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Effect of Temperature and Rest Intervals on Static Strength

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Abstract: Determination of strength is one of the essential factors in industrial ergonomic design. The strength of an individual is highly influenced by various factors related to work or work environments such as heavy lifting, temperature, repetitive tasks, rest intervals, humidity, elevation, and noise. All these factors should be taken into consideration when assessing the optimization of a workstation. Among these factors, rest interval duration and ambient temperature of the workplace are major influencing factors. Previous studies have investigated the effect of rest intervals and temperature under different work environment settings. However, there is a need to understand the combined effect of temperature and rest interval duration. In this study, the effect of ambient temperature and rest interval duration on static strength is investigated by performing grip strength tests in three different ambient temperatures (38 ºF, 72 ºF, and 84 ºF) and at three rest intervals (30-Sec, 1-Min, and 2-Min). The static strength data collected from sixteen participants were analyzed using ANOVA and post-hoc tests to determine the effect of temperature and rest intervals. The results show that the average static strength increases with the increase in ambient temperature and rest interval duration. Further, the percentage of initial strength was analyzed over ten minutes of experiment duration to determine the suitable resting period for a particular ambient temperature. For warm and room temperatures, the 2-Min resting period is suitable whereas for cold temperatures 30-Sec is beneficial. The results are consistent with the fact that when lifting heavy items, the warming up of the muscles may play a role to avoid injuries. Conversely, if muscles have cooled off and tightened for an extended period, it can be seen that accidents may occur in a work environment. This study provides potential real-world ramifications in that the optimum rest period for different temperatures can be considered when assessing work.

Keywords: Static Strength, Rest Intervals, Ambient Temperature, Grip strength

1. Introduction

Strength is the maximum force that one can exert voluntarily (Pulat, 1997). It is essential to the capabilities of human beings, as it is an important factor in industrial ergonomic design. Grasping tools and items are a very common occurrence in the workplace. Also, strength and fatigue are crucial factors in the completion of tasks in the workplace. The strength of an individual is highly influenced by various factors such as anthropometry, amount of exercise, ambient temperature, and rest interval (Aghazadeh et al., 1989). In addition, strength is affected by work or work environments such as heavy lifting, temperature, repetitive tasks, rest intervals, and noise. Moreover, the body's physiological and biomechanical processes change with environmental temperature (Zheng, Li, Bu, & Wang, 2019). It is essential to understand the individual and combined effect of rest interval and ambient temperature on the muscle strength to prevent workplace injuries and improve worker's productivity.

De Salles et al. (2009) have studied the effect of different rest intervals on a strength training program and concluded that there was no effect of rest periods on strength training. However, repetitive heavy lifting increases a worker's chances for injury which may result in spinal injuries. Any excessive repetitive task may have adverse effects on the quality of work done. Barredo and Mahon (2007) have compared the effects of exercise and rest breaks on musculoskeletal discomfort during computer tasks and reported that there is evidence supporting the use of exercise and rest breaks in reducing musculoskeletal discomfort in computer tasks, but there is no evidence suggesting additional benefits of exercise over rest breaks alone. Balci and Aghazadeh (2003) have observed that 15-minute work with micro breaks has resulted in lowest discomfort, highest accuracy, speed and performance for data entry and mental arithmetic tasks for visual display terminal operators. Savage and Pipkins (2006) have concluded that there is a significant impact of rest periods on the productivity of workers. There have been extensive studies in the field of strength training that can be useful to observe specific patterns of rest period results. According to Willardson and Burkett (2006), it was concluded that the amount of rest depends on the required performance parameter. When training to increase maximum strength, a rest interval between 1-2 minutes is desirable. Whereas for increasing maximum power, the rest intervals about three minutes are beneficial. The study recommends the use of 30-60 seconds to increase growth hormone levels for hypertrophy. For muscle endurance training, short 30 second intervals for different muscle groups and long intervals of three minutes for similar muscle group exercises are preferred (Willardson & Burkett, 2006). Concerning women, the same seems to be true. The study of Willardson (2006) on the effect of rest intervals on bench press performance has concluded that 3-minute rest interval was the best for sustaining the number of repetitions for heavy and light loads. Whereas Scudese et al. (2015) study on the effect of rest interval on repetition consistency and perceived exertion during maximum loaded bench press have shown that 2-minute rest interval is suitable for entire three repetitions maximum load for the bench press and minimum of 3-minute rest interval for lower perceived exertion. Similarly, Simão et al. (2006) have observed that 2-minute rest interval was beneficial compared to 1-minute rest interval in strength training on older men. The study by Matos et al. (2019) has concluded that 2-minutes is the ideal recovery time between sets and exercises, for both chest and back, which allowed sufficient muscle function.

Nevertheless, it is essential to determine the rest period that is required for a worker to avoid injury. To understand the failure point at which accident can occur, García-López et al. (2007) have studied the effect of short and long rest intervals between sets on elbow-flexor muscular endurance during resistance training. It was concluded that short-term elbow-flexor resistance training to failure, allowing one or four minutes of rest between sets, induces similar gains concerning local muscular endurance. Whereas for the non-resistance training in young men, the study by Gentil et al. (2010) have shown that the maximum strength was not dependent on rest ratio. De Souza Jr et al. (2010) have studied the effects of hypertrophy and strength with constant and decreasing rest intervals in young men. The study results show that the constant rest interval of 2-minutes and a decreasing rest interval from 2-min to 30-sec were useful for strength and hypertrophy training.

Employers, however, can often reduce the accident proneness of the situation by changing environmental factors of the job site. In some cases, the environmental factors cannot be avoided, such as an outside environment. In the construction industry, environmental factors have been outlined and studied in detail, one of which is rest periods' effect on lifting. The rest period allows a worker to become more productive. There are specific guidelines to determine the optimum amount of work possible for each shift if a worker works for an eight-hour shift. Rest periods give a worker the ability to do more difficult tasks for an extended amount of time. In many states, it is a law to provide a 20-minute lunch break, which has been shown to reduce accidents on the job legitimately. The correlation of rest periods to the ambient temperature can be useful in real-life situations, such as an outdoor job site or shop.

2. Objectives

The objective of this study is to understand the effect of rest interval and ambient temperature on static strength. In addition, to determine the optimum rest interval required for each ambient temperature.

A hypothesis is that as the core body temperature rises above the average body temperature, performance decreases. Inversely, as core temperature decreases below 98.6 ^{o}F, several factors reduce the body's ability to produce certain gross movements. Potentially, for the group performing work in a higher temperature work environment, more extended rest periods may benefit the worker by allowing the body to lower the core's temperature enough for full recovery. Quite the opposite way affect those workers who are working in a colder environment. While productivity loss does occur due to muscle fatigue in general, the fact that shorter rest periods allow the body to stay at a higher core temperature may slow the onset of fatigue. Therefore, allowing a much lower productivity loss in the shorter rest periods versus the longer rest periods.

3. Materials and Methods

Sixteen university students voluntarily participated in this experiment. Before the start of the experiment, the objectives and procedures were explained to the participants, and each participant gave verbal and written consent. The procedure used in this experiment included testing participants' static strength at different ambient temperatures with different rest periods using grip strength as a metric. The hand dynamometer was used to record the grip static strength. As a part of the experiment, participants squeezed the hand dynamometer following the static grip strength experiment protocol and the data was recorded. The order of the temperatures and rest periods tests were randomized for each of the participants. The three rest intervals used in this study were 30-Seconds, 1-Minute, and 2-Minute. The three different ambient temperature used in this study is the control group (Room) working at room temperature; the raised temperature group (Warm) working at a temperature elevated above room temperature, and the lowered temperature group (Cold) working at a temperature below that of room temperature. Testing was performed over the course of three days.in the following manner:

Day 1: The experiment was performed at normal room temperature (i.e., 72ºF). Participants were brought into a room that was determined to have the correct temperature (72ºF). Later, the participants squeezed the dynamometer for 10 minutes. During this ten minute period, the subject utilized their rest period between squeezes of the dynamometer.

Day 2: The procedure was repeated on day two, except for using a higher temperature. The participants were tested using a closed room with a heater running to produce a temperature well above that of room temperature. At the time of the test, the temperature was determined to be 84ºF.

Day 3: The steps from Day-1 were repeated but for a temperature lower than room ambient temperature. A walk-in cooler was utilized to mimic a cold working environment. A temperature of 38 ºF was used during this time.

The static grip strength data collected during the experiment was the dependent variable whereas three ambient temperatures and rest intervals were considered as independent variables. To evaluate the effect of experimental conditions on static strength, a univariate ANOVA and Bonferroni post-hoc test were performed. Further, to understand the combined effect of temperature and rest intervals on static strength, the percentage of initial strength was analyzed over the entire experiment duration.

4. Results and Discussion

4.1 Effect of Temperature on Static Strength

The *p*-value of ANOVA analysis of static strength between three temperature groups is 5.72E-20. The *p*-value of Bonferroni post-hoc test between pair of groups such as heat & room, room & cold, and cold & heat are 4.03E-09, 0.0005, and 3.48E-19, respectively. The results of ANOVA and Bonferroni post-hoc test concludes that there is a significant effect of temperature on static strength. The average static strength at heat temperature conditions is higher compared to room and cold with a percentage difference of 16% and 28% respectively. The average static strength decreases from room to cold temperature with a percentage difference of 12%. From the results, it can be concluded that the average static strength increases with increase in ambient temperature (Figure 1).

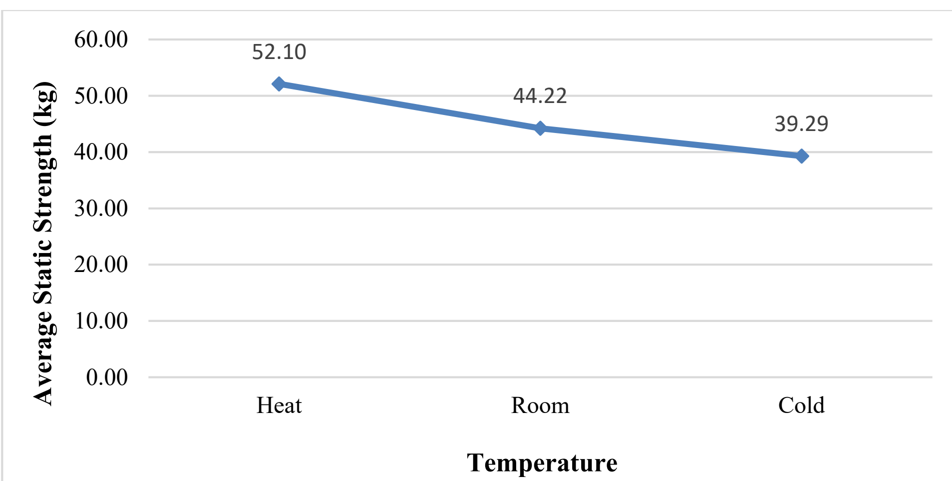

Figure 1. Average Static Strength versus Different Temperatures

4.2 Effect of Rest Intervals on Static Strength

A significant effect exists between the average static strength and rest intervals for three ambient temperatures. The *p*-value of ANOVA analysis between three rest interval groups for heat, room, and cold ambient temperatures are 0.0004, 3.12E-16, and 4.63E-16 respectively. The *p*-value Bonferroni post-hoc test between pair of rest interval groups for all the temperatures are shown in Table 1. The Bonferroni correction is 0.016 ($\alpha' = \alpha /n$), where n is a number of hypotheses tested. The result shows that there is a significant difference (*p*-value < α') between the rest interval groups except in case of cold temperature between 1-Min & 2-Min. For all the three ambient temperatures, the average static strength increases with an increase in rest interval from 30-seconds to 2-minutes (Figure 2). Table 1 shows the percentage difference between different rest interval groups for three temperature conditions.

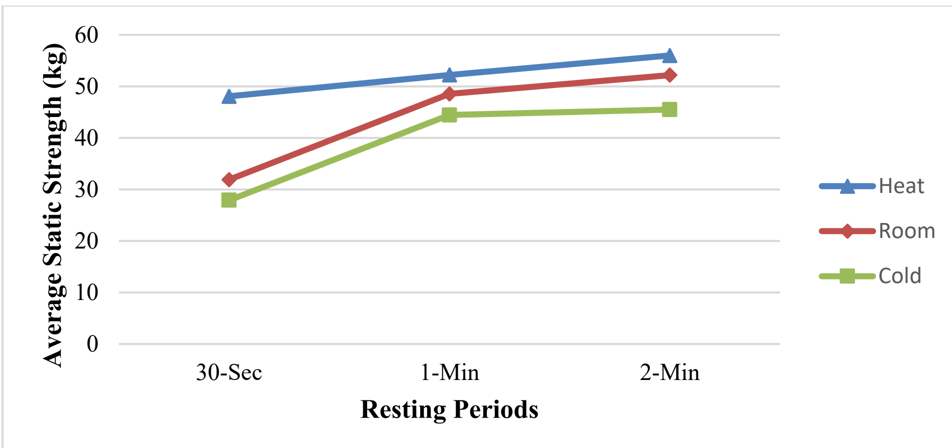

Figure 2. Average Static Strength versus Rest Intervals

Table 1. *p*-values of Bonferroni Post-hoc Test and Percentage Difference

Rest Intervals	Heat		Room		Cold	
30-Sec & 1-Min	0.0004	8%	1.50E-12	41%	5.15E-13	46%
1-Min & 2-Min	2.43E-05	7%	1.90E-11	7%	0.44	2%
2-Min & 30-Sec	6.28E-09	15%	7.80E-10	48%	0.0003	48%

4.3 Combined Effect of Temperature and Rest Intervals on Static Strength

The percentage of initial strength is calculated using the static strength recorded throughout the experiment duration. The trends are analyzed throughout the duration of the experiment period (i.e., 10-Minutes). Figure 3, 4, and 5 show the trends established after completing the three days of testing. The trends shown in Figure 3 represent the data collected for the 2-Minute rest interval. Both the room and warm temperature observations share a similar reaction over the 10-Minutes testing period. Both tests show a slight increase in the percentage of initial strength. The cold temperature observations, however, show a slight decrease in the percentage of initial strength. Figure 4 represents the data collected for the 1-Minute rest interval where there is a common trend amongst all three temperatures being tested. The trends show a decrease in the percentage of initial strength over the ten minutes experiment duration. The trends shown in Figure 5 represent the data collected for the 30-Second rest interval. The warm and cold temperatures show a common trend, which is the decrease in the percent of initial strength over the ten minute period. The cold temperature, however, shows an increase in the percent of initial strength over the ten minute period.

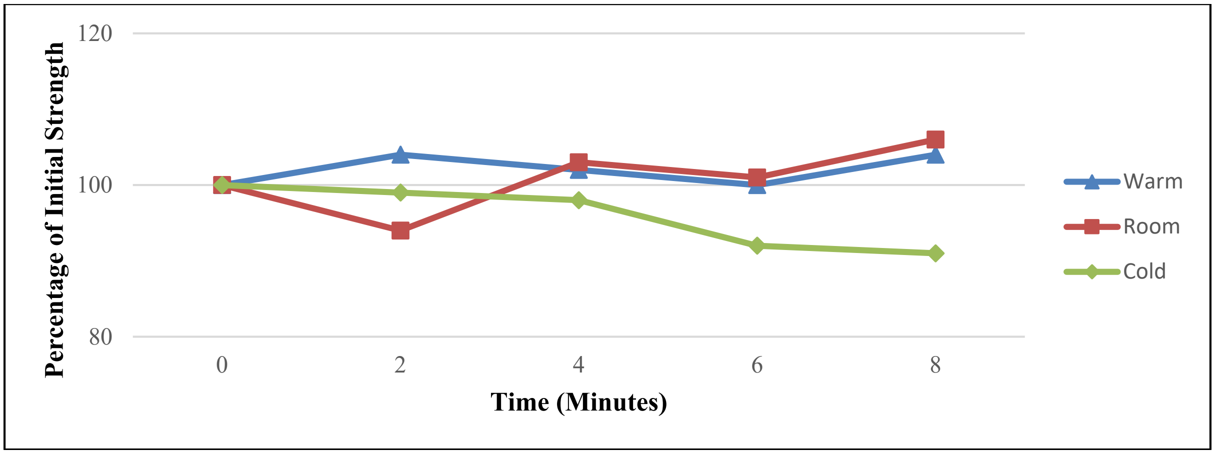

Figure 3. Percentage of Initial Strength for 2-Minute Rest Interval

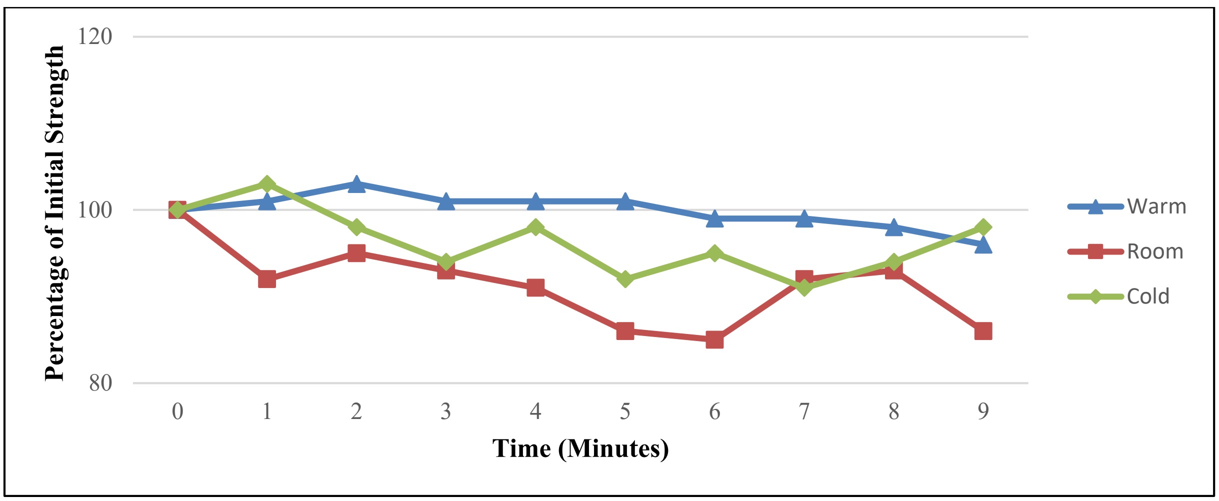

Figure 4. Percentage of Initial Strength for 1-Minute Rest Interval

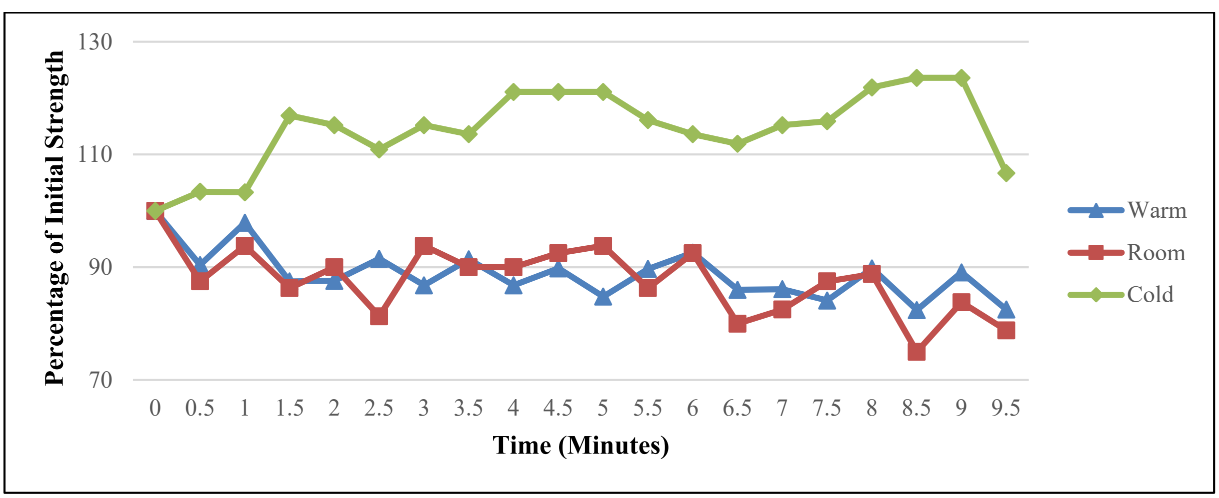

Figure 5. Percentage of Initial Strength for 30-Second Rest Interval

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5. Conclusion

This study concludes that with the increase in temperature and rest interval the static strength increases. Moreover, when working at room temperatures, the two shorter rest intervals result in a decrease in the percent of initial strength. However, the longer rest interval allows the muscles to recover and strength increases over the ten minutes. Therefore, when working in a setting in which the temperature is approximately 72ºF, it is recommended that longer rest periods be allowed.

When working at temperatures well above room temperature, the results show that, again, longer rest periods allow the muscles to recover. This results in an increase in strength over the ten minute period. When using this information to evaluate rest intervals in environments where the temperatures are relatively high, the results show that rest periods of 2-Minutes are optimal.

When working at temperatures well below room temperature, the results show that the shorter rest intervals are beneficial. The muscles, which start off cold and frigid due to the low temperature, react well to the short rest periods. The shorter rest periods allow the muscles to warm up. Therefore, strength increases over the ten minute period. The longer rest periods allow the muscles to cool down, resulting in a decrease in the percent of initial strength. These results suggest that in colder environments, shorter rest periods allow strength to increase as the muscles stay warm.

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