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DOI

[10.3233/WOR-213484](https://doi.org/10.3233/WOR-213484)

Publication date

2021

Document Version

Final published version

Published in

Work

Citation (APA)

Dekker, M. C., van Egmond, R., Molenbroek, J. F. M., & Vink, P. (2021). Developments in work-related upper limb disorders (WRULD) amongst Dutch university students from 2004 to 2014. *Work*, 69(2), 379-394. <https://doi.org/10.3233/WOR-213484>

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Developments in work-related upper limb disorders (WRULD) amongst Dutch university students from 2004 to 2014

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Received 25 December 2019
Accepted 30 December 2020

Abstract.

BACKGROUND: Former studies on work-related upper limb disorders (WRULD) within university education report substantial prevalence rates. In this study, developments in WRULD amongst students in the period 2004–2014 were investigated. Our findings can be a benchmark for future studies, in particular when there are major societal changes as in the case of the COVID-19 pandemic.

OBJECTIVE: Differences in time (academic year), how long students have been studying (year of studying), relations with computer time and societal changes were points of interest.

METHODS: 2254 students (average age 20.0 years) responded to a questionnaire on WRULD. Students experiencing complaints were further questioned about the severity of complaints and associated body locations.

RESULTS: The average percentage of students experiencing complaints was 57%. The highest prevalence rates and severity scores were found in the first and last recorded academic years. The neck, shoulder, back and wrist were most often indicated. The prevalence of complaints raised from the 1st (49%) to the 4th (75%) year of studying. Two seriousness measures showed highest scores in the 5th/6th/7th year of studying. Relations were found between both the prevalence and seriousness of complaints with reported computer time.

CONCLUSIONS: After an initial decreasing trend from the academic year 2006/2007 to 2010/2011 there was an increase in WRULD amongst students from 2010/2011 to 2013/2014. Limiting financial and study time factors may have played a role. Structural attention for WRULD prevention and risk factors seems to be effective in reducing prevalence and severity of WRULD. This seems to be even more necessary due to recent COVID-related changes in the students' lives.

Keywords: RSI, MSD, prevalence, seriousness, COVID-19

1. Introduction

1.1. Background

Work-related upper limb disorders (WRULD) in the occupational environment of The Netherlands is annually investigated by Van der Molen et al. [1,

2] of the Dutch Centre for Occupational Diseases based on the national notification and registration system. These studies show figures from computer-related occupations and manual labour in, e.g., transport, industry, and construction and indicate that musculoskeletal disorders are the second largest occupational illness – after psychological disorders – in The Netherlands. Within this musculoskeletal disorders category, the two most frequently reported occupational diseases are WRULD of the shoulder/upper arm (referring to non-specific WRULD of this region) and the tennis elbow (a specific form of

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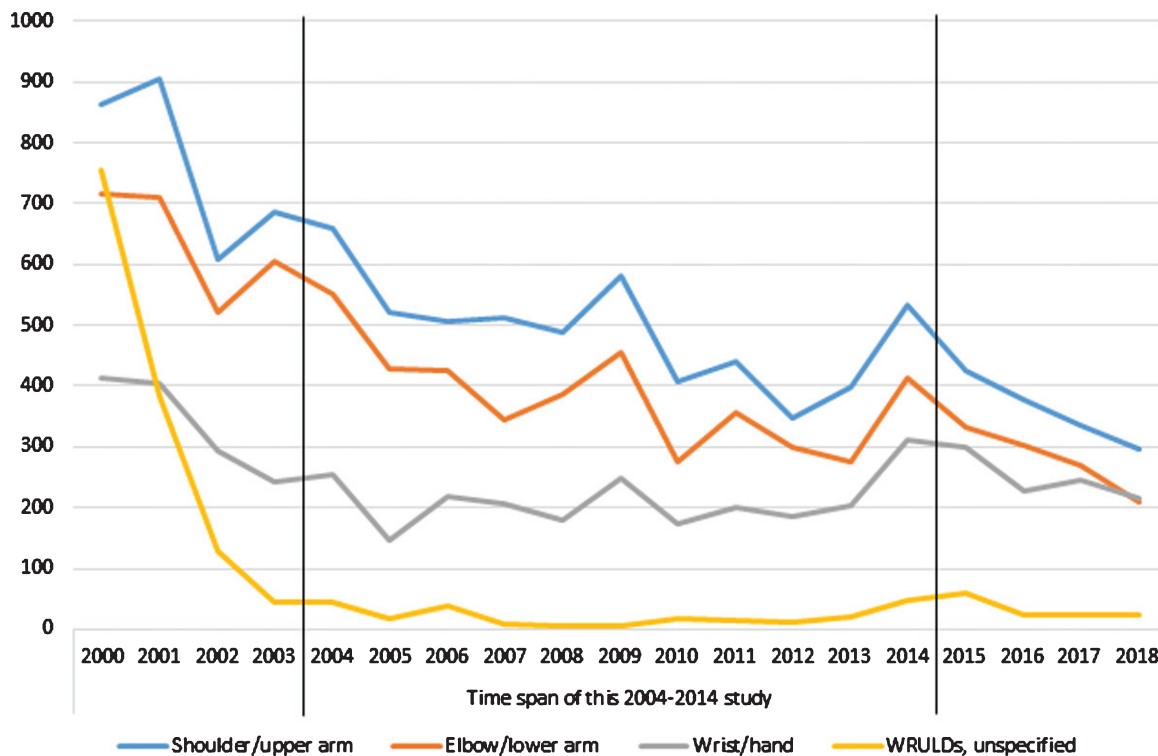


Fig. 1. Number of reported WRULDs divided by body region from 2000 till 2018 in the Netherlands. Each line refers to multiple (specific and non-specific) forms of WRULD. Tennis elbow is included in the line 'elbow/lower arm'. The lowest line refers to WRULD in unspecified regions. The black vertical lines indicate the time span of our 2004-2014 study. Source: national registry of Netherlands Center of Occupational Diseases 2019.

WRULD). Since 2001 the reporting of occupational diseases related to the upper extremities has reduced as can be seen in Figs. 1 and 2. Figure 1 shows the numbers reported WRULD per body region and Fig. 2 shows the total numbers reported WRULD as percentage of all reported occupational diseases from 2000 till 2018 in the Netherlands. A possible explanation for this decline is the structural attention in The Netherlands for work-related causes and prevention measures in the work environment, in particular in computer work [1].

However, a cross-sectional study on WRULD over such time span does not, as far as we know, exist for younger age groups. This seems strange because the use of personal computers, notebooks, and mobile phones has substantially increased in study, work activities, and leisure. This is a consequence of the digitalization and the more important role of the internet over the last 20 years. For their studies, digital reports and assignments, online assessments and examinations and online lectures have become more and more the standard. Recently, students had to change their life style drastically and abruptly

due to the COVID-19 pandemic. Academic teaching became also in the Netherlands (almost) entirely virtual and on distance. Workload and restrictive governmental measures made students to be confined to their student homes with long working hours in front of their computer screen. Thus, the important questions are what the impact is of these developments on their health, and if these developments influenced the number and severity of WRULD complaints before they start their job. This is, of course, also a relevant question from an economical point of view. There are several studies that have addressed WRULD complaints of younger age groups over a shorter period of time. For example, the health effects of computer-related activities of secondary school students [3–5] and young adults [6–9] are explored. Dutch studies on WRULD within university education report WRULD prevalence of 76% [8] and 60% [9]. The cross-sectional study of Dekker and Festen-Hof [9] on WRULD among the student population of the Faculty of Industrial Design Engineering (IDE) at the Delft University of Technology from 1999 through 2003 showed that WRULD led to inconveniences and

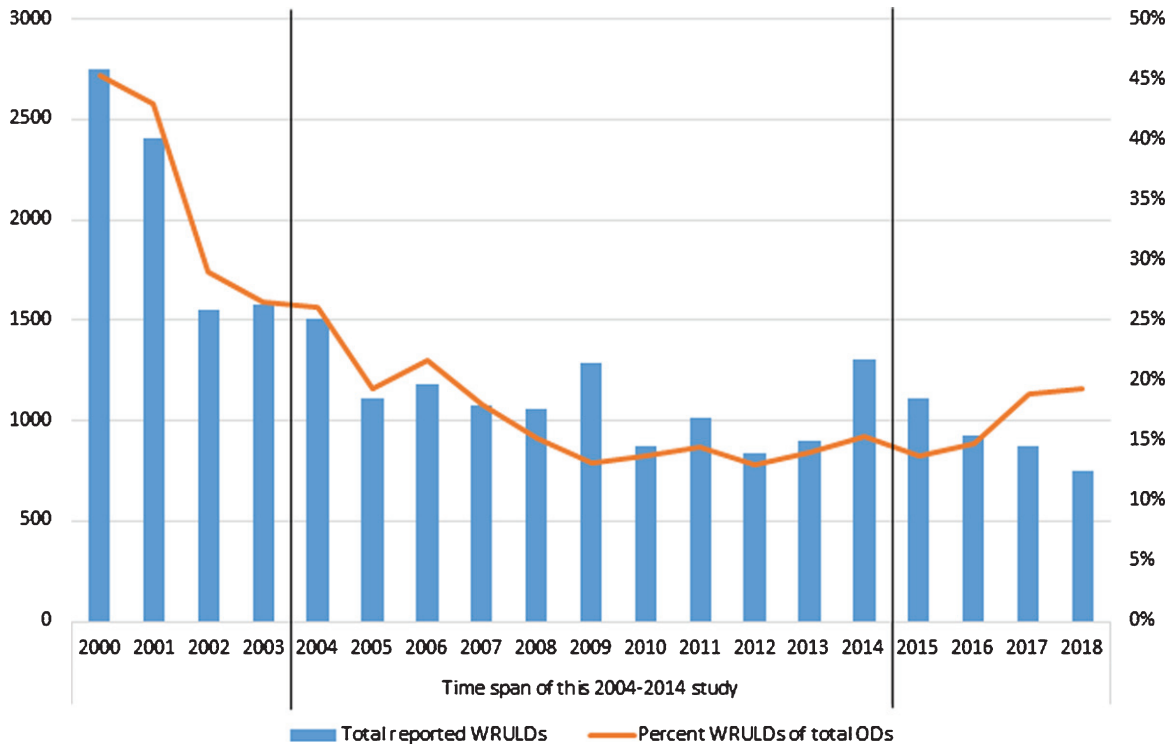


Fig. 2. The total number of reported WRULDs (blue bars) and the percentage of these (red line) to the total number reported occupational diseases (ODs) from 2000 till 2018 in the Netherlands. The black vertical lines indicate the time span of our 2004–2014 study. Source: national registry of Netherlands Center of Occupational Diseases 2019.

in some cases to absence, study delay and even dropping out of studies. In this paper it has also been shown that the related human and financial damage was substantial. Furthermore, risk factors have been indicated in this paper such as students' high work-load, long working hours, mentally demanding work and varying and not always adequate workplaces including the intensively used workplaces at home. The latter aspect has become particularly relevant in today's COVID-19 era where students work at home. Because the Dekker and Festen-Hof study [9] showed the impact of WRULD on students' health and productivity, the IDE Faculty supported monitoring studies on WRULD for a time period that stretches over 10 years, from 2004 till 2014.

1.2. Aims of the current study

In several studies [5, 10–12], an association was found between self-reported computer working hours and the prevalence of WRULD symptoms. In the former study among IDE students [9], the question was raised whether the higher percentage of students experiencing complaints in higher study years

was related to the higher reported average number of computer hours per day in these years. Therefore, we investigated in the (2004–2014) study of this paper the relationship between the prevalence of WRULD symptoms and the time spent using a computer (whether for study, work or leisure). There are few studies available about the seriousness of WRULD symptoms in relation to computer working hours. However, the survey of Hakala et al. [13] examined the intensity of musculoskeletal pain and level of inconvenience to everyday life among adolescents in relation to their time spent using a computer and indicated that daily computer use of 2 hours or more is related to moderate/severe computer-associated pain at the neck- shoulder, low back, head, eyes, hands, and fingers or wrists. The relationship between the seriousness of WRULD complaints and the reported average number of computer hours per day received also attention in the study of our paper. In summary, we analysed the data obtained from the students in the period 2004–2014 on the following measures,

1. The prevalence (3.1), occurrence (3.3), duration (3.5) and seriousness (3.7, 3.9 and 3.11)

- of WRULD complaints throughout the years 2004 – 2014,
2. The prevalence (3.2), occurrence (3.4), duration (3.6) and seriousness (3.8, 3.10 and 3.11) of WRULD complaints of students in different years of studying,
 3. The body locations associated with the complaints (3.12),
 4. The reported average number computer working hours per day spent by students throughout the academic years 2004 – 2014 (3.13),
 5. The reported average number computer working hours per day spent by students of different years of studying (3.14),
 6. And the relation between WRULD prevalence (3.15) and seriousness (3.16) versus reported averaged number of computer working hours per day.

2. Methods

2.1. Procedure and participants

To acquire measures on WRULD a survey was set out among IDE students of the Delft University of Technology comparable to the former survey among IDE students [9]. The research was set up and executed by the WRULD working group of IDE, a multidisciplinary group aiming to disseminate information on WRULD prevention and to reduce risk factors within the IDE study environment [9]. The WRULD working group is an initiative of the (Board of Educational of the) IDE faculty. Consequently, the monitoring of WRULD related health complaints among their students has been executed with approval of and within the policy of the university. The goal of the research and its anonymous nature was indicated at the start of the questionnaire. This way, all subjects were informed that data was acquired on group level and not on individual level. Students were asked by the researchers to participate and could refuse without reason giving.

The study of this paper was conducted in the academic years 2004/2005, 2006/2007, 2008/2009, 2010/2011 and 2013/2014 (in the figures respectively labelled with '04/'05, '06/'07, '08/'09, '10/'11, and '13/'14). The questionnaire was distributed in the 1st, 2nd, 3rd and 4th year of study after IDE examinations or WRULD information sessions. Students had to indicate how long they have been studying ('years of studying'). In the following analyses we

only make use of this indication 'year of studying'. The sample of this study also includes students in their 5th, 6th and even 7th years of studying, who had to redo the course or did not study on schedule. It was made clear that the questionnaire was not intended for master students who didn't follow the IDE bachelor (such as international students) by verbal announcement during the passing round of the questionnaires. Therefore, the survey was administered in Dutch.

2.2. Measurement

Participants filled in the questionnaire on paper. Handwriting was chosen over online typing because of subjects' possible sensitiveness for computer-related WRULD. The questionnaire started with an introduction, outlining the goal and emphasising the anonymous nature of it. A general part included questions about age, gender, length and weight. The part in which the prevalence and seriousness of WRULD was monitored, included questions concerning the prevalence of WRULD-related complaints after computer work, their location in the body, and their occurrence and duration. It was considered that the complaints were more serious when lasting longer and occurring more frequently, and thus the seriousness was determined by the multiplication of the occurrence of the complaints and their duration, expressed in the total number of hours per year in which respondents experienced complaints and indicated with 'seriousness OxD'. An alternative estimation on the seriousness of the complaints, the 'seriousness LDA', was based on a checklist [14] of daily activities such as tooth brushing, hand writing, carrying a bag etc. The respondents had to indicate to what extent the complaints were limiting them in these daily activities. And there was a part of the questionnaire focusing on possible risk factors and included a question about respondents' number of computer hours per day.

2.3. Statistical analyses

The WRULD measures as previously indicated among IDE students of different years of studying were calculated and described over time. The Likelihood Ratio Test and one-way ANOVA were used to see if significant differences can be found between years of studying and between academic years, and to investigate relationships with daily computer working hours. In the following paragraph the total number of respondents (N) varies per analysis

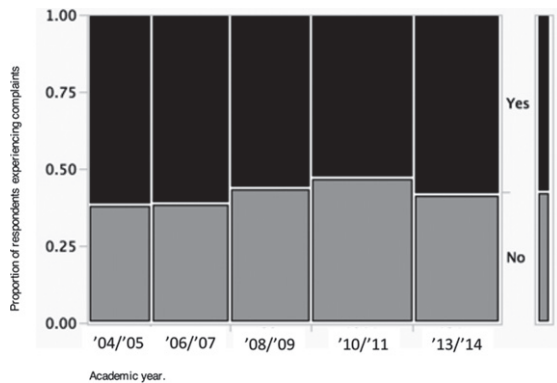


Fig. 3. Proportions of students experiencing WRULD complaints as a function of the academic years, '04/'05 ($n = 346$), '06/'07 ($n = 433$), '08/'09 ($n = 444$), '10/'11 ($n = 560$), '13/'14 ($n = 471$).

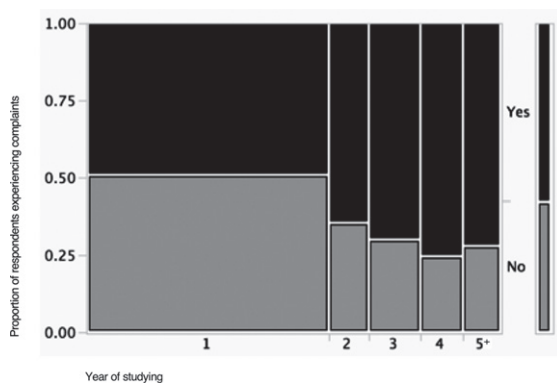


Fig. 4. Proportions of students experiencing WRULD complaints as a function of their years of studying, 1 ($n = 1308$), 2 ($n = 214$), 3 ($n = 280$), 4 ($n = 227$), 5+ ($n = 198$). The year of studying 5+ contains students who study in their 5th, 6th or 7th years. $N = 2227$.

because of a small percentage missing values (e.g. forgotten/unwillingness to indicate year of studying, age etc.) in the respondents' data.

3. Results

Two-thousand-two-hundred-and-fifty-four (2254) students participated in this survey (58.6% males/40.1% females/1.3% unknown). The average age was 20.0 years (minimum 16 years, maximum 46 years, SD 2.2). The response rate was estimated at 90–99% for students responding to the questionnaires distributed in the 1st year of study and 30–90% for those responding to the questionnaires distributed in higher years of study. In the Figs. 3, 4, and 8 the width of the bars indicates the proportion of respondents numbers belonging to the specific category. There

are different numbers of respondents per measure as presented in the following figures and tables. As can be seen, some measures concern the entire population researched and others only the group of students experiencing complaints. Moreover, missing answers of the respondents create also minor differences in sizes of the respondents groups per measure.

3.1. Prevalence of complaints in successive academic years

After a short introduction on WRULD, the respondents were asked whether they ever experienced physical complaints, such as pain, numbness, tingling or loss of strength, after working with a computer. In Fig. 3, a mosaic graph presents the proportion of students experiencing WRULD as a function of academic year, including all years of studying (1 through 7 years). The percentages of complaints over the academic years are quite consistent. Percentages of students reporting complaints vary between 53% in academic year 2010/2011 and 61% in the academic years 2004/2005 and 2006/2007. There is a significant effect over the academic years ($\chi^2(4, N = 2254) = 10.03, p = 0.04$). The percentage of students experiencing complaints decreases from 2006/2007 till 2010/2011 and there is a slight increase to the last measured academic year 2013/2014 (58%). The average percentage of students experiencing complaints over all five academic years is 57%.

3.2. Prevalence of complaints per year of studying

The mosaic graph in Fig. 4 presents the proportion of students experiencing WRULD after working with a computer as a function of years of studying, including all five academic years. Percentages of students reporting WRULD complaints vary between 49% in the 1st year of studying and 75% in the 4th year of studying. There is a significant effect over the years of studying ($\chi^2(4, N = 2227) = 111.72, p < 0.0001$). Relatively more students of higher years of studying experience complaints than students of the 1st year of studying. There is a slight decrease in the combined 5th/6th/7th year of studying (71%).

Table 1
Occurrence of complaints in percentage of the group respondents with complaints within the successive academic years

	2004/2005 <i>n</i> = 201	2006/2007 <i>n</i> = 251	2008/2009 <i>n</i> = 237	2010/2011 <i>n</i> = 285	2013/2014 <i>n</i> = 255	All <i>N</i> = 1229
Once a year	16%	20%	24%	15%	11%	17%
Once a month	45%	49%	49%	47%	42%	47%
Once a week	31%	22%	21%	27%	33%	26%
Once a day	7%	8%	6%	11%	15%	10%

χ^2 (12, *N* = 1229) = 35.42, *p* < 0.0004.

Table 2
Occurrence of complaints in percentage of the group respondents with complaints within the years of studying. *N* = 1221

	1st year <i>n</i> = 607	2nd year <i>n</i> = 131	3rd year <i>n</i> = 187	4th year <i>n</i> = 161	5th, 6th and 7th year <i>n</i> = 135	All <i>N</i> = 1221
Once a year	17%	12%	17%	17%	21%	17%
Once a month	48%	43%	47%	53%	35%	47%
Once a week	26%	29%	29%	23%	32%	27%
Once a day	9%	16%	7%	7%	12%	10%

χ^2 (12, *N* = 1221) = 20.92, *p* = 0.0516.

3.3. Occurrence of complaints in successive academic years

In this paragraph the data of students that reported complaints were analysed in relation to the occurrence of their complaints, obtained by a 4-alternative forced task: 'once a year', 'once a month', 'once a week', and 'once a day'. They only chose one level. In Table 1, the percentages of complaints per academic year are shown as a function of level of occurrence. As can be seen in the right-most column, most students experienced complaints once a month (47%) or once a week (26%). There is a significant effect of the occurrence of complaints over the academic years. Complaints are experienced less frequent in the academic year 2008/2009 compared to the academic years 2004/2005 and 2006/2007. More students experienced yearly (24%) and monthly (49%) complaints in the academic year 2008/2009 and less students suffered from weekly (21%) and daily (6%) complaints. In the last two academic years 2010/2011 and 2013/2014 however, there is an increasing percentage of students suffering from weekly (respectively 27% and 33%) and daily (respectively 11% and 15%) complaints and a decreasing percentage students experiencing yearly complaints (respectively 15% and 11%) and monthly complaints (respectively 47% and 42%).

3.4. Occurrence of complaints per year of studying

In this paragraph the effect of the number of years of studying on the occurrence of WRULD

was analysed. In Table 2, the percentages of complaints per year of studying are shown as a function of level of occurrence. There are no clear differences in the levels of occurrence of complaints over the years of studying. The effect over the years of studying is not significant - although close to. However, complaints seem to occur most frequently in students who study in their 2nd year (29% once a week and 16% once a day) and combined 5th, 6th and 7th years (32% once a week and 12% once a day).

3.5. Duration of complaints in successive academic years

The duration of students' WRULD complaints was obtained by a 6-alternative forced task: 'continuous', 'a couple of days', '12–24 hours', '6–12 hours', '1–6 hours', 'and less than 1 hour'. They only chose one level. In Table 3, the percentages of complaints per academic year are shown as a function of duration level. As can be seen in the right-most column, most students experienced complaints lasting for less than 1 hours (52%) and 1–6 hours (31%). There is a significant effect of the duration of the complaints over the academic years. In the academic year 2008/2009 the percentage students experiencing complaints 'of less than 1 hour' is highest (58%). Percentages of complaints lasting more than 12 hours (12–24 hours, a couple of days, and continuous) are highest in the academic year 2004/2005 (15%), 2008/2009 (12%) and 2013/2014 (16%).

Table 3
Duration of complaints in percentage of the group respondents with complaints within the successive academic years

	2004/2005 n = 209	2006/2007 n = 260	2008/2009 n = 244	2010/2011 n = 292	2013/2014 n = 269	All N = 1274
Less than 1 hour	49%	53%	58%	54%	45%	52%
1–6 hours	29%	32%	27%	31%	35%	31%
6–12 hours	6%	5%	2%	8%	4%	5%
12–24 hours	6%	3%	3%	2%	3%	3%
A couple of days	7%	5%	6%	3%	7%	5%
Continuous	2%	1%	3%	2%	6%	3%

χ^2 (20, N = 1274) = 41.37, p = 0.0033.

Table 4
Duration of complaints in percentage of the group respondents with complaints within the years of studying

	1st year n = 628	2nd year n = 138	3rd year n = 190	4th year n = 168	5th, 6th and 7th year n = 142	All N = 1266
Less than 1 hour	61%	46%	44%	46%	38%	52%
1–6 hours	28%	33%	31%	33%	39%	31%
6–12 hours	4%	4%	6%	6%	6%	5%
12–24 hours	1%	2%	7%	7%	7%	3%
A couple of days	3%	7%	9%	6%	8%	5%
Continuous	3%	8%	3%	2%	1%	3%

χ^2 (20, N = 1266) = 86.57, p < 0.0001.

Table 5

Seriousness OxD of complaints in percentage of the group respondents with complaints within the academic years. The indicated number of hours are the calculated hours per year in which respondents experienced complaints

	2004/2005 n = 198	2006/2007 n = 247	2008/2009 n = 234	2010/2011 n = 282	2013/2014 n = 251	All N = 1212
1–50 hours	56%	64%	69%	56%	45%	58%
50–100 hours	17%	14%	12%	15%	18%	15%
100–200 hours	9%	10%	8%	15%	14%	11%
200–400 hours	3%	4%	4%	4%	4%	4%
400–800 hours	5%	2%	2%	2%	4%	3%
800–1600 hours	5%	4%	2%	5%	6%	4%
> 1600 hours	6%	2%	3%	3%	9%	5%

χ^2 (24, N = 1212) = 53.47, p = 0.0005.

3.6. Duration of complaints per year of studying

The duration level of the complaints was also analysed per year of studying. Table 4 shows the percentages of complaints per year of studying as a function of duration level. There is a significant effect of the duration of the complaints over the years of studying. The complaints of students who have been studying for more than one year last longer than those of students who are studying in their 1st year. This can be seen by the low percentage of complaints of more than 6 hours in the 1st year of studying (11%) as compared to 21% in the 2nd year, 25% in the 3rd year, 21% in the 4th year, and 22% in the combined 5th/6th/7th year of studying. The percentage of complaints lasting more than 24 hours (a couple of days and continu-

ous) is highest in the 2nd (15%) and 3rd (12%) year of studying,

3.7. Seriousness OxD in successive academic years

The seriousness of students' WRULD complaints was calculated as the multiplication of the occurrence x duration and expressed in the total number of hours per year in which respondents experienced complaints. Respondents chose one option from a 7-alternative forced task: '1–50 hours', '50–100 hours', '100–200 hours', '200–400 hours', '400–800 hours', '800–1600', and '> 1600 hours'. Table 5 presents the percentages of complaints per academic year as a function of seriousness OxD level. There is a sig-

Table 6

Seriousness OxD of complaints in percentage of the group respondents with complaints within the years of studying. The indicated number of hours are the calculated hours per year in which respondents experienced complaints

	1st year <i>n</i> = 598	2nd year <i>n</i> = 131	3rd year <i>n</i> = 181	4th year <i>n</i> = 159	5th, 6th and 7th year <i>n</i> = 135	All <i>N</i> = 1204
1–50 hours	61%	48%	54%	61%	50%	58%
50–100 hours	16%	17%	13%	11%	18%	15%
100–200 hours	10%	11%	15%	11%	13%	11%
200–400 hours	3%	5%	5%	5%	4%	4%
400–800 hours	2%	3%	4%	5%	4%	3%
800–1600 hours	4%	7%	3%	4%	7%	4%
> 1600 hours	4%	10%	6%	3%	5%	5%

χ^2 (24, *N* = 1204) = 37.80, *p* = 0.0363.

nificant effect of the seriousness of the complaints over the academic years. Over the five academic years, the less severe complaints of 1–50 hours per year are seen most (58%, see right-most column), and is true for all recorded years in particular the year 2008/2009 (69%). The highest percentage of more serious complaints of more than 200 hours per year were found in the years 2004/2005 (19%) and 2013/2014 (23%). The highest percentage of students experiencing complaints of > 1600 hours per year was found in the academic year 2013/2014 (9%).

3.8. Seriousness OxD per year of studying

The analysis of the seriousness OxD of complaints over the years of studying is reflected in Table 6. There is a significant effect of the seriousness OxD over the years of studying. The percentage of less severe complaints of 1–50 hours per year is highest in the 1st (61%) and 4th (61%) year of studying. The highest percentage of more serious complaints (> 200 hours per year) are experienced by the students in their 2nd (25%) followed by the students in the combined 5th/6th/7th year of studying (20%). The highest percentage of students experiencing complaints of > 1600 hours was found in the 2nd year of studying (10%).

3.9. Seriousness LDA in successive academic years

The alternative investigation on the seriousness of the WRULD complaints was based on the questioned limitation of seven daily activities. These were, writing, holding a book while reading, holding a telephone, opening a jar, carrying a bag, button up clothes and teeth brushing. For each activity, there was a theoretical scaling based on a 5-alternative forced task: 1 'no difficulty', 2 'some difficulty', 3 'quite some difficulty', 4 'very much difficulty', 5

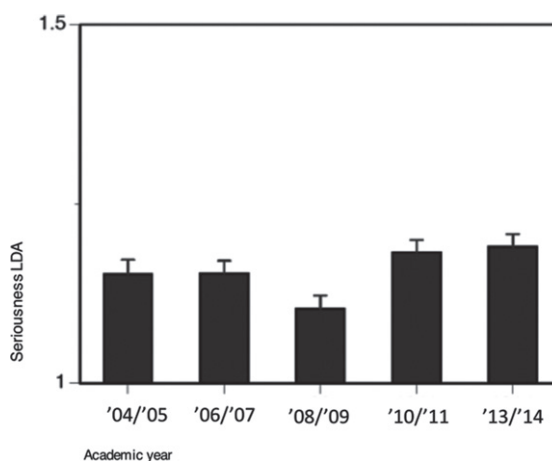


Fig. 5. Seriousness LDA; average score and standard error of the theoretical scaling of the seriousness of complaints expressed in limitation of daily activities within the successive academic years, '04/'05 (*n* = 203), '06/'07 (*n* = 257), '08/'09 (*n* = 241), '10/'11 (*n* = 285), '13/'14 (*n* = 260). Only respondents with complaints. One-way ANOVA. *N* = 1246.

'impossible'. The average score (seriousness LDA) implicated the total scores for all seven daily activities divided by seven. In Fig. 5, a bar chart presents students' limitation of daily activities as a function of academic year. The seriousness LDA over all five academic years is 1.16. There is a significant effect of the seriousness LDA over the academic years (F (4,1241) = 3.52, *p* = 0.0073). Students in the academic years 2010/2011 and 2013/2014 had more difficulties with their daily activities (respectively 1.18 and 1.19) as compared to the years 2004/2005 (1.15) and 2006/2007 (1.15). The lowest average score is measured in the year 2008/2009 (1.10).

3.10. Seriousness LDA per year of studying

Students' limitation of daily activities as a function of year of studying is presented in the bar chart of Fig. 6. There is a significant effect of

the seriousness LDA over the years of studying ($F(4,1233) = 2.38, p = 0.049$). The average score is higher in students studying multiple years (2nd – 1.17, 3rd – 1.18, 4th – 1.15, 5th/6th/7th – 1.21) as compared to students in their 1st year (1.14) although there is a slight decrease in students studying in their 4th year.

3.11. Comparison of the two types of seriousness of complaints; seriousness OxD versus seriousness LDA

The seriousness OxD in relation to seriousness LDA is indicated in Table 7. There is a significant effect of the seriousness OxD on the seriousness LDA. The average score in limitation of daily activities is higher in respondents suffering more hours per year from WRULD complaints, e.g. 1.10 for students experiencing 1–50 hours complaints in comparison to 1.47 for students experiencing >1600 hours complaints. Nevertheless, in respondents experiencing 100–200 hours complaints per year the

average limitation of daily activities is relatively high (1.27).

3.12. Body locations of complaints

The respondents could indicate multiple body locations where they experienced WRULD complaints. The results of all academic years and all years of studying together are shown in Fig. 7. The regions in the body that were indicated most often were, neck (58%), shoulders (53%) and back (43%), followed by wrist (41%).

3.13. Average number of computer working hours per day in successive academic years

The average number of computer working hours per day (whether for study, work or leisure) was questioned to the total respondents group. Respondents chose one option from a 5-alternative forced

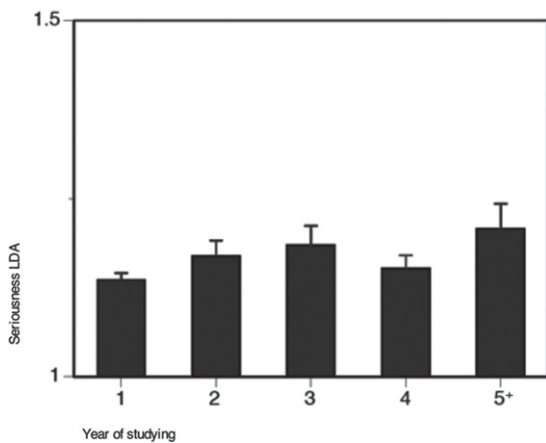


Fig. 6. Seriousness LDA; average score and standard error of the theoretical scaling of the seriousness of complaints expressed in limitation of daily activities within the successive years of studying, 1 ($n = 615$), 2 ($n = 130$), 3 ($n = 189$), 4 ($n = 170$), 5+ ($n = 134$). The years of studying 5+ contains students who study in their 5th, 6th or 7th years. Only respondents with complaints. One-way ANOVA. $N = 1238$.

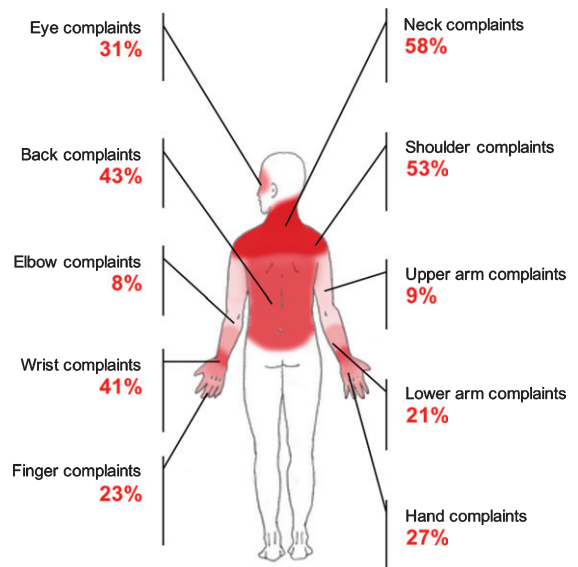


Fig. 7. Body locations of complaints in percentages of the group respondents with complaints.

Table 7

Comparison of two types of seriousness of complaints: seriousness OxD (occurrence x duration) and seriousness LDA (limitation of daily activities). Only respondents with complaints

	$n = 677$	$n = 181$	$n = 131$	$n = 44$	$n = 34$	$n = 47$	$n = 55$	$N = 1169$
Seriousness OxD	1–50 hrs	50–100 hrs	100–200 hrs	200–400 hrs	400–800 hrs	800–1600 hrs	> 1600 hrs	All
Seriousness LDA Mean/SE	1.10 / 0.01	1.12 / 0.02	1.27 / 0.02	1.15 / 0.04	1.24 / 0.05	1.41 / 0.04	1.47 / 0.04	1.15

$F(6,1162) = 30.10, p < 0.0001$.

Table 8
Average number computer working hours per day in percentage of the total respondents group within the academic years. Total respondents group. $N=2181$

	2004/2005 $n=332$	2006/2007 $n=423$	2008/2009 $n=427$	2010/2011 $n=543$	2013/2014 $n=456$	All $N=2181$
0–1 hours	7%	4%	2%	1%	0%	2%
1–2 hours	23%	16%	15%	9%	10%	14%
2–4 hours	42%	43%	41%	43%	29%	40%
4–6 hours	23%	26%	32%	34%	30%	30%
>6 hours	5%	12%	10%	13%	30%	14%

$\chi^2(16, N=2181)=199.84, p<0.0001$.

Table 9
Average number computer working hours per day in percentage of the total respondents group within the years of studying. Total respondents group. $N=2156$

	1st year $n=1269$	2nd year $n=208$	3rd year $n=268$	4th year $n=218$	5th, 6th and 7th year $n=193$	All $N=2156$
0–1 hours	4%	0%	0%	0%	0%	2%
1–2 hours	20%	2%	7%	4%	4%	14%
2–4 hours	46%	29%	40%	31%	20%	40%
4–6 hours	24%	40%	37%	38%	35%	30%
>6 hours	6%	29%	16%	28%	41%	15%

$\chi^2(16, N=2156)=425.65, p<0.0001$.

task: '0–1 hours', '1–2 hours', '2–4 hours', '4–6 hours', and '>6 hours'. Table 8 presents the percentages of respondents per academic year as a function of average computer working hours per day. There is a significant effect in the average number of computer working hours per day over the academic years. The percentage of more than 4 computer working hours per day increases every academic year (2004/2005 – 28%, 2006/2007 – 38%, 2008/2009 – 42%, 2010/2011 – 47%, and 2013/2014 – 60%). The percentage of more than 6 computer working hours per day is highest in 2013/2014 (30%).

3.14. Average daily number of computer working hours per years of studying

The percentages of respondents per year of studying as a function of the questioned average computer working hours per day is shown in Table 9. There is a significant effect in the average number computer working hours per day over the years of studying. The more years students have studied, the more hours they work with the computer. Except for the 2nd year of studying (having a relatively high percentage) the percentage of students spending more than 4 hours per day in front of the computer increases gradually every year of studying (1st – 30%, 2nd – 69%, 3rd – 53%, 4th – 66%, 5th/6th/7th – 76%).

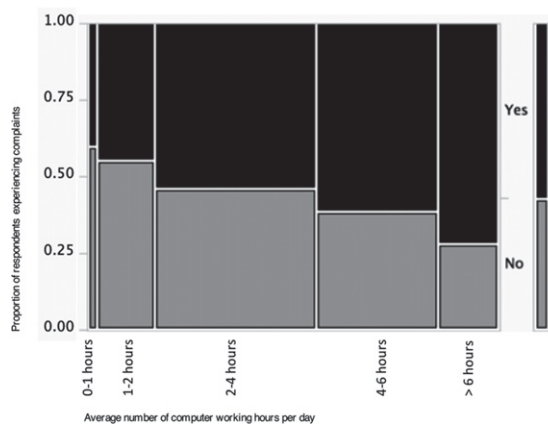


Fig. 8. Proportions of students experiencing complaints as a function of computer working hours per day, 0–1 hours ($n=52$), 1–2 hours ($n=304$), 2–4 hours ($n=863$), 4–6 hours ($n=646$), >6 hours ($n=316$). Total respondents group. $N=2181$.

3.15. Risk factors: Relation between prevalence and number of computer hours per day

The analysis was made to investigate a relationship between the number of computer hours per day and the prevalence of complaints. In Fig. 8, a mosaic graph presents the proportion of students experiencing WRULD complaints as a function of computer working hours per day. There is a significant effect ($\chi^2(4, N=2181)=31.16, p<0.0001$) between the prevalence of complaints and the reported average number of computer

Table 10

Relation between the seriousness OxD of the experienced complaints and the reported average number of computer working hours per day.
Complaints group

	0–1 hours <i>n</i> = 21	1–2 hours <i>n</i> = 131	2–4 hours <i>n</i> = 437	4–6 hours <i>n</i> = 380	> 6 hours <i>n</i> = 207	All <i>N</i> = 1176
1–50 hours	2%	12%	39%	32%	15%	58%
50–100 hours	1%	11%	45%	29%	15%	15%
100–200 hours	2%	8%	29%	40%	21%	11%
200–400 hours	2%	11%	33%	28%	26%	4%
400–800 hours	0%	8%	28%	33%	31%	3%
800–1600 hours	0%	12%	22%	39%	27%	4%
> 1600 hours	4%	9%	27%	31%	29%	5%

χ^2 (24, *N* = 1176) = 19.45, *p* = 0.0280.

working hours per day. The higher the reported average number of computer hours per day, the higher is the percentage of students experiencing complaints. The lowest percentage of complaints (40%) is found in students working 0–1 hours per day with the computer and the highest (72%) in students who work more than 6 hours per day.

3.16. Risk factors: Relation between seriousness OxD and the number of computer hours per day

In this last analysis the relationship between the seriousness OxD of the complaints and the reported average number of computer working hours per day was investigated. The results are presented in Table 10. There is a significant effect between the seriousness OxD of the experienced complaints and the reported average number of computer working hours per day. Students experiencing more serious complaints of more than 100 hours per year work more often > 4 hours per day with the computer (100–200 hours – 61%, 200–400 hours – 54%, 400–800 hours – 64%, 800–1600 – 66%, and > 1600 hours – 60%) in comparison to students experiencing less severe complaints of less than 100 hours per year (1–50 hours – 47%, 50–100 hours – 44%). Nevertheless, these students experiencing complaints of more than 100 hours per year have relatively high percentages of students that work for only 0–1 hours and 1–2 hours per day with the computer.

4. Discussion

We will discuss the results in four sections. Section 4.1 addresses the differences between academic years. Section 4.2 presents possible reasons that explain differences between academic years. Section 4.3 addresses how WRULD evolve over the number

of years of studying. Section 4.4 addresses possible explanatory factors causing differences between years of studying. Finally, we compare our outcomes with previous findings in Section 4.5.

4.1. Differences between academic years

In the time-period 2002–2014 a decrease in the prevalence, occurrence, duration and the two alternative measures for the seriousness of WRULD have been observed from the first (2004/2005) to the third (2008/2009) or fourth (2010/2011) recorded academic year followed by an increase of these values to the fourth or fifth academic year (2013/2014). In this last academic year 2013/2014, the prevalence is only slightly lower than the highest level in 2004/2005. The seriousness OxD (and also its separate factors occurrence and duration) and seriousness LDA show the highest scores in the last academic year 2013/2014.

The complaints group data of all academic years (and all years of studying) show a clear relationship between the seriousness OxD and the seriousness LDA indicating that the limitation in daily activities is higher in respondents suffering more hours per year from WRULD complaints.

4.2. Possible explanatory factors causing differences between academic years

This aggravation of WRULD in the last academic years cannot be explained by the increase of daily computer working hours spent by students every academic year as observed in this study and the in this study confirmed relationships between both WRULD prevalence/reported daily computer working hours and seriousness OxD of WRULD complaints/reported daily computer working hours. Because initially, WRULD amongst IDE students

seemed to ameliorate during the first three years of our measurements despite the students' increasing daily computer working hours. As discussed in the previous study [9] on WRULD amongst IDE students and in parallel to the possible effect of the previously discussed nation-wide attention for work-related causes and prevention measures in the professional work environment [1], the IDE prevention programme [9] may have contributed to this reduction of WRULD problems over the first three or four academic years. Can we distinguish which internal and external factors of the IDE student community have contributed to the aggravation of WRULD starting from 2008/2009?

Several far-reaching developments in the study regulations might have contributed to these changes in the WRULD figures. The Bachelor-before-Master rule has been enforced at Delft University of Technology in September 2010, after a negotiation period starting in 2006. Up to then, it was possible for students who had not yet completed their Bachelor's degree programme to start a Master's degree programme at the same institution. Since the implementation of the Bachelor-before-Master rule, students had to finalise their total Bachelor programme before starting their Masters. The rule was implemented nation-wide in 2012 when it was incorporated into the Dutch Higher Education and Research Act (WHW). Another important measure in particular for the 1st year students, was the Binding Recommendation on the Continuation of Studies (BSA) introduced in September 2009. Students had to attain a minimum number of credits (starting with 50% in 2009 and tightened to 75% in 2012) in their first Bachelor year in order to be allowed to continue with their studies. In the same period of time the study grant (= studiefinanciering in Dutch) was abolished. In September 2012 the grant for only Master students was replaced by a loan system and in autumn 2015 as well for new 1st year students. These three measures were not yet in force in the early recorded academic years 2004/2005 up to 2006/2007. It is most likely that these three societal measures have increased the study load and consequently stress for students. The relationship between stress and the occurrence of WRULD amongst adolescents and students has been established in former studies [15, 16].

4.3. Differences between years of studying

Regarding the WRULD related trends in the years of studying there is clear difference between students

studying in their 1st year as compared to students studying multiple years. The values for prevalence, seriousness OxD (and its separate factors occurrence and duration) and seriousness LDA are lower in students who just started studying as compared to students who have been studying for a longer time. The prevalence of WRULD increases up to the 4th year of studying and shows a slight reduction in the combined 5th/6th/7th year. The occurrence, duration and consequently the seriousness OxD show the highest values for the 2nd year of studying and the second highest for the combined 5th/6th/7th year of studying. The seriousness OxD in the 4th year of studying is relatively low. When considering the alternative seriousness LDA, the inhibition increases in the first three years and shows as well a reduction in the 4th year of studying and the highest value for inhibition in the combined 5th/6th/7th year of studying.

4.4. Possible explanatory factors causing differences between years of studying

The low prevalence rate of complaints in students in their 1st year as compared to students studying multiple years is expected and similar to the results in the former study on WRULD amongst IDE students [9]. These 1st year measurements were taken around the second month of their studies so students didn't meet many deadlines yet and spent the least daily computer working hours from all years of studying. The gradual increase of WRULD complaints prevalence throughout the higher years goes in parallel with the gradually increasing daily computer time in higher years of studying. The question stated in the former study [9], whether the higher percentage of students experiencing complaints in higher years of studying was related to the higher reported average number of computer hours per day in these years, can be positively answered. However, more aspects might play a role in the increasing prevalence in higher years of studying, such as the high study load of the master programme, their improved commitment and responsibility towards clients and peers in real-life projects, and perhaps also the more tangible financial consequences of their studying.

The slight reduction in WRULD prevalence in students in their 5th/6th/7th year of studying is standing out of this pattern and might be explained by students' improved freedom in organising their study activities. Most students in their 5th/6th/7th year of studying are enabled to choose courses of interest, to define their individual graduation project, to alternate between

Table 11
Percentages of complaints per body locations - in relation to the group respondents with complaints

	Eyes	Neck	Shoulders	Back	Upper arm	Elbow	Lower arm	Wrist	Hand	Fingers
2004–2014 - complaints group $N=1293$	30,8%	58,2%	53,4%	43,2%	8,7%	8,2%	21,2%	40,9%	27,5%	23,1%
2002/2003 - complaints group $N=92$	34,8%	54,3%	55,4%	38,0%	7,6%	14,1%	26,1%	60,9%	30,4%	28,3%

tasks and between study and non-study related activities.

The effect of the seriousness OxD over the years of studying and the increase in seriousness OxD in the 2nd and combined 5th/6th/7th year of studying was not found in the previous study on IDE students [9], but are in line with the observed high scores of daily computer working hours in these years of studying. However, the scores of both the seriousness OxD and seriousness LDA gives an opposite picture in the 4th (relatively low scores) and 5th/6th/7th year of studying (relatively high scores) as compared to the aforementioned prevalence rates. A possible explanation could be that students in the 4th year of studying may have learned how to cope with their WRULD risk factors within the IDE environment and prevent them from getting worse. For students in the combined 5th/6th/7th year of studying on the other hand, their WRULD complaints history, the pressure to finalise all courses, to find a suitable graduation project, and to bring their master study to a successful conclusion might contribute to aggravation of the complaints.

4.5. Comparison with previous findings

The body locations of the complaints that were most often indicated by the complaints group in this study were, the neck (58%), shoulders (53%) and back (43%), followed by wrist (41%). The results of all body locations can be seen in Table 11 together with the results of the academic year 2002/2003 as described in the former study on IDE students [9]. Percentages are taken in comparison to only the respondents group with complaints. The results of the 2002/2003 measurements shows similar percentages for most body locations. Nevertheless, the (2004–2014) study of this paper shows a lower percentage of wrist complaints.

Highest prevalence rates of neck and shoulder complaints were also found in the studies of Palm et al. [5] on upper secondary school students and in the study of Hakala et al. [13] on adolescents. Also Noack-Cooper et al. [6] found in their study on college students the neck region to be the most common site of frequent discomfort and pain.

As stated at the start of this discussion, the association of self-reported average number of computer working hours and the prevalence of WRULD symptoms as found in other studies [5, 10–12] was confirmed in our findings. The higher the reported average number of computer hours per day, the higher is the percentage of students experiencing complaints. Also the relationship in the Hakala et al. study [13] between the self-reported average number of computer working hours and the seriousness of WRULD symptoms was confirmed in our study based on the found relationship between computer hours and seriousness (OxD). Nevertheless, students experiencing more serious complaints (of more than 100 hours per year) have relatively high percentages of students that work little hours (0-1 hours and 1-2 hours per day) with the computer. Their complaints might hinder their long-term working with the computer.

Boström et al. found in their study [7] among young adults that pain, ache, numbness or tingling symptoms in the upper back, neck and upper extremities had a relation with self-reported generally reduced productivity. In the (2004–2014) study of this paper, these body locations were also investigated and subjects experienced similar complaints (pain, numbness, tingling). So, it is probable that the complaints found in our study influenced students' productivity as well. The economic consequences for both the individual student, the government as well for the university, of students who were no longer even able to study (their entire programme) due to WRULD were previously described and estimated for the student population of Delft University of Technology [9].

At the beginning of this paper we saw the decreased reporting of WRULD between 2001 and 2018 in the occupational environment of The Netherlands [1, 2]. It is tempting to compare these results with our results of the Dutch student population. Unfortunately, this comparison does not hold because the investigated population of the Dutch Centre for Occupational Diseases includes beside computer-related occupations also professions in e.g. the transport, industry, and construction sectors. There are also differences in the body locations studied. However, we learned from

these professional figures that structural attention for causes and prevention measures for WRULD in computer work possibly contributed to the downward trend. It seems that we can also bring about such a WRULD prevalence decrease in the educational environment as was also shown in the studies of Jacobs et al. [3, 4]. Such a positive trend in the prevalence but also in the severity of the complaints appeared to have been initiated in the first academic years of our study, possibly as a result of the structural attention for WRULD prevention and risk factors within the student environment of our focus [9]. Looking at the extent and severity of WRULD complaints during the last academic years of our study, it seems that governments should be cautious about (the introduction of) loan systems combined with limitations on study time in view of not only a healthy student population but also a healthy well educated group of young professionals entering the market.

The effects on WRULD of the actual societal change in students' lives due to the COVID-19 restrictive measures and related increase of stress, still need to be investigated. However, from the first short term studies on this actual topic we can deduce that the pandemic seems to have both positive and negative effects on physical complaints of computer workers. Celenay et al. [17] showed that due to COVID-19 individuals in Turkey of the age group 20–65 who stayed at home compared with those who continued to go to work had more low back pain problems. Nevertheless, this increase was not shown at all regions; rates of neck, upper-back, and shoulder pain were lower. Another study in Turkey on individuals aged between 12–78 years conducted by Sengul et al. [18] showed a small decrease in the frequency of pain and discomfort in multiple body regions and a small increase of the severity of pain and discomfort in body regions - (lumbar) back region and the neck - during the quarantine when compared to the level before the quarantine. A third Turkish study by Pekiyaş and Pekiyaş [19] on the age group 18–50, showed that individuals working at home during the COVID-19 pandemic developed moderate shoulder and low back pain. The study of Leirós-Rodríguez et al. [20] on university students during the Spanish lock down between the months March and May 2020, found a musculoskeletal pain increase of the middle (dorsal) region of the back and in both shoulders (this region only in woman) and a reduction of pain in the elbows, hands and one of the shoulders during the lockdown in which students had transitioned from classroom learning to online learning. If we look at

these studies, it seems that back pain increased in the situation of online working from home and that more distal upper limb disorders decreased. Nevertheless, further research is needed to investigate the effects of COVID-19 on WRULD amongst students.

5. Limitations of the study

There are some limitations which might have influenced the outcomes of the research. The awareness for WRULD might have been high in particular for the first year student group, because these questionnaires were handed out at the end of a WRULD prevention information session. This might have influenced the awareness of participants' complaints. However, this was done every year which means that trends in time are still valid.

Unfortunately we did not continue with the questionnaires after 2014. However, our results show that the data on prevalence and seriousness is quite consistent over the investigated academic years, beside the fluctuations attributed to the described societal changes. Since we are not aware of such substantial societal changes within the period 2014 up till 2020, we might assume that the result would not have been too different as compared to our last measured academic year.

Another limitation is that the meaning of the questioned term 'computer' has changed over the time span 2004–2014. Starting with mainly desk top computer stations, it transformed to more and more mobile solutions via laptops, tablet and smart phones. Honan [21] described that these changes evoked a shift to working from anywhere imaginable and ever-present access to data over the internet. She indicated that additional risks have been introduced to the neck, thumbs and hands when using mobile devices, which might have influenced our outcomes.

The reported computer working hours and associated complaints do not distinguish between computer work for study, work and leisure. The study-related causes mentioned in the discussion might not be totally valid, because leisure activities could be relevant as well. On the other hand the intermingling of study, work and leisure activities is a reality and preventive interventions might impact all.

6. Conclusion

More than half of the students surveyed between 2004–2014 experienced WRULD symptoms, especially in the neck, shoulder, back and wrist. The

highest prevalence rates were found in the first and last recorded academic years. Also the highest percentages of more serious complaints (based on the multiplication of their reported occurrence and duration of their complaints as well as their limitation in seven daily activities) were found in these academic years. The prevalence of complaints among students raises from their 1st to their 4th year of studying. Both measures for the seriousness of the complaints show highest scores in students who are studying in their year 5th/6th/7th year. Relations were found between the reported number daily computer hours and WRULD prevalence and the reported number daily computer hours and the seriousness of the WRULD complaints. However, not all results could be explained on the basis of the reported computer time spent. Societal changes like the introduction of loan systems combined with limitations in study time may have played an even more important role. It is very likely that the societal changes in students' lives resulting from COVID-19 are also driving a change in WRULD amongst students. Our study confirmed that structural attention for WRULD prevention and risk factors seems to be effective in reducing the number and severity of WRULD complaints. For these reasons, prevention programmes remain important and must be adapted to the recent societal changes.

Acknowledgments

We are appreciative for the voluntarily participation in this study of two-thousand-two-hundred-and-fifty-four (2254) students Industrial Design Engineering. Additionally, we would like to thank Cesar therapists Cees Verhoeven and Jeroen Hutten and the involved IDE staff members to help distributing and collecting the questionnaires. Furthermore, we are grateful to Henk van der Molen and colleagues of the Dutch Centre for Occupational Diseases for allowing us to include the figures on reported occupational diseases related to upper limb disorders in our article. And we are very thankful to Renate de Bruin (now owner of Erin Ergonomics and Industrial Design), who started a questionnaire on the WRULD topic already in 1999, helped evolving the questionnaire as used in our study and advised on several aspects of this paper.

Conflict of interest

None to report.

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