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Variability in the skin exposure of machine operators exposed to cutting fluids

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Objective This study describes a new technique for measuring skin exposure to cutting fluids and evaluates the variability of skin exposure among machine operators performing cyclic (repetitive) work.

Methods The technique is based on video recording and subsequent analysis of the video tape by means of computer-synchronized video equipment. The time intervals at which the machine operator's hand was exposed to fluid were registered, and the total wet time of the skin was calculated by assuming different evaporation times for the fluid. The exposure of 12 operators with different work methods was analyzed in 6 different workshops, which included a range of machine types, from highly automated metal cutting machines (ie, actual cutting and chip removal machines) requiring operator supervision to conventional metal cutting machines, where the operator was required to maneuver the machine and manually exchange products.

Results The relative wet time varied between 0% and 100%. A significant association between short cycle time and high relative wet time was noted. However, there was no relationship between the degree of automatization of the metal cutting machines and wet time.

Conclusions The study shows that skin exposure to cutting fluids can vary considerably between machine operators involved in manufacturing processes using different types of metal cutting machines. The machine type was not associated with dermal wetness. The technique appears to give objective information about dermal wetness.

Key terms hand eczema, occupation, skin exposure.

Exposure to cutting fluids is a common cause of contact dermatitis on the hands and arms of machine operators (1, 2). Contact dermatitis is an inflammation of the skin; it can occur via either nonimmunologic or immunologic mechanisms. Irritant contact dermatitis occurs via nonimmunologic mechanisms, and both environmental and host-related factors are of importance. The single most important environmental factor is the role of water and wet work (3). Most cases of contact dermatitis in metal working operators exposed to cutting fluids are of the irritant type (2). Contact dermatitis can also occur from contact allergic sensitization to specific substances in the cutting fluids (eg, biocides). The intensity and duration of skin exposure influence the risk of contact dermatitis of both the nonimmunologic and immunologic type.

Methods for evaluating dermal exposure include techniques with a collection medium placed on the machine operator's skin, removal techniques with which deposited substances are removed by washing or wiping, and fluorescent tracer techniques with which fluorescence of substances deposited on the skin is measured (4). The exposure can indirectly be measured through changes in the skin. Evaporimeters measure the evaporation of water from the skin (5) and laser Doppler flow meters record the blood flow (6, 7). In a previous study we used the occurrence of oil acne as an indicator of skin exposure to cutting fluids in a workshop (8). However, oil acne is rare when water-based cutting fluids are used. Today, many cutting fluids are water based. The physician treating a machine operator with hand eczema usually

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estimates the exposure only based on the operator's medical record.

The objective of this study was to develop and evaluate a new technique for estimating skin exposure. A further objective was to study the variability of skin exposure to cutting fluids among machine operators using different types of metal cutting machines (ie, actual cutting, chip removal and grinding machines).

Subjects and methods

New technique for recording skin wetness

The technique used is based on video recording and subsequent analysis of the video tape. The equipment was developed by Engström & Medbo (9) for analyzing the interrelationship between productivity and, for example, musculoskeletal work load (in this specific case chosen to be articulated as work postures). The video tape is complemented with time coding, replayed with a continuously variable speed. The video recorder is then connected to a computer, and the video sequences are shown on a monitor. The activities on the tape are registered by a specially designed maneuver panel shown on the computer screen. During the analysis, the video observer records the starts and stops of specific activities (ie, when the machine operator gets cutting fluids on his hand, etc). The time intervals at which the machine operator's hand is exposed to fluid are stored in a computer file. The computer-synchronized video equipment and developed software make it possible to run the tape at different speeds, in turn allowing a detailed time analysis with a resolution of 0.04 seconds.

From the video tape the time periods (t_w) during which the machine operator's hand is exposed to cutting fluids are registered. Note that the skin will remain wet some time after the actual wetting has occurred (ie, until the cutting fluid has evaporated or the machine operator has cleaned and dried his hand. We are not aware of any technique measuring the evaporation time suitable for shop floor registration of the work of a machine operator. We have therefore assumed a constant evaporation time (E) after each wetting event. For the i:th wetting event, the corresponding duration of dermal wetness is prolonged by time t_{di}, that is, the shortest of either the evaporation time E or the time until the hand comes in contact with the cutting fluid during the next wetting event. It is obvious that, if the evaporation time is longer than the time between subsequent wetting events, the skin will be wet all the time.

In this study we have investigated cyclic work (ie, the same production tasks were done several times during a workshift). If the hand was wet n times during the measurement period, the total wet time (W_T) is given by:

$$W_T = \Sigma_i (t_{wi} + t_{di}),$$

where i runs from 1 to n.

If the total worktime during the measurement period is T, the relative wet time (W_R) during the observed cycles is given by:

$$W_R = \Sigma_i (t_{wi} + t_{di}) / T. \qquad \text{(equation 1)}$$

According to Rieger (10), the evaporation time for emulsions rarely exceeds 3 min. For each machine operator, W_T was calculated for evaporation times (E) of between 0 and 3 minutes.

Our experience during this work was that the machine operators rarely cleaned their hands during the cyclic work. However, if the machine operator did clean his hands, these events had to be recorded during the cycles and considered in the calculations. In the analysis we have studied the relative wet time (W_R) and the wetting times (t_{wi}) for the hand which had the longest relative wet time.

Subjects

Twelve different machine operators from 6 workshops were included in the study. For 2 cases (denoted numbers 8 and 9 in table 1), the production task and the machine used were the same, but the work methods varied with different machine operators. To simplify the video recording, we deliberately selected stationary work (ie, operators occupied with work beside a metal cutting machine). The study was limited to metal workshops using water-based cutting fluids. The workshops were chosen to give a range of machine types from highly automated to conventional, manually maneuvered, metal cutting machines (table 1). The most automated metal-cutting machines exchanged tools and products automatically through computer control and utilized computer-controlled tools. With the conventional metal-cutting machines, the tools and the products were manually exchanged. Between 4 and 56 cycles were recorded for the 12 work methods, ranging from video registrations from approximately 20 to 400 minutes in order to cover a wide scope of machine types and work methods.

Results

There was considerable variation in the observed cycle times, from 41 seconds to 33 minutes (table 1). The relations between the relative wet time and the evaporation time in work methods 1, 2 and 7 are presented in figure 1. Work method 2 shows an operator using a highly automated machine with a long cycle time (mean 33 minutes), for which the relative wet times were very short even if the estimated evaporation time was 3 minutes. In work method 1, the operator used a machine with a mean cycle time of 4 minutes, during which the products were automatically handled. In this case the relative wet time varied between 30% and 60% of the total worktime depending on the estimated evaporation time of 1—3 minutes. The machine operator in work method 7 used a computer-controlled machine, but he would still be wet almost all the time regardless of whether the evaporation time was 30 seconds or 3 minutes. The mean cycle time in this operation was only 41 seconds.

For each work method, a relative wet time was calculated on the assumption of an evaporation time of 2 minutes (table 1). Table 1 shows that the relative wet time varied considerably between the work methods. In work methods 8 and 9 the machine and production were the same. The machine operator in work method 9 had a more efficient work method (due to fewer controls of finished products and shorter distance between the machine and the products), which resulted in shorter cycle times (mean 114 seconds compared with 179 seconds). He also used crepe paper when he grabbed the wet products and was not in contact with the cutting fluid at all (W_R=0), while the machine operator using work method 8 had a relative wet time of 77%.

There was an association between cycle times and relative wet times when an evaporation time of 1, 2 or 3 minutes was assumed (figure 2). Short cycle times were associated with large relative wet times. The relationship was similar for evaporation times between 1 and 3 minutes (r=–0.621 for E=2 min, P=0.034). However, the time that the skin was in contact with the cutting fluid (t_{wi} mean) did not show a significant association with cycle time (r=0.286, P=0.4).

The mean wetting times (t_{wi}) varied considerably (3—47 seconds) (table 1). There was no significant correlation between relative wet time (with an evaporation time of 2 minutes) and a mean wetting time (r=0.23; P=0.5) for the different work methods.

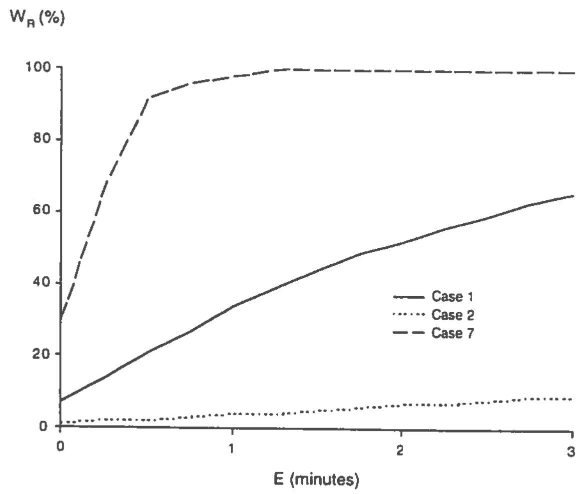

Figure 1. Relative wet time (W_R) according to evaporation time (E) in work methods 1, 2, and 7.

The degree of automatization (ie, how automated the metal-cutting machines were) did not show any obvious relationship with the relative wet times. The relative wet time was 51% for the machine with automated material handling (work method 1), while shorter as well as longer relative

Table 1. Types of metal cutting machines and production tasks, cycle times, relative wet times, and wetting times. (CV = coefficient of variation of the cycle times, W_R = relative wet time, according to equation 1, t_w = mean of the wetting times)

Work method	Type of metal cutting machine[a]	Production tasks	Mean cycle time (s)	CV (%)	W_R (%)	t_w (s)
1	Computer-controlled cutting tools, automatic exchange of tools and products	Cutting rails	237	91	51	11
2	Computer-controlled cutting tools, automatic exchange of tools and manual exchange of products	Working flanges	1993	2	7	23
3	Computer-controlled cutting tools, automatic exchange of tools and manual exchange of products	Machine working clamps	745	24	17	3
4	Computer-controlled cutting tools, manual exchange of tools and products	Testing of drills	710	96	18	23
5	Computer-controlled cutting tools, manual exchange of tools and products	Turning large bearings	1779	8	21	5
6	Computer-controlled cutting tools, manual exchange of tools and products	Turning small bearings	156	16	74	4
7	Computer-controlled cutting tools, manual exchange of tools and products	Beveling axe handles	41	30	100	14
8[b]	Manually controlled cutting tools, manual exchange of tools and products	Turning pipes	179	30	77	37
9[b]	Manually controlled cutting tools, manual exchange of tools and products	Turning pipes	114	25	0	0
10	Manually controlled cutting tools, manual exchange of tools and products	Drilling holes in L profiles	409	46	99	8
11	Manually controlled cutting tools, manual exchange of tools and products	Drilling holes in large girders	404	29	56	9
12	Manually controlled cutting tools, manual exchange of tools and products	Drilling holes in discs	1467	11	22	47

[a] The type of metal cutting machines used is ranked according to the degree of automation where number 1 is the most automated machine incorporating automated material handling, automated exchange of tools and computer-controlled tools.
[b] Identical cutting machines.

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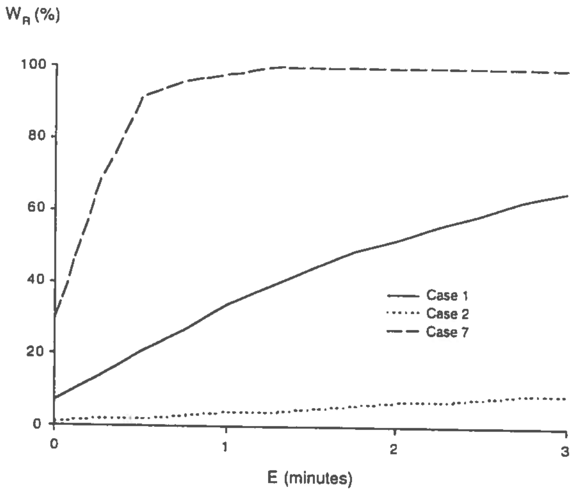

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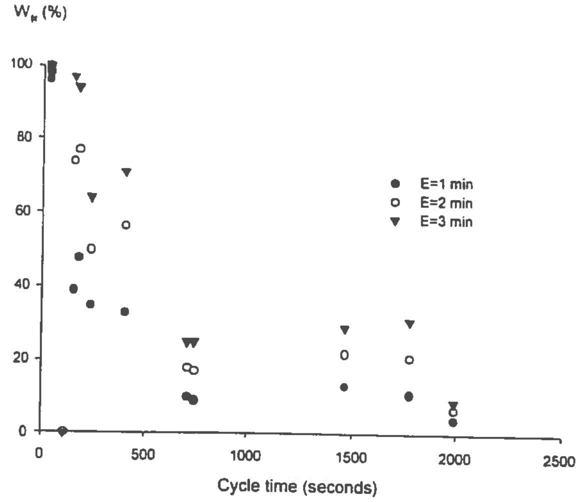

Figure 2. Relative wet time (W_R) according to cycle time on the assumption of evaporation times (E) of 1, 2, and 3 minutes.

wet times occurred with conventional metal cutting machines.

The work methods were classified into activities of handling the machine, moving products, and cleaning products and tools. In 5 (work methods 1, 2, 5, 7, and 10) of the 12 cases (ie, 42%), cleaning caused the hand to be soaked with cutting fluid. In 2 cases jigs were used. The hand was soaked in both cases during the handling of the jig. Moving products caused wetting of the hand in all cases but 3. In 2 of the work methods (5 and 11) the machine operator used cranes to move the products. In case 8 the machine operator wrapped the product in crepe paper when he moved it to and from the machine.

Discussion

This study indicates that there is an association between cycle time and relative wet time. However, case 9 with a rather short cycle time had no wetting. Thus merely measuring the cycle time gives an insufficient measure of the relative wet time. There was no obvious association between the type of machine and the relative wet time, even though it might have been assumed that highly automated manufacturing processes would mean a rather short wet time for the skin.

In most cases, the work method was defined by the machine type used and the production task performed (ie, the actual possibility for the operator to choose alternative sequences of worktasks, including type of worktask, was in fact determined by the machine design). However, work methods 8 and 9 showed that the relative wet time could be reduced by applying another work method, despite the fact that the production task and the machine type were the same. Hence, in some cases, the machine operator can affect the relative wet time by varying the work methods. This ought to be the case especially for machines with a low degree of automatization since the proportion of manual worktasks is more extensive and since alternative work sequences might exist.

Exposure of the skin is an important determinant of the risk of contact dermatitis. Therefore, patients with hand eczema caused by contact with cutting fluids may require an analysis of the actual amount of dermal exposure, not only of the cutting fluid content.

This study was limited to 12 cases, which were not randomly selected. However, the results show that dermal wetness of the hands can vary considerably, from 0% to 100%, for machine operators performing cyclic work with metal-cutting machines using cutting fluids. Our findings indicate that classifying the type of cutting machine used seems to be a nonvalid surrogate for an actual measurement of the wet time in predicting the degree of wetness on the hands of machine operators.

Furthermore, since some of the work methods studied involved very little actual skin contact with the cutting fluids, it might sometimes be possible to transfer an operator with irritant contact dermatitis to another type of work method within a specific workshop, or, if a worker has allergic contact dermatitis (eg, caused by a biocide) the cutting fluid can be replaced by one with a different composition. However, many types of contact dermatitis among machine operators are nonallergic.

Our technique is based on the ocular observation of video tapes and the registration of time sequences to record the moment of time the hand of a machine operator is in contact with a cutting fluid. Such contact can occur in rinsing operations, the gripping of a wet product or a tool, or the touching of machine parts that are covered with cutting fluid. The latter type of contact requires some judgment as to whether the object or machine is wet. Therefore it is important that the person analyzing the video tape also be present at the workshop studied during some of the video recording.

For the calculation of the relative wet time, a specific evaporation time has to be assumed. We are not aware of any method measuring different evaporation times on a shop floor. Evaporation times probably depend on, for example, the composition of the cutting fluid, which may vary between days and different worksites and according to the temperature of the cutting fluid and the amount of fluid deposited on the skin. Therefore the relative wet times estimated for our cases may not be entirely comparable, and consequently the analysis between, for example, cycle times and relative wet times may be biased. However, large relative wet times may still imply that the machine operator is at risk of contracting contact dermatitis.

Depending on the type of contact (eg, rinsing, volar grip or finger grip), the amount of cutting fluid transferred to the skin differs and, consequently, so does the evaporation time.

One possibility for developing the technique to estimate the relative wet time would be to analyze each type of contact separately and to assume a longer evaporation time for rinsing, a shorter evaporation time for finger grip, and the like. The size and location of the wetted hand area might also, in this case, be of importance.

However, an analysis based exclusively on the time of contact with a wet surface may, in most cases, be misleading since very short but frequent contacts give a long relative wet time despite a short total wet time, due to the fact that evaporation time has not been taken into account.

The absorption of components in the cutting fluid varies according to substance. If the purpose is to measure the uptake of substances and systemic effects, other methods may be more suitable (eg, measuring the concentration of the substance in blood). However, our technique may be a complement to analyzing wet periods if there is a need to decrease dermal exposure.

Sprince et al (11) did not find any association between dermatitis and skin exposure to cutting fluids when measured with a dermal dosimeter attached to the midforearm. However, they did find an association between daily self-reported number of hours when the operators' skin or clothes were wet from cutting fluids. A dermal dosimeter only measures the cumulative dose, not the frequency with which the skin becomes wet or the time during which the cutting fluid evaporates from the skin. A cumulative dose may therefore be a less appropriate measure of skin wetness in the cyclic work reported in this paper, since the skin is in intermittent contact with the fluid during the workshift.

Our study was restricted to cyclic work with cutting fluids, but the technique suggested can be used to study the dermal wetness in several types of worksites (eg, kitchen work in restaurants, work in the food processing industry, cleaning, etc). Since it gives an objective measure of the total and relative wet time, it is obviously better than a description of worktasks or a short visit to the worksite, as is the traditional approach what is in reality a complex interaction between man and machine.

Acknowledgments

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