was used to compare the quote of QST results after/before vibration exposure between the intervention group and control group. A linear regression analysis, also adjusted for A(8) value, was made within the intervention group. The statistical analysis was made in SPSS 25.0 (IBM, North Castle, NY). If $P \leq 0.05$, it was considered statistically significant.

2.6. Ethical considerations

Mountain bike cycling is associated with unavoidable risks of collision and fall injuries. During the intervention, the risk was deemed not to be higher than during exercise under normal conditions. The vibration exposure time was also considered to be in the range for normal exercise and assumed not to cause any permanent injuries. All individuals were assigned a decoded identification number. The code key was kept in a password-protected database within the

IT system of Region Örebro County. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the ethical board of Uppsala, Sweden (reference number 2020-03757).

3. Results

The intervention group consisted of 10 individuals, all of whom were right-handed, and one of whom was a regular nicotine user (snuffer). The cycling skills of the individuals varied from recreational level to competitor at the national level. Besides two individuals who had multiple sclerosis and psoriasis, no other individual had any disease. Four individuals reported occupational usage of vibrating tools, wherefore two had quit usage but two were exposed. Seven individuals reported experience of any re-occurring symptoms (pain, numbness, whitening, weakness) prior to the intervention. The majority, five, of these individuals did not have any experience of usage of vibrating tools. Baseline characteristics are found in Table 1.

Table 1. Baseline characteristics of the intervention group and the control group, where n corresponds to the number of individuals

		Cyclists (n=10)	Control (n=7)
Sex, n	Male	9	7
	Female	1	0
Age, median (range)		39 (19–51)	44 (33–64)
Age, n	≤ 35	4	1
	36–50	5	4
	≥ 51	1	2
Dominant hand, n	Right	10	7
	Left	0	0
Smoking habits, n	Non-smoker	10	6
	Smoker	0	1
Snuff habits, n	Non-snuffer	9	6
	Snuffer	1	1
BMI	Mean	22.1	
	Median	22.1	
	Standard deviation	1.6	
	Min	19.4	
	Max	25.4	
Height	Mean	180.9	
	Median	183.0	
	Standard deviation	7.4	
	Min	169	
	Max	191	

The total distance of cycling (on the trail and during transport on asphalt), distance on the trail and velocity were in mean 23.2 km (CV 23 %), 13.6 km (CV 40%), 15.4 km/h (CV 21 %), respectively. The mean RMS and A(8) values for the intervention group were 8.48 ms^{-2} (CV 28 %) and 3.68 ms^{-2} (CV 32 %), respectively. The median A(8) value was 3.55 ms^{-2} (1.9–5.7 ms^{-2}), which was used to dichotomize the intervention group.

Key grip strength before vibration exposure was the only variable from QST that had a statistically significant difference between the dichotomized groups ($P = 0.047$). No statistically significant difference was found for QST results after vibration exposure or when comparing QST results before and after vibration exposure within the dichotomized groups. The intervention group had a normal distribution for all QST results both before and after vibration exposure. The T-test showed no statistically significant differences between the intervention and control groups regarding results from QST before vibration exposure.

For vibration sense digitorum II, the multiple linear regression analysis between the intervention group and control group showed a statistically significant difference after/before vibration exposure ($B = 16.57$; 95% CI = 6.85–26.29, $P = 0.003$; Table 2).

Table 2. Multiple linear regression analysis between the intervention and control groups for the QST quote results after/before vibration exposure. Adjusted for A (8) value.

	r^2	*B*	95% CI *B*	*P*-value
Hand grip (kg)	0.28	10.05	0.11–19.99	0.048
Pinch grip (kg)	0.15	−2.28	−13.76–9.21	0.676
Key grip (kg)	0.05	3.83	−6.97–14.63	0.457
Monofilament digitorum II (g)	0.06	−631.26	−2258.41–995.89	0.417
Monofilament digitorum V (g)	0.05	−97.58	−343.77–148.60	0.407
Vibration sense digitorum II (SI)	0.61	16.57	6.85–26.29	0.003
Vibration sense digitorum V (SI)	0.47	15.06	1.69–28.43	0.030

Abbreviations: r^2 *explained variation; B regression coefficient; 95%; CI B the confidence interval for B; SI sensory index.*

Statistically significant differences were also found for hand grip strength (B = 10.05; 95% CI = 0.11–19.99, P = 0.048) and vibration sense digitorum V (B = 15.06; 95% CI = 1.69–28.43, P = 0.030). No statistically significant difference was found for any quote of QST result after/before vibration exposure when compared within the intervention group (Table 3).

Table 3. Linear regression analysis within the intervention group for the QST quote results after/before vibration exposure. Adjusted for A (8) value

	r^2	*B*	95% CI *B*	*P*-value
Hand grip (kg)	0.10	−2.94	−10.12–4.24	0.373
Pinch grip (kg)	0.17	5.42	−4.22–15.05	0.231
Key grip (kg)	< 0.01	0.69	−6.14–7.51	0.823
Monofilament digitorum II (g)	0.11	−60.50	−201.49–80.49	0.351
Monofilament digitorum V (g)	< 0.01	3.41	−153.94–160.75	0.961
Vibration sense digitorum II (SI)	0.14	2.06	−2.09–6.20	0.286
Vibration sense digitorum V (SI)	0.22	3.46	−1.86–8.78	0.172

Abbreviations: r^2 *explained variation; B regression coefficient; 95% CI B the confidence interval for B; SI sensory index*

4. Discussion

This study aimed to investigate the effects of mountain bike cycling on the nerve function in the hands of cyclists with quantitative sensory testing, QST. The main result from our intervention study is that there was no statistically significant difference in hand nerve function after exposure to mountain bike cycling on the trail.

The mean A(8) value retrieved from the intervention group in our study (3.68 ms^{-2}) was considerably lower than was measured in elite mountain bike endure cyclists during competition, i.e., A(8) at 5.84 ms^{-2} in a study conducted by Kirkwood et al. [29]. One explanation for the lower A(8) value in our study could be the difference in the degree of velocity and therefore also in vibration exposure [30]. The influence of velocity on exposure to HAV has not been taken into consideration in the present study. However, it can be assumed that during competition, the velocity is higher, especially downhill in the case of enduro mountain bike cycling.

Despite high vibration doses from mountain bike cycling, cyclists in the intervention group did not lower their QST result. For explanation, the small sample of cyclists might have lowered the sensitivity of detecting acute effects in the study group.

Another factor that may have had an impact was the time between the end of cycling on the trail to the start of QST; approximately between 10-15 minutes for transport on asphalt from the trail. According to a study by Burström et al. [17], acute effects from vibration usually cease within 15 minutes after exposure. Nevertheless, cycling on asphalt also gave rise to HAV but not in doses as high as on the trail. From previous measurements, it was suggested that the time of mountain bike cycling to get an A(8) value of 2.5 ms^{-2} would take 78 minutes on asphalt compared to 24 minutes on the trail. [24]. However, the cycling on asphalt during transport from the trail might have contributed to a lesser reduction in QST results compared to if the QST had been performed immediately after cycling on the trail. In addition, the individuals learning the technique for some tests may have altered the QST results. On the other hand, high test-retest reliability for whole hand grip and pinch grip using Jamar dynamometer and pinch gauge has been shown by Mathiowetz et al. [33].

After adjusting for A(8), the vibration exposure for the intervention group showed 16.57 times less effect on vibration sense for digitorum II than did the control group. Partly, this difference could be attributed to the strong reduction in QST result among the controls. Furthermore, less efficient transmissibility of vibrations through the handlebars for the intervention group, compared to the polishing machine for the control group, could also have contributed to the observed difference. Under certain circumstances, a highly variable and very low transmissibility was demonstrated by Ciementin et al. [26] for standard cycling on streets with pavement. Descriptive data of vibration transmissibility for mountain bike cycling on the trail has unfortunately not been found in the literature. Many technical aspects of the cycles can potentially alter the exposure to HAV, e.g. properties of the suspension fork and tyre pressure. Another possible explanation could be a difference in vibration frequency of the exposure between the two groups. HAV exposure at a frequency of 125 Hz has the greatest impact on vibration perception threshold, according to a study by Malchaire et al. [3422]. In the present study, it cannot be ruled out that there was a difference in HAV exposure at 125 Hz between the intervention group and the control group since vibration frequency was not extractable from the exposure measurements.

Furthermore, 39% of the variability of B for vibration sense digitorum II could not be explained by the regression analysis, which was considered an effect of variance in individual acceptability for vibrations, age, bicycle, and the road of choice. Similar explanations could be used for B and r^2 for vibration sense dig V and hand grip strength. As previously mentioned, the FAII receptors primarily mediate the sense of vibrations, while the SAI receptors mediate the sense of surface topography. From our QST result, no type of mechanoreceptor can be pointed out as more affected than the other by mountain bike cycling.

5. Practical Applications.

In the present study, no acute effects on nerve function in the dominant hand were observed after mountain bike cycling on the trail, despite high levels of vibrations through the handlebars. Therefore, the results suggest that hand-arm vibration exposure, within the tested dose interval from mountain bike cycling on the trail, may not alter acute effects in hand nerve function. Nevertheless, these findings should be interpreted with cautiousness due to elements of uncertainty, e.g. the small sample of cyclists (n=10) that might have lowered the sensitivity of detecting acute effects; potential influence on QST result from the time of transport on asphalt for the cyclists between the trail and the QST test.

The addressed uncertainties imply a need for further research to determine risks for effects related to HAV among cyclists. Furthermore, generated data may enhance benchmarking in technical development to reduce unnecessary exposure to HAV in cycling sport. Previously recommended measures to decrease the risk of cyclist's palsy, which involve frequent change of position of the hands during riding, avoiding excessive body weight on the handlebars, keeping a neutral position of the wrist angle, and using padded (foam) gloves [4], may also be relevant for decreasing health risks related to vibrational exposure.

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