# EFFECT OF MODERATE COLD EXPOSURE ON MANUAL DEXTERITY: ASSESSMENT WITH TWO DEXTERITY TESTS

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**ABSTRACT**

Moderate cold exposure at -5°C and 5°C significantly decreased finger and hand skin temperatures. A keyboard typing test responded promptly to the decreases in the hand temperature even when the hand temperature was above the threshold temperature (20°C) for performance decrement that was defined in the previous studies. This finding could be helpful to building safety guidelines for working in cold environments.

**INTRODUCTION**

Manual performance is a combination of many kinds of skills that require good tactile sensitivity, hand dexterity, muscle strength and motor coordination. Dexterity is defined as ‘‘fine, voluntary movements used to manipulate small objects during a specific task’’ [1] and is typically an integral part of a thorough evaluation of the hand. An examination of dexterity provides a unique way of evaluating the neuromotor function of the entire hand because sensation and intrinsic hand strength combine to produce the manipulative skills that facilitate dexterous movements. A study conducted by Williams et al. [2] demonstrated that dexterity was the best predictor of independence in activities of daily living (ADL) within a cohort of geriatric females.

Exposure to cold environments has been reported to cause impairment in hand performance [3-7]. Such impairment could result in a reduction in manual performance; more importantly, it has been revealed that this impairment may lead to an increased number of accidents [4]. Even though a critical influence of hand and finger skin temperature on manual performance under severe cold exposure (-25°C to -20°C) [3,6] or mild cold exposure (above 5°C) [5] has been reported, to our knowledge, the degree to which skin temperature contribute to hand and finger dexterity under moderate cold exposure (-5°C to 5°C) seems not to be well documented. Furthermore, it is not clear which dexterity tests are sensitive to moderate cold exposure.

In this study, the Grooved Pegboard Test (GPT, Lafayette, IN) was used to examine changes in finger and manual dexterity in the participants. This test was preferred over other more commonly used dexterity tests (e.g., Purdue pegboard test) because its performance requires fine manipulations at the thumb and index fingers; each peg has a key along one side and must be rotated appropriately to match the groove before being inserted into the corresponding hole [8]. In addition to the grooved pegboard test, a keyboard typing test was also used to assess hand dexterity and motor coordination. Keyboard typing is an everyday, routine activity for a large portion of the population. With the increasing usage of mobile devices, individuals may present the need to type in the cold. Typing involves quick and accurate finger movements, which can be partially attributed to finger dexterity, however, the activity of typing is unique in the way that it also involves factors such as cognitive abilities (i.e practice, skill), finger agility (i.e finger tapping utilizing all fingers in patterned movements), and tactile sensitivity (ability to discern how hard/far to press a key). In this study, typing speed and accuracy were examined for individuals exposed to the cold temperatures. The purpose of this study was to determine whether the Grooved Pegboard test and keyboard typing test were sensitive to moderate cold exposures.

## METHODS

Ten young healthy male participants (age: 21.1±0.9 years; BMI: 23.7±4.9 kg/m$^2$), mainly university students, participated in this study. All participants were normotensive, nonsmokers, and not taking any medications that might alter the cardiovascular or thermoregulatory responses to cooling. The protocol was approved by the Toronto Rehabilitation Institute Research Ethics Board. Prior to data collection, each participant was provided a clear description of what was required for participation and thereafter was asked to carefully read and sign the consent form. Participants were given the right to withdraw from the study at any stage.

A repeated measures design was used and each participant was tested under two cold conditions: T1: air temperature = -5 ± 0.1 °C, relative air humidity 64 ± 4% and T2: air temperature = 5 ± 0.1 °C, relative air humidity 39 ± 11%. On the first visit to the laboratory, participants were randomly assigned to receive either T1 or T2, followed by the remaining condition during the second visit. T1 and T2 treatments were counterbalanced. The skin temperatures were measured using thermistors (Mon-a-therm Temperature Probe, Nellcor Puritan Bennett Inc., Pleasanton, CA, USA) from 7 sites: forehead, lower back, right forearm, back of right hand, back of the intermediate phalanx of right thumb, right middle finger, and right little finger. Skin temperature values were recorded throughout the experiment at 8-s intervals with a data logger (Smartreader 8+, ACR Systems, Canada). The tip of each thermistor was in direct contact with the participants' bare skin. Each thermistor tip was covered with a 3-cm strip of 3M TransporeTM tape (3M Health Care, USA) to help minimize the effect of the ambient air on the reading.

The laboratory protocol involved 20 min baseline period, 20 min cold exposure period and 20 min recovery period. During the baseline period, the participants sat in a thermally neutral room with air temperature 22 ± 0.9 °C, air velocity less than 0.2 m/s and relative air humidity 40 ± 6%. The clothing they wore consisted of a long-sleeved shirt, briefs or boxers, trousers, ankle socks and running shoes. After the baseline period, the participants put on a winter coat, a scarf and a hat, then walked slowly 10 m to a climatic chamber. This ensemble resulted in an estimated insulation (clo) value of approximately 1.3 at rest. However, all subjects were bare-handed for the duration of the experiment. Thus, we sought to achieve the ''worst case'' scenario and isolated the effects of hand temperature on dexterity [4]. After the cold exposure the participants walked slowly back to the thermally neutral room and removed their winter coat, scarf and hat. During the periods that the participants were not performing tests, they were sitting quietly.

During each period, at minute 15, the participants performed two dexterity tests.

1) Grooved Pegboard test. This test is a unique dexterity assessment in that each peg has a ridge on one side and therefore must be oriented correctly to fit into a hole on the pegboard. This lock-and-key feature of the peg and pegboard necessitates visual attention to task and thumb and index finger manipulation of the peg. This test consisted of grooved pegs and keyholes positioned at different angles. All pegs were grooved identically, and participants were to correctly place the pegs in the holes from left to right, row by row. The results from this test were the number of pegs the participant could place within the 30 seconds.

2) Typing test. This test uses a standard typing program, to measure words per minute (wpm) with error correction factor, participants were given 2 minutes to type as many words as possible. To eliminate any typing bias or memory recognition of word strings, the program administered words in the form of 5 random letters per word with no letter repetition in adjacent letters. Punctuation marks, upper case lettering, and the space key were also removed to reduce bias.

Preliminary analyses included calculation of mean (SD) values of all of the examined parameters. All skin temperature data were stored as 1-min averages and the values at the end of the dexterity tests were used for the analysis. All conditions were compared using repeated-measures ANOVA followed by post hoc t-tests incorporating a Bonferroni adjustment. The results were considered significant when $p < 0.05$.

## RESULTS

The effects of cold exposure on skin temperatures

After 15 min of sitting in the cold, skin temperatures at lower back remained warm, while temperature at forehead decreasing from 33.0± 1.0°C to 30.8 ± 2.4°C at T2(5°C) condition and decreasing to 30.7 ± 1.8°C at T1(-5°C) condition ($p<0.05$), but there was no difference in temperature at forehead between T1 and T2 conditions. Skin temperature at forearm decreased significantly only at T1 condition ($p=0.007$) but not at T2 condition ($p=0.26$). Hand and finger skin temperatures decreased significantly during the cold exposure, and showed significant difference at the end of the 15-min exposure between T1 and T2 (Table 1~~Table 1~~).

Manual performance

The results of the manual tasks are summarized in Table 1~~Table 1~~. When compared to the tests performed at 5°C and 22°C, the grooved pegboard test showed a significant deterioration at -5°C ($p< 0.01$). In the typing test there were significant decreases in typing speed at -5°C and 5°C when compared to the tests performed at 22°C. Compared with baseline, the typing accuracy decreased significantly at -5°C ($p=0.006$) and showed a trend of decreasing at 5°C (0.05).

A significant positive correlation was found between the hand skin temperatures of the right hand and the performance in grooved pegboard test ($r = 0.40$, $p=0.01$), typing speed ($r = 0.56$, $p< 0.001$) and typing accuracy ($r = 0.46$, $p= 0.003$). Finger Skin temperatures showed a significant correlation with the two manual tests. Skin temperature at the forearm was significantly correlated to the performance in the grooved pegboard test ($r = 0.38$, $p=0.02$), typing speed ($r = 0.48$, $p=0.002$) but not typing accuracy ($r = 0.03$, $p= 0.85$). Grooved pegboard scores showed no significant correlation with the typing speed ($r = 0.18$, $p=0.27$) or typing accuracy ($r = 0.19$, $p=0.23$).

Table 1: Skin temperatures and manual tests results at the end of 15 min exposure to -5°C and 5°C, as well as the baseline values. The values are mean and SD of ten test participants.

| | -5°C (T1) | | +5°C (T2) | | +22°C (baseline) | |
|---|---|---|---|---|---|---|
| | mean | SD | mean | SD | mean | SD |
| $T_{lower\ back}$ (°C) | 32.5 | 2.8 | 33.6 | 2.5 | 33.6 | 1.4 |
| $T_{forehead}$ (°C) | 30.7* | 1.8 | 30.8* | 2.4 | 33.0 | 1.0 |
| $T_{forearm}$ (°C) | 30.1* | 1.0 | 30.8 | 0.6 | 31.4 | 1.1 |
| $T_{hand}$ (°C) | 15.0*# | 1.5 | 21.3* | 2.0 | 28.8 | 2.2 |
| $T_{thumb}$ (°C) | 9.3*# | 2.6 | 15.5* | 4.3 | 27.0 | 3.7 |
| $T_{middle\ finger}$ (°C) | 4.7*# | 2.5 | 11.3* | 3.6 | 26.1 | 4.2 |
| $T_{little\ finger}$ (°C) | 4.7*# | 1.4 | 11.3* | 3.8 | 25.8 | 4.1 |
| Pegboard score | 11.4*# | 2.9 | 14.2 | 2.4 | 15.1 | 1.7 |
| Typing speed (wpm) | 18.1* | 5.0 | 20.3* | 6.1 | 24.5 | 5.9 |
| Typing accuracy (%) | 89.1* | 4.1 | 91.0 | 5.2 | 95.9 | 3.2 |

Value significantly different from *Baseline (+22°C), #T2 (+5°C): $p<0.05$.

## DISCUSSION

The present results show that marked changes occur in hand and finger temperatures within 20 min of exposure to -5°C or 5°C when the participants wore their regular winter clothing. At -5°C, both manual tests showed significant deteriorations. At 5°C, typing speed was significantly decreased and typing accuracy was marginally affected. However, the grooved pegboard test was not affected by the milder cold exposure of 5°C.

Exposure to -5°C wearing regular winter clothing induced a significant decrement of the finger dexterity as reflected by the two dexterity tests performed during the cold exposure. The measured skin temperatures in the fingers and hand were clearly below the limits that were regarded as performance decrement levels [9].

The short-term cold exposure at 5°C decreased thumb temperature rapidly to around 15.5°C and middle finger temperature to around 11.3°C with the hand temperature decreased to 21.3°C. However, the grooved pegboard test was not affected by the cold exposure at 5°C. Using the Purdue pegboard test, Daanen [4] found a slight decrease in manual dexterity at finger skin temperature of

20-22°C and a strong decrease at finger skin temperature of 15-16°C. Heus et al. [9] concluded that there was a minimum decrease of finger dexterity at local hand and finger temperatures of 20°C. The present results on the grooved pegboard test do not agree with the literature cited above. It could be suggested that the grooved pegboard test, which was a good method of assessing fine dexterity and motor speed, was less affected by the cooling of fingers than was the Purdue pegboard test.

On the other hand, the effect of milder cold exposure on dexterity were illustrated quantitatively by the results of the typing test in which the typing speed was significantly affected and typing accuracy was slightly affected by the cold exposure at 5°C. The study by Fox [10] supports this result, showing that typing speed decreased significantly at local hand temperatures of 22°C. Enander [11] reported that the tasks involving manipulation of small objects are more affected by cold exposure. Therefore, the results from this study indicated that the typing test could be used to detect the changes in the manual dexterity due to moderate cold exposure.

## CONCLUSIONS

The grooved pegboard test was not sensitive to detect the deterioration of the manual performance when participants were exposed to milder cold exposure at 5°C but the typing test responded promptly to the decreases in the hand temperature even when the hand temperature was above the threshold temperature (20°C) for performance decrement that was defined in the previous studies.

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