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Assessment of isometric muscle exertion in short-term considering task-rest schedule

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Abstract. Numerous workers experience occupational diseases, especially musculoskeletal disorders, due to various physical, psychological, and individual factors. Among known risk factors for musculoskeletal disorders, work-rest patterns and muscle fatigue are to be named. Assessment of muscle fatigue plays an important role, leading to a proper design for a work-rest program. This study investigated isometric muscle strength in Iranian workers during repetitive activities based on gender and rest time. It has been attempted to present a model for isometric muscle strength. In a laboratory experiment, 31 students comprised of 19 males and 12 females participated, and muscle strength was recorded by a dynamometer. Minitab software results analysis proved that females' upper body muscles showed a higher level of resistance to fatigue than males. Furthermore, test results for each individual were more in line with cubic regression so that four models with a high *R-Sq* index (at least 94.4%) and high *R-Sq* (adj) index (at least 77.8%) were presented to predict isometric muscle strength in short-run. Finally, it has been suggested to use male workers for repetitive activities with a high workload and enough rest time and use female workers for repetitive activities with low workload and high frequency.

1. Introduction

In European countries, about 20 million workers experience occupational diseases annually, and most of the occupational diseases (about 40%) fall into the category of work-related musculoskeletal disorders (WMSDs) [1–3].

WMSDs can be caused by various physical, psychological, and individual factors. Physical risk factors can include some cases like manual handling (e.g., lifting [3] and pushing/pulling [2]), non-neutral postures (e.g., bending and twisting), and repetitive movements [1]. Static and intermittent static muscle activity, duty cycle, work-rest patterns, and muscle fatigue are among the known risk factors for musculoskeletal disorders [4–6].

Muscle fatigue is one of the leading causes of musculoskeletal disorders in the industry, especially for physical work and Manual Material Handling (MMH) [6], so lumbar muscle fatigue is a potential risk factor for increasing low back pain [7]. In general, physical fatigue can be defined as 'any reduction in the maximal capacity to generate force or power output' [8]. Physical fatigue might lead to decreased productivity and quality in production systems [9].

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Physical fatigue is one of the significant consequences of shift schedule [10], physical exertion [11], physical demands associated with shiftwork [12], long working hours [13], increased work intensity, and prolonged standing among workers population [14,15]. Fatigue is a challenging ergonomic issue that endangers safety because it reduces productivity and increases injury rates, so it must be carefully managed with its reasons [16,17].

Muscle fatigue assessment is helpful not only for a work-rest time-appropriate design but also for reducing workers' musculoskeletal injuries and preventing physical fatigue in physical activities [18,19]. On the other hand, muscle strength recovery is influenced by rest time length, so rest times should be adjusted to allow muscle recovery occurrence. Generally, time is a significant issue for ergonomics in production system interventions. These interventions use tools like work-rest patterns and daily duration of exposures to workers' health and contribution to production [20].

This study investigated isometric muscle strength while performing repetitive activities based on gender, rest time, muscle recovery, and fatigue in Iranian workers. It has also been attempted to present a model for isometric muscle strength in the short run. Before going any further, there is a brief review of previous studies of isometric muscle strength, work-rest schedule, muscle recovery, and fatigue.

Although it was stated that anthropometric measurements [21] are not good predictors of isometric muscle strength [22], Mital and Ayoub [23] showed that by considering them, the model explains a higher percentage of the response variation. Kroemer and Marras [24] stated that usually, the maximum capacity of a person's muscular strength in tests could not be measured. Individuals apply force with a safety margin below the capacity level, while in technical terms, it is called the Maximum Voluntary Contraction (MVC), which is used as a gold standard for measuring fatigue [8].

Dababneh et al. [25] studied the impact of added rest breaks on the productivity and well-being of 30 workers in the meat-processing plant. They found that workers, in general, might not as readily accept the fragmentation of break time into short and frequent breaks and prefer long, infrequent breaks. While [26] does not offer long and infrequent breaks for data entry and cognitive tasks. Also, McLean et al. [27] examined the benefits of scheduled rest breaks (microbreaks) at computer terminals. They concluded that microbreaks had no detrimental effect on worker productivity and positively reduced discomfort in all areas studied.

Lee [28] calculated the Minimum Acceptable Handling Time Interval (MAHTI) for four-hour lifting and lowering activities using a physiological approach and revealed that with increasing load weight, MAHTI increases significantly nonlinearly. On the other hand, this time for lifting activity is significantly greater than the same lowering activity. Balci and Aghazadeh [26] examined the effect of rest time on performance. They found that the impact of the work-rest schedule was significant on performance, muscular load level, and perceived discomfort. In this way, Adamo et al. [29] stated that intermittent periods of complete rest reduce muscle fatigue, and ergonomic interventions such as increased scheduled breaks or job rotation have been suggested to reduce upper limb muscle fatigue in repetitive low-load activities [30].

Shin and Kim [18] examined the relationship between cumulative fatigue of trunk muscles and change in recovery time and, by analyzing fatigue level with analysis of variance (ANOVA), showed that in 5 min recovery time, 90% of the subjects showed a recovery of at least two trunk muscles, while in 4 min recovery time, 70% of subjects experienced such conditions. Also, Jin [31] declared that obtaining knowledge about any abnormality of the recovery phase can help develop an appropriate work-rest schedule.

Mathiassen and Winkel [32] considered three ergonomic interventions (Reduced work pace, increased break allowance, and shortened working days) in light assembly work. They concluded that shortened working days were more effective in limiting acute fatigue than the other two interventions. Iridiastadi and Nussbaum examined the effect of contraction level, duty cycle, and cycle time on muscular fatigue and endurance during intermittent static activity. They concluded that contraction level and duty cycle significantly affect muscular endurance and fatigue, but cycle time is only significant for electromyogram (EMG) spectral measures [33,34].

Ref. [35] presented a four-parameter model for estimating fatigue during an isometric contraction that demonstrated the potential for predicting muscle fatigue in response to a wide range of stimulation patterns. After presenting a new simple dynamic muscle fatigue model, considering the external load, workload history, and individual differences [6], using this model during a single-arm pushing experiment showed that females' resistance to muscular fatigue was more than males' in the pushing task [19]. Also, [36] showed that females' shoulder fatigue resistance was higher than males' at lower intensity levels.

Based on the literature review, there is a research gap in studying the work-rest schedule and its effects on muscle recovery among Iranian workers, so we tried to investigate this topic using experimental work.

2. Methods

2.1. Methodology

This study aims to obtain results applicable to Iranian workers and production systems in domestic industries, including repetitive tasks (like assembly and MMH). This study, including two parts of experimental work and result analysis, has been cross-sectional plus laboratory work, in which volunteers' anthropometric data was recorded through interviews. The dependent variable is isometric muscle strength, while the independent variables of the study are age, gender, height (cm), weight (kg), and rest time (second).

2.2. Sample size & participants

The study population for this research was bachelor students from the Industrial Engineering Faculty of Iran University of Science and Technology (IUST) located in Tehran. The bachelor student population of the Industrial Engineering Faculty in January 2020 was 329, with both male and female students [21]. We used the Cochran formula to calculate the theoretical sample size. With a confidence level of 95% and a sampling error of 0.1, the theoretical sample size was 74.35. But restrictions on the spread of the Coronavirus did not let us realize it. So, we had to decrease the confidence level to 87%, and the theoretical sample size was 29.09. Regarding the theoretical sample size, a sample size of 31 in this study would be sufficiently precise to estimate with an 87% confidence interval.

In this study, using random sampling, 31 volunteer students of the Industrial Engineering Faculty participated. This group comprises 19 males and 12 females, and the experiments were conducted in the Advanced Ergonomics Lab in the School of Architecture and Urban Development at IUST. The conditions and purposes of the experiments were fully explained to the students.

2.3. Procedure

A dynamometer with a gram-force (gr.f) unit has been used in the current study. This dynamometer can display the isometric force of muscles at any moment [3] (as shown in Figure 1). Besides, this device can be adjusted to show the maximum isometric force applied in a short interval [3], and this capability was used in this study.

In laboratory work, participants stand completely on a dynamometer base, gripping two-handed chainsaws so that handles are held in the palm of their hands in a way that fingers are tightened around the handle. Grasping the handle as the power grip, in which the elbow angle is 90 degrees, and the wrist has no flexion (Figure 2). In this case, the handle's height was adjusted to have a 90–degree elbow. Then, the volunteer pulls the handles upwards without excessive force that causes fatigue or overexertion. Following the mentioned steps by the volunteer, the maximum isometric force recorded by the dynamometer has been written down.

Figure 1. Dynamometer manufactured by Iranian danesh salar.

Considering four different rest times (one minute, 30 seconds, 15 seconds, and 10 seconds) [37] with a stopwatch, this test was repeated four other times (according to Figure 2), and the results were recorded. At the end of the experiment, every volunteer's height, weight, and age had been written down. Paired t-test, Anderson Darling test, Univariate linear regression, nonlinear regression, and Pearson correlation coefficients were used to analyze data while obtaining a significant relationship between the independent and dependent variables of the research. It should be noted that some similar cubic curves in terms of coefficients and appearance merged by averaging the points and fitting a new cubic curve. The confidence level of 0.95 was also considered for all methods, and Minitab software (Version 16) has been used to analyze the experiment's data.

3. Results

Volunteers' mean height was 171.554 cm, with a standard deviation of 8.951 cm. Volunteers' mean weight was 71.378 kg with a standard deviation of 18.027 kg, and volunteers' mean age was 21.355 years with a standard deviation of 1.279 years.

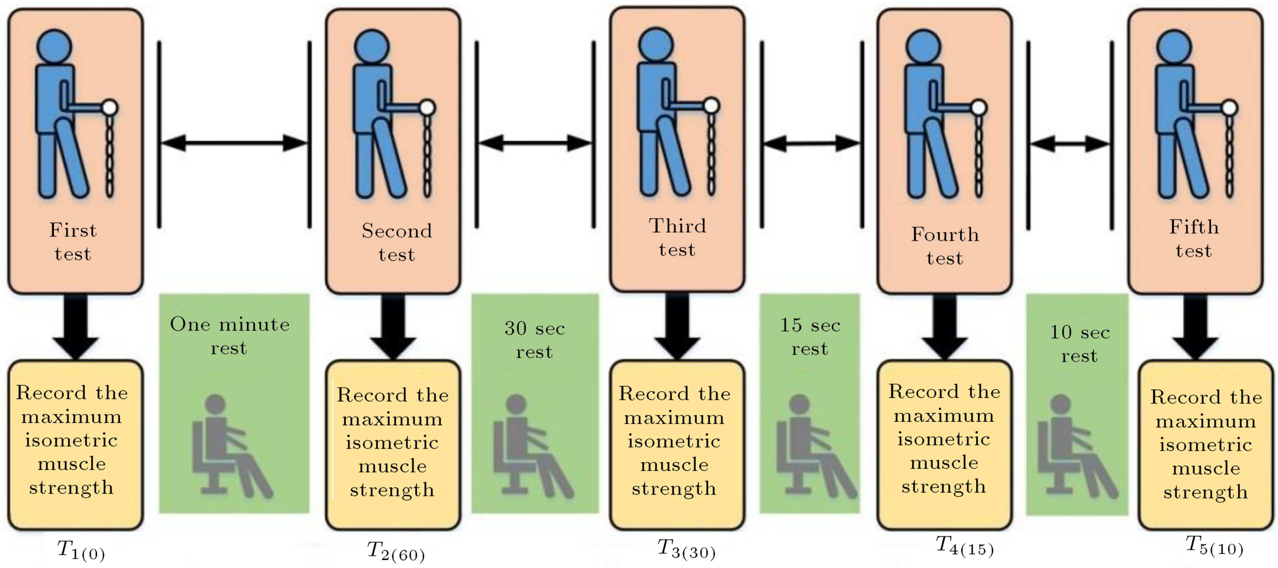
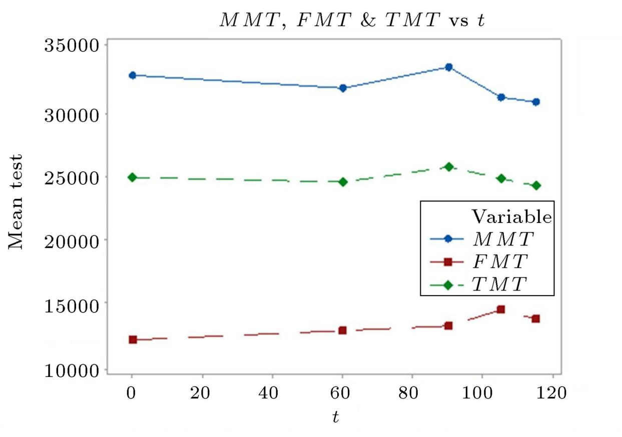


Figure 2. Isometric muscle strength experimental procedure.

Table 1. Result abbreviations.

$T_{1(0)}$: Initial measurement	MMT_i: Average measurements for males in ith test
$T_{2(60)}$: Second measurement after 1 minute rest	FMT_i: Average measurements for females in ith test
$T_{3(30)}$: Third measurement after 30 seconds rest	TMT_i: Average measurements for all volunteers in ith test
$T_{4(15)}$: Fourth measurement after 15 seconds rest	t: Time (second)
$T_{5(10)}$: Fifth measurement after 10 seconds rest	IMS_i: Isometric Muscle Strength of the ith volunteer



	Men ($MMT_i \pm SD$)	Women ($FMT_i \pm SD$)	All ($TMT_i \pm SD$)
$T_{1(0)}$ (gr.f)	33055.3 ± 16855.4	12025.0 ± 6111.11	24914.5 ± 17105.1
$T_{2(60)}$ (gr.f)	32065.8 ± 13295.1	12783.3 ± 5574.71	24601.6 ± 14443.2
$T_{3(30)}$ (gr.f)	33693.7 ± 16922.1	13175.0 ± 5934.40	25751.0 ± 16968.9
$T_{4(15)}$ (gr.f)	31331.6 ± 13960.1	14462.5 ± 5645.56	24801.6 ± 14084.8
$T_{5(10)}$ (gr.f)	30936.8 ± 13568.3	13716.7 ± 5761.92	24271.0 ± 13976.1

Figure 3. Mean isometric muscle strength in five tests by males and females.

In Table 1, the results are presented according to the abbreviations. As shown in Figure 3, an average of each measurement, according to males and females, can be found. In the five measurements, females' average isometric muscle strength was 63%, 60%, 61%, 54%, and 56% lower than the isometric muscle strength of males, respectively. In other words, in every test, the average isometric muscle strength of females is 59% lower than that of males. Also, the normality of the data for both males ($p-$value $= 0.719$) and females ($p-$value $= 0.939$) was confirmed by the Anderson-Darling test, and no data deletion was required. Finally, a paired t-test showed a significant difference between the muscular isometric strength recorded for males and females ($p-$value $= 0.000$).

In Figure 4, to make each volunteer's isometric muscle strength trend during five tests more comprehensible, diagrams of isometric muscle strength were recorded for 31 individuals, plotted by gender and slope sign of regression line. The accuracy of the fitted linear regression lines is low, and the purpose of the diagrams is to observe the isometric muscle strength general trend individually. In Figure 4, it should be noted that the numbers represent the volunteer number, and the graphs on the left have a positive slope, while the graphs on the right have a negative slope. According to Figure 4, nine males and nine females have ascending slopes, while ten males and only three females have descending slopes in isometric muscle strength linear regression graphs. It means that only 25% of females experienced a downward trend in

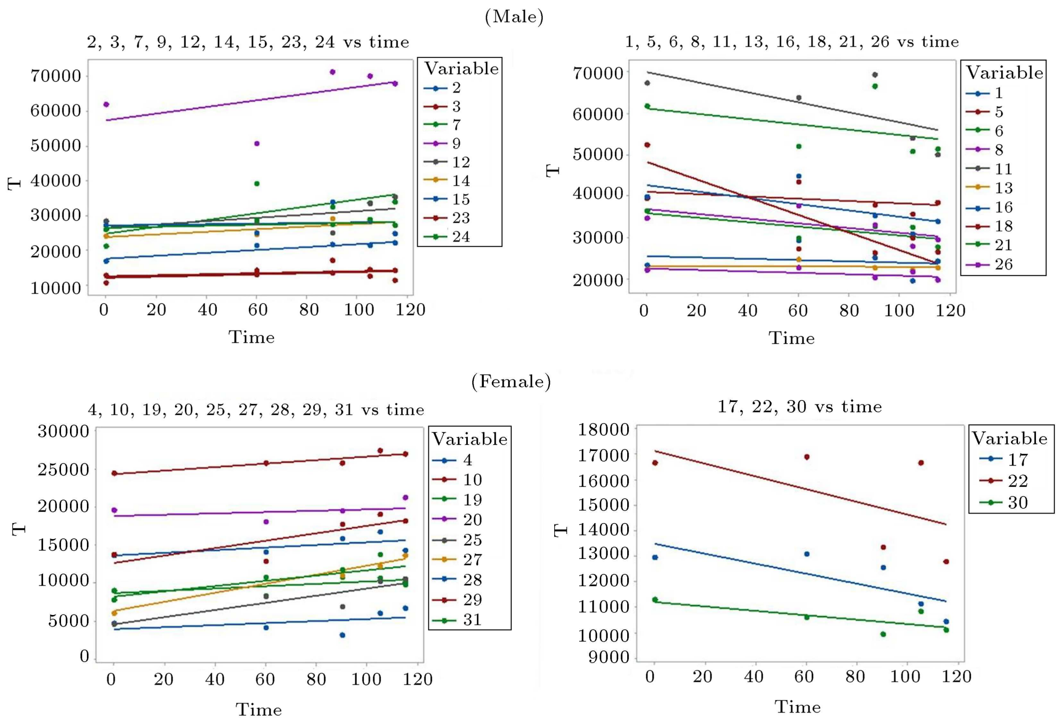


Figure 4. Linear regression graphs of isometric muscle strength for each individual by gender and slope of the line.

isometric muscle strength, while 75% experienced an increase in isometric muscle strength with a low slope. 53% of males experienced a downward trend, while 47% of them experienced an upward trend.

According to Figure 5, linear regression and Pearson correlation coefficient were used to obtain the correlation between the results of the five tests; correspondingly, a significant relationship between the isometric muscle strength of both tests was seen, so that the minimum $R\text{-}Sq$ was 79.8% and the maximum was 97.3%. There is no meaningful relationship between the mean measurements for males and females in the ith test ($R\text{-}Sq = 41.3\%$). Additionally, there was also a significant relationship between mean measurements for females and time ($R\text{-}Sq = 79.8\%$), but not for males ($R\text{-}Sq = 29.6\%$).

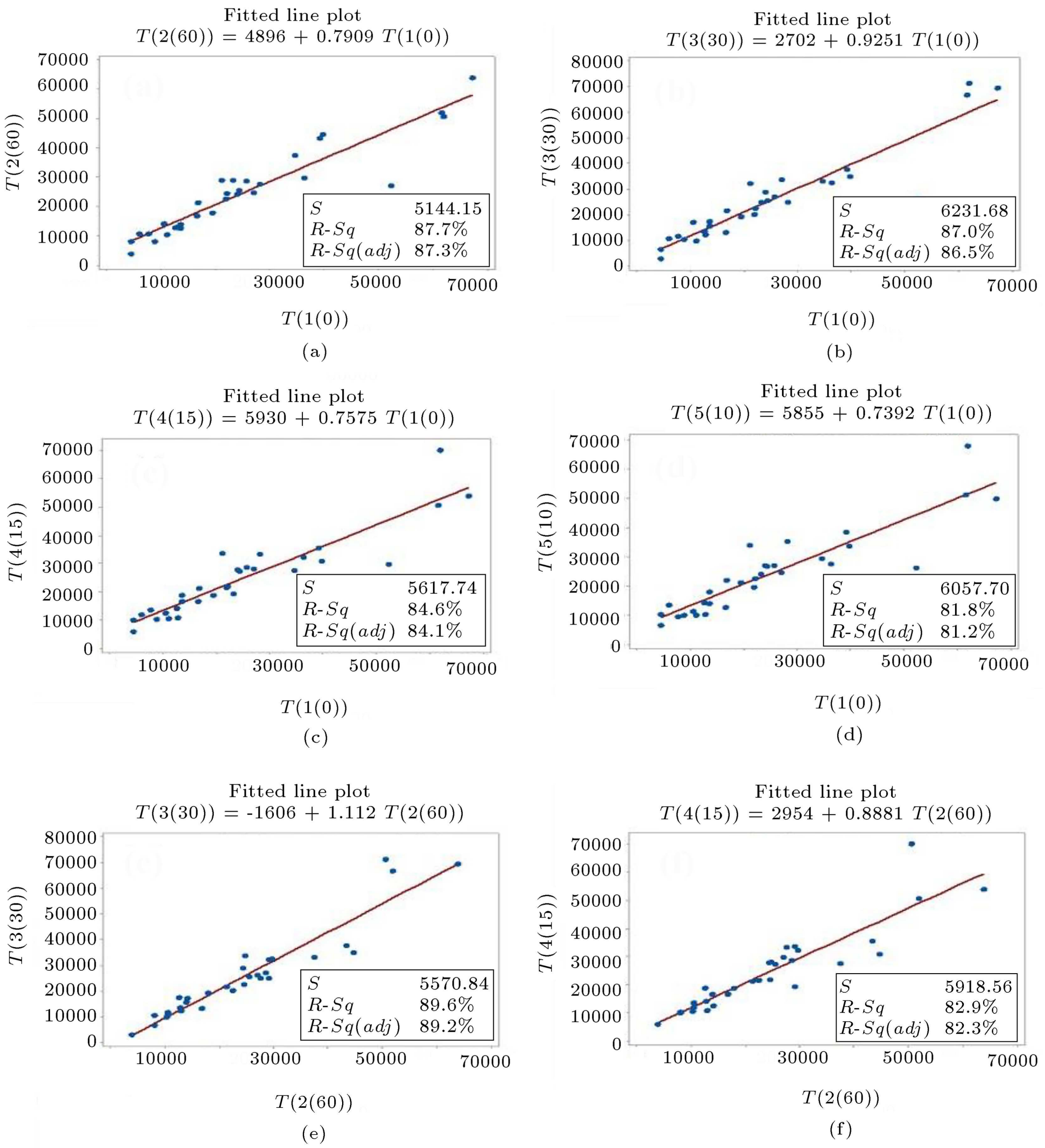
A nonlinear regression (third-degree) was used to determine the isometric muscle strength fluctuations in all five tests. According to Figure 6, a cubic curve was obtained for each group by separating males' and females' data. Also, through fitting a cubic curve for individuals, a high percentage of the response variable variation is explained in all three curves (between 79.2% and 89.9%).

By fitting a cubic curve for each of the individual's five tests (Table A.1 in Appendix A), it seems that many curves are almost similar in terms of coefficients and appearance. As explained in part (2.3. Procedure), by fitting a new cubic curve, the accuracy of the newly fitted cubic curve increased ($R\text{-}Sq$ between 94.4% and 98.8%). Figure 7 shows the four categories of curves resulting from the above process (Figure S1 in the supplementary data file). The test results of 24 individuals (77% of volunteers) corresponded roughly to one of the four curves above.

4. Discussion

In each test, females' average isometric muscle strength was 59% lower than that of males. From first to second, third to fourth, and fourth to the fifth test, males showed isometric muscle strength decreased. This is while females only showed isometric muscle strength loss from the fourth to fifth test, which means isometric muscle strength drop occurred in males more frequently and earlier than females; it means females' upper body muscle resistance to fatigue was more than males. Previous studies have emphasized greater resistance to muscular fatigue in females than males in arm pushing activity [19] and shoulder muscle fatigue at lower intensity levels [36].

On the other hand, males did not have proper muscle recovery within one minute. However, after 90 seconds, muscle recovery occurred, and again, this recovery did not occur in 15 or 10 seconds (Figure 3). Nevertheless, at low applied force levels, females showed suitable muscle recovery for one minute, 30 seconds, and 15 seconds, and only in 10 seconds no muscle recovery has occurred (Figure 3). So, the effect of rest time length on muscle recovery and the relationship between upper body muscle fatigue and change in recovery time [18] was confirmed. In this

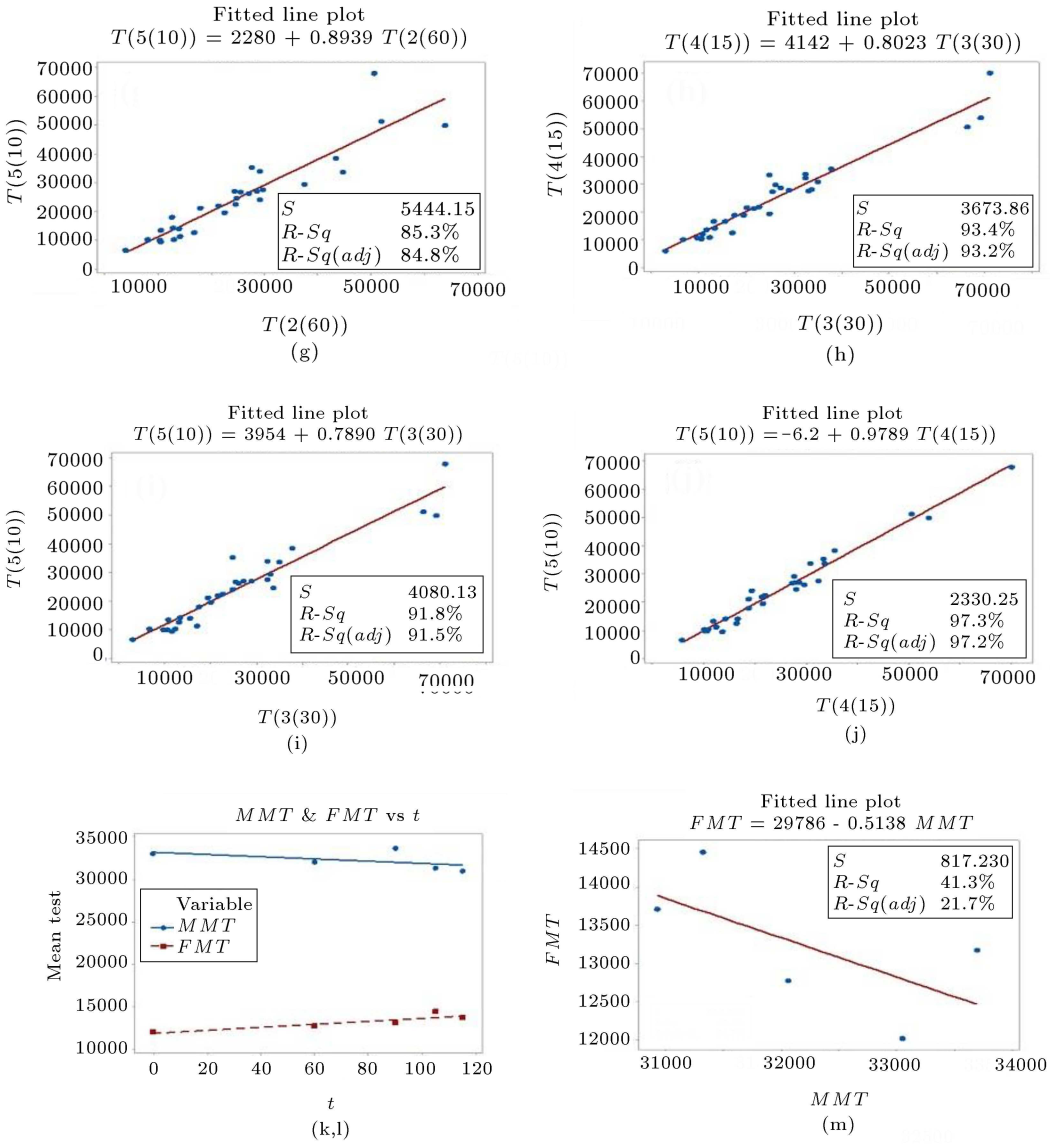


No.	X	Y	Regression Line Equation	$R-Sq$	Pearson Correlation Coefficient
a	$T_{1(0)}$	$T_{2(60)}$	$Y = 4896 + 0.7909X$	% 87.7	0.937
b	$T_{1(0)}$	$T_{3(30)}$	$Y = 2702 + 0.9251X$	% 87.0	0.933
c	$T_{1(0)}$	$T_{4(15)}$	$Y = 5930 + 0.7575X$	% 84.6	0.920
d	$T_{1(0)}$	$T_{5(10)}$	$Y = 5855 + 0.7392X$	% 81.8	0.905
e	$T_{2(60)}$	$T_{3(30)}$	$Y = -1606 + 1.112X$	% 89.6	0.946
f	$T_{2(60)}$	$T_{4(15)}$	$Y = 2954 + 0.8881X$	% 82.9	0.911

Figure 5. Graphs and regression equations of five tests isometric muscle strength results.

case study, it can also be concluded that short and frequent rest times are more suitable for females, while longer and infrequent rest breaks are more suitable for males, in contrary to what was suggested in the previous study about long and infrequent breaks for all workers [25].

Generally, the isometric muscle strength of the volunteers did not follow the linear or quadratic curves during the five tests. It seems that the cubic curve can demonstrate muscle strength fluctuations in a short time based on rest duration. In Figure 7, a decrease (increase) in isometric muscle strength from one test

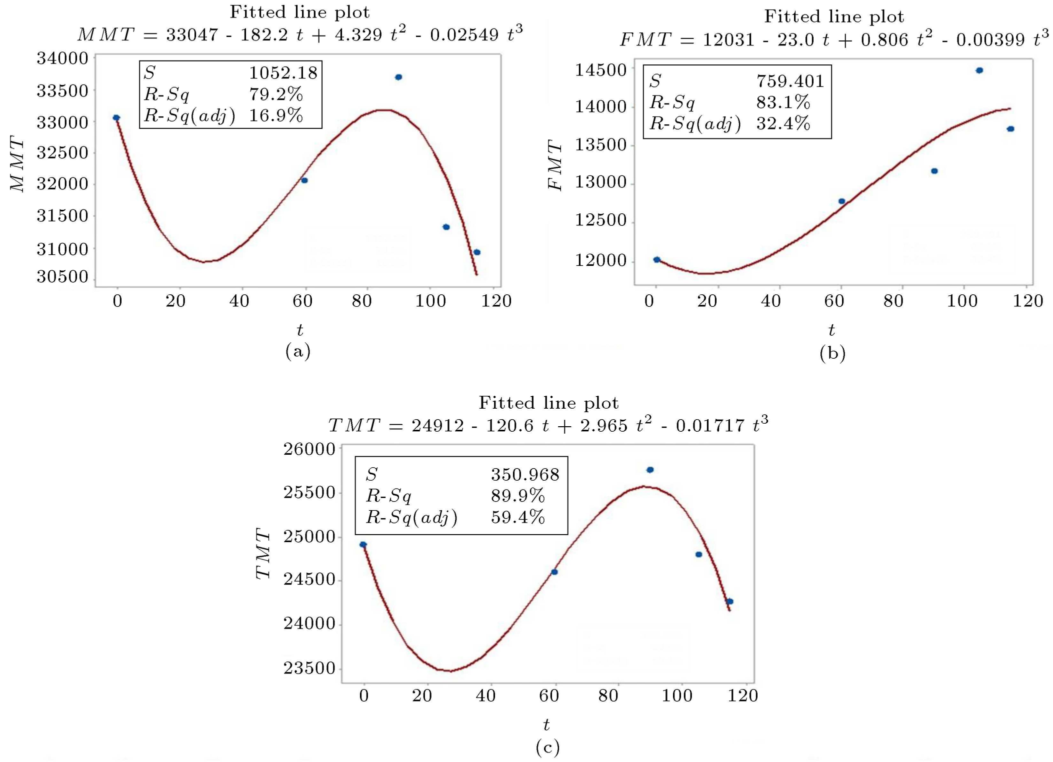


No.	X	Y	Regression Line Equation	$R-Sq$	Pearson Correlation Coefficient
g	$T_{2(60)}$	$T_{5(10)}$	$Y = 2280 + 0.8939X$	% 85.3	0.924
h	$T_{3(30)}$	$T_{4(15)}$	$Y = 4142 + 0.8023X$	% 93.4	0.967
i	$T_{3(30)}$	$T_{5(10)}$	$Y = 3954 + 0.7890X$	% 91.8	0.958
j	$T_{4(15)}$	$T_{5(10)}$	$Y = -6.2 + 0.9789X$	% 97.3	0.986
k	t (sec)	MMT_i	$Y = 33220 - 13.56X$	% 29.6	- 0.544
l	t (sec)	FMT_i	$Y = 11914 + 17.82X$	% 79.8	0.893
m	FMT_i	MMT_i	$Y = 42841 - 0.8029X$	% 41.3	- 0.642

Figure 5. Graphs and regression equations of five tests isometric muscle strength results (continued).

to the next test shows insufficient (sufficient) rest time for muscle recovery.

According to Figure 5, there was a meaningful correlation between the result of each test and the result of the next one. Decreasing the rest time between the two experiments increased the correlation between the successive isometric muscle strength values. For example, between the first and second tests with a 1-minute interval, the Pearson correlation coefficient is 0.937, while between the second and third tests with a 30-second interval, this coefficient is 0.946. Between the third and fourth tests with a 15-second



No.	X	Y	Nonlinear Regression Equation	$R-Sq$	$R-Sq$ (adj)
a	t (sec)	MMT	$MMT = 33047 - 182.2t + 4.33t^2 - 0.03t^3$	% 79.2	% 16.9
b	t (sec)	FMT	$FMT = 12031 - 23.0t + 0.81t^2 - 0.004t^3$	% 83.1	% 32.4
c	t (sec)	TMT	$TMT = 24912 - 120.6t + 2.97t^2 - 0.017t^3$	% 89.9	% 59.4

Figure 6. Third-degree isometric muscle strength charts for males, females, and all individuals.

interval, this coefficient is 0.967, and finally, between the fourth and fifth tests with a 10-second interval, the Pearson correlation coefficient is 0.986. There is also a correlation between the mean muscle isometric strength of females and time, while for males, there is not (Figure 5).

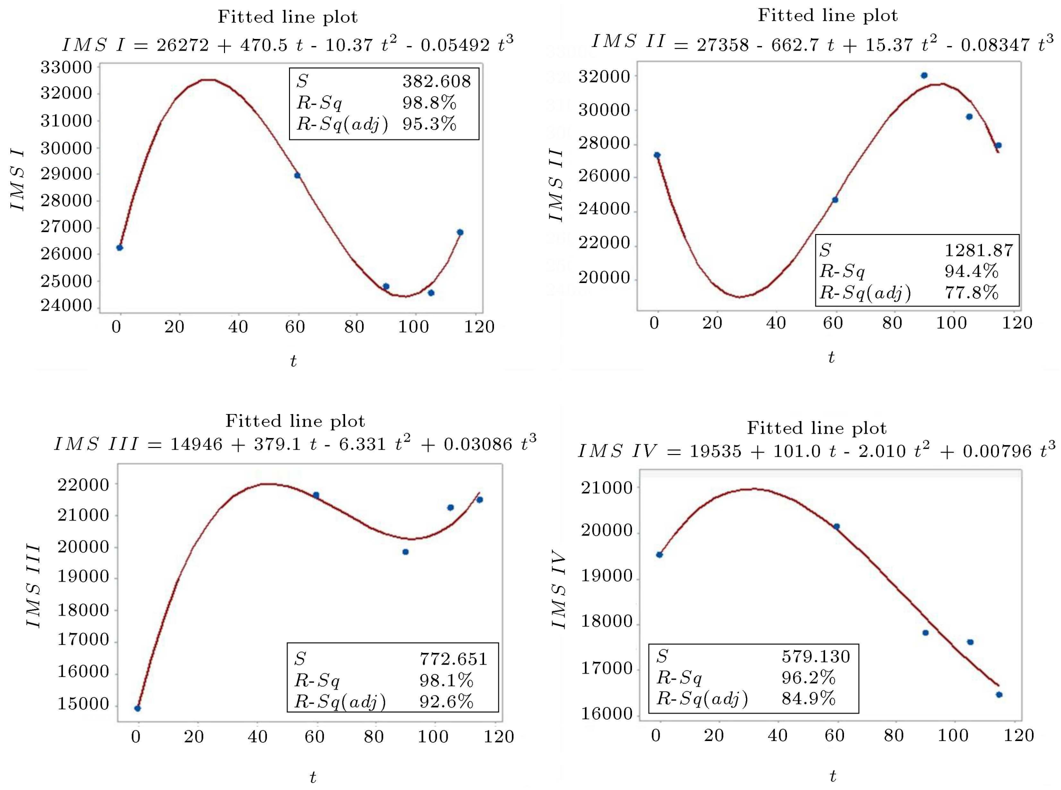
In Figure 6, three categories of cubic graphs presented for predicting short-term isometric muscle strength show that muscular isometric strength fluctuations are higher in males than in females, which is sinusoidal also, while females' isometric muscle strength trend is upward. On the other hand, the cubic graph for all volunteers looks very much like the males' cubic curve due to the greater number of males in the test and their more substantial muscle strength values. In Figure 7, since the four presented categories of cubic graphs are grouped according to the apparent similarity of individuals' graphs, both the R-Sq and the R-Sq (adj) significantly improve over Figure 6. Increase from (79.2%–89.9%) range to (94.4%–98.8%) for R-Sq, and increase from (16.9%–59.4%) range to (77.8%–95.3%) for R-Sq (adj), admit this improvement; however, only 77% of volunteers follow one of these curves.

5. Conclusion

The results showed a significant relationship between changes in rest-time duration with maximal isometric muscle strength, and rest time can affect muscle recovery or cumulative fatigue. On the other hand, gender is an influential factor in isometric muscle strength, and this strength is meaningfully higher in males than in females.

Females' upper body muscles are more resistant to fatigue than males; it means females became tired later and lower than males in this case study. However, on average, females' applied force was 41% of males. Therefore, in this case study, it is recommended to use male workers for repetitive activities (such as Manual Material Handling (MMH) and assembly) that require a high amount of force and sufficient resting time and use female workers for repetitive tasks that require low applied force with high rhythm or the frequency with short rest time.

Besides, results have shown that performing repetitive activities with applying force is influenced by task frequency and duration of rest time between



No.	Nonlinear Regression Equation	$R - Sq$	$R - Sq\ (adj)$
I	$IMS_I = 26272 + 470.5t - 10.37t^2 + 0.05t^3$	% 98.8	% 95.3
II	$IMS_{II} = 27358 - 662.7t + 15.37t^2 - 0.08t^3$	% 94.4	% 77.8
III	$IMS_{III} = 14946 + 379.1t - 6.33t^2 + 0.03t^3$	% 98.1	% 92.6
IV	$IMS_{IV} = 19535 + 101.0t - 2.01t^2 + 0.008t^3$	% 96.2	% 84.9

Figure 7. Four categories of common cubic isometric muscle strength graphs among volunteers.

activities. Therefore, the production/assembly line pace must be adjusted so that the worker can rest at an appropriate time and then do the next force exertion. So, in a situation where the production line speed is increased for some reason, assistant worker(s) must join in proportion to the increased speed and required rest time.

The research contributions are (1) investigating and mathematical modeling of maximal isometric muscle strength among Iranian students in the short term considering rest time, and (2) investigating muscle recovery and muscle fatigue during repetitive tasks among Iranian collegians based on gender. The research limitations can be stated below: (1) The sample size consisted of university students only. (2) The sample size was small to generalize the results to Iranian workers.

While using a greater sample size among Iranian workers, research results can also be used to design assembly and packaging lines in domestic industries, design appropriate work-rest schedules, and select workers based on gender and work conditions to perform repetitive activities. Additionally, three categories of generalized cubic graphs and four classified cubic graphs can predict isometric muscle strength in the short term for bachelor students.

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Declaration of conflicting interests

The authors declare that there is no conflict of interest.

Supplementary data

Supplementary data is available at:
file:///C:/Users/SHAMILA/AppData/Local/Temp/Supplementary%20Data%20File.pdf

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Appendix A

The equations of cubic fitted curves of isometric muscle strength for 31 volunteers can be found in Table A.1.

Table A.1. Fitted nonlinear curves of isometric muscle strength for 31 volunteers.

Volunteer number	Nonlinear regression equation	*R-Sq*	*R-Sq (adj)*
1	$IMS_1 = 23271 + 658.2t - 12.99t^2 + 0.06t^3$	75.6%	2.5%
2	$IMS_2 = 16897 + 183.1t - 2.4t^2 + 0.01t^3$	99.4%	97.6%
3	$IMS_3 = 12802 - 35.2t + 0.83t^2 + 0.003t^3$	96.6%	86.5%
4	$IMS_4 = 4659 + 101.5t - 3.18t^2 + 0.02t^3$	84.6%	38.5%
5	$IMS_5 = 39290 + 616.2t - 13.05t^2 + 0.07t^3$	95.4%	81.5%
6	$IMS_6 = 36460 - 670.7t + 13.75t^2 - 0.07t^3$	96.9%	87.6%
7	$IMS_7 = 21261 + 1085t - 18.3t^2 + 0.09t^3$	99.0%	95.8%
8	$IMS_8 = 34682 + 399.5t - 7.84t^2 + 0.03t^3$	92.0%	67.9%
9	$IMS_9 = 61882 - 1801t + 38.84t^2 - 0.20t^3$	98.4%	93.7%
10	$IMS_{10} = 24407 + 43.0t - 0.63t^2 + 0.004t^3$	87.0%	48.0%
11	$IMS_{11} = 67202 - 842.3t + 21.35t^2 - 0.13t^3$	88.3%	53.4%
12	$IMS_{12} = 28326 + 346.8t - 1.75t^2 + 0.07t^3$	86.5%	46.0%
13	$IMS_{13} = 22298 + 221.7t - 4.26t^2 + 0.02t^3$	98.9%	95.8%
14	$IMS_{14} = 24094 - 324.6t + 8.25t^2 - 0.05t^3$	97.7%	90.9%
15	$IMS_{15} = 27182 - 869.1t + 21.16t^2 - 0.12t^3$	91.5%	65.9%
16	$IMS_{16} = 39786 + 878.3t - 18.77t^2 + 0.09t^3$	97.6%	90.4%
17	$IMS_{17} = 12948 - 12.77t + 0.65t^2 - 0.006t^3$	98.5%	94.1%
18	$IMS_{18} = 52272 - 986.0t + 12.33t^2 - 0.05t^3$	98.7%	94.6%
19	$IMS_{19} = 8998 - 208.3t + 4.81t^2 - 0.03t^3$	99.1%	96.5%
20	$IMS_{20} = 19540 - 33.8t - 0.06t^2 + 0.004t^3$	75.7%	2.6%
21	$IMS_{21} = 61529 - 1377t + 31.08t^2 - 0.17t^3$	64.4%	0.0%
22	$IMS_{22} = 16676 + 58.0t - 1.33t^2 + 0.003t^3$	40.0%	0.0%
23	$IMS_{23} = 10685 - 156.7t + 6.22t^2 - 0.04t^3$	88.0%	52.0%
24	$IMS_{24} = 25911 + 114.3t - 1.52t^2 + 0.006t^3$	69.1%	0.0%
25	$IMS_{25} = 4613 + 265.0t - 5.28t^2 + 0.03t^3$	90.6%	62.6%
26	$IMS_{26} = 22063 + 75.9t - 1.54t^2 + 0.006t^3$	60.3%	0.0%
27	$IMS_{27} = 6050 + 248.1t - 4.16t^2 + 0.02t^3$	100%	100%
28	$IMS_{28} = 13659 - 216.8t + 5.57t^2 - 0.03t^3$	83.8%	35.1%
29	$IMS_{29} = 13753 - 359.8t + 8.21t^2 - 0.04t^3$	99.7%	98.8%
30	$IMS_{30} = 11306 - 15.5t + 0.01t^2 + 0.0004t^3$	59.3%	0.0%
31	$IMS_{31} = 7767 - 144.4t + 5.05t^2 - 0.03t^3$	78.0%	12.1%

Biographies

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