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Job Redesign Needs for Aged Workers

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The aim of this paper is to explore and present a proposal for redesigning elements of the workplace for aged workers. The method of research was to observe, record, and measure the actions of sitting workers performing assembly operations on electrical products in the Kani Plant Nagoya Works of Mitsubishi Electric Co. (Japan). The evaluation index used in the experiment was obtained by measuring time motion elements, cycle time per product, and motion velocity waves of elderly workers. Those motion characteristics were then compared to the motion characteristics of young workers. The results led to job redesign elements being identified to reduce handling factors of high difficulty for aged workers and to the necessity to consider a coefficient of correction in Method Time Measurement (MTM) according to differences in the manufactured object's weight.

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1. INTRODUCTION

In the labor environment in Japan, important negative factors like the rapid fluctuation in the exchange rate, high wages, and the aging of our labor force are creating difficulties for industries still dependent on manual assembly activities during production. In the case of the fluctuating exchange rates, some companies have taken measures such as introducing industrial robots, rationalizing production through automation, and increasing on-site production overseas. But these solutions have created other problems as in the case of overseas production. Rising production prices and labor-management problems as well as blue-collar unemployment in Japan have appeared. And though automation can be implemented in many cases, from the production system standpoint, manpower is still the core of man-machine systems. The Toyota Motor Co. (Japan) manpower system is an example of this.

In the case of the second factor (i.e., the aging of our labor force), Japan is rapidly becoming an aged society at an unprecedented rate unlike that experienced in any other country. Better medical care and changing lifestyles have resulted in more elderly people remaining active in the workforce for a longer time. In Japan, the population is aging at a rate four times that of Europe and America. The Population Research Institute of the Welfare Ministry estimates that people over 65 years old will form 25% of Japan's population in 2015 (Nagamachi, Kawakami, Kumashiro, Une, & Tange, 1985). This means that our country will have the largest ratio of the elderly in the world, resulting in a considerable depreciation of labor productivity. To deal with this situation, the government, research laboratories of enterprises, and other institutes are cooperating in finding solutions to this problem. Although many researchers, including the authors, have looked at some means of solving this problem (Fitts, 1954; Fitts & Peterson, 1964; Kawakami & Ueno, 1986; Langolf, Chaffin, & Foulke, 1976; Miyashiro, 1985; Miyashiro & Yokomizo, 1987; Nagamachi, Kawakami, Une, & Tange, 1983; Shibata, Ooba, & Inooka, 1993), few studies of the elements involved in job area redesign for older workers have been done. This paper presents a proposal for the redesign of job area elements based on an experimental model.

2. METHODS

The concept model for our research is shown in Figure 1. This concept has been designed on the basis of an ongoing series of research projects. The research method gives consideration to the motion characteristics of workers and the influence differences in workers' ages have on these characteristics. Also considered were the effects these characteristics have on operation efficiency. Experiment I was conducted with workers assembling electromagnetic opening and shutting devices in the assembly workshop of the Kani Plant Nagoya Works of Mitsubishi Electric Co. (Japan). The outline of Experiment I and the work conditions are shown in Table 1. The preconditions of the experiment were as follows:

1. The operation involved in Experiment I was light work and the objects that were assembled were lightweight and could be held by hand.
2. The working position was a sitting position.
3. The working area was within the maximum job handling area.
4. The participants were well practiced and experienced in the action of the object operations.

The system for measurement in Experiment I was a Video Tape Recorder (VTR) system HSV-200 (NAC, Japan) and a stopwatch 1/100 s (SEIKO, Japan). A VTR camera was set vertically beside the participants.

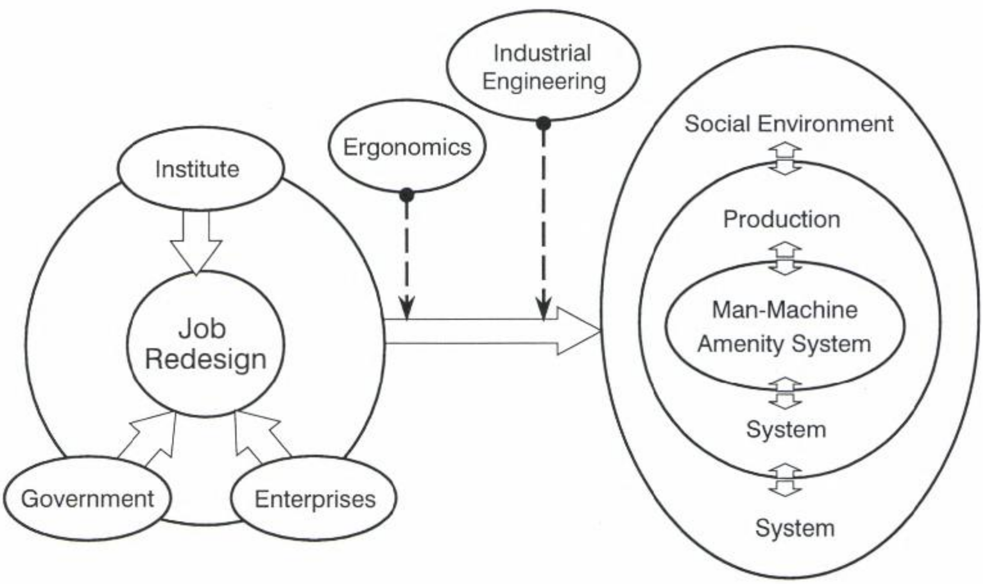

Figure 1. The concept of redesign for aged workers.

TABLE 1. Contents of Experiment I

Conditions	Labor type: intensive work		
	Parts used: air-driver, cutting pliers for assembling		
	Posture: sedentary type		
Participants	Young workers: 4	average age: 20.5 (range 19–21)	
	Aged workers: 4	average age: 50.5 (range 50–51)	
	Participants well practiced in the actions of the object operations		
	Data gathered under stable work		
Operation	Assembly workshop of electromagnetic opening and shutting machines		
	Product 1	number of parts: 40	size: 8 × 8 × 10 cm
		number of types: 16	weight: (finished goods): 980 g
	Product 2	number of parts: 4	size: 8 × 8 × 6 cm
		number of types: 4	weight: (finished goods): 282 g
	Coefficient of correction in MTM: 1.00		

Notes. Product 1: The degree of difficulty is low; Product 2: The degree of difficulty is high; MTM—Method Time Measurement.

During the experiment sampling, data were recorded randomly to eliminate irregularities caused by the participants being conscious of the camera. The evaluation index used was based on (a) the cycle time that it takes to assemble each product and the rate of the increase of motion time according to the motion elements, (b) the change of motion velocity waves recorded.

3. RESULTS AND DISCUSSION

3.1. The Influence of Age Disparity on Assembling Motion Time

As can be seen in Table 2, there is a difference between the average cycle time it takes to assemble product P1 by younger and by older participants. The results of Experiment I show that the difference is significant ($p < .01$). In short, young workers are superior to aged workers in operation efficiency. Also, the scattering of the aged worker's cycle time is 4.3 times larger than that of the young worker's. The individual difference in operation ability also becomes obvious in proportion to age. Past experience of the participants in similar work affects efficiency and this experience was also examined. The participants were divided into two groups (M6, M7—people of experience; M5, M8—people of inexperience). The results of Experiment I showed a significant difference between experienced workers and inexperienced workers ($p < .01$). A ratio of the actual performing motion time (Actual Time) to the net motion time (Normal Time), that is, Method Time Measurement (hereafter MTM) Standard was established. It was 84.6% for people of experience and 104.8% for people of inexperience. These figures show that the presence of experience in similar work affects the operation efficiency considerably. When these figures were applied to the regression ($Y = 0.32 X + 78.1 \pm 9.4$), which is the ratio of the number of parts types to motion time obtained from previous research (Kawakami & Ueno, 1990), the experienced people's values are within the limits of regression. Therefore, it cannot be denied that the various functions of human beings decrease proportionally as they become older but the technical skills that have been accumulated in the past affect job efficiency positively and provide some compensation for loss of function.

TABLE 2. Cycle Time by Product (Product P1), $n = 60$

Participants	M1 (M5)	M2 (M6)	M3 (M7)	M4 (M8)	$\bar{\chi}$	σ
Young	198.2	202.3	193.4	205.2	199.8	7.2
Aged	(233.5)	(193.6)	(186.8)	(238.3)	(213.1)	24.6

Notes. Normal Time (standard Method Time Measurement): 225 s; M1, M2, M3, M4—younger workers; M5, M8—older workers of inexperience doing assembling work; M6, M7—older workers of experience doing assembling work.

TABLE 3. Cycle Time by Product (Product P2), $n = 60$

Participants	M1 (M5)	M2 (M6)	M3 (M7)	M4 (M8)	$\bar{\chi}$	σ
Young	69.8	75.5	73.1	76.5	73.8	4.1
Aged	(82.7)	(80.3)	(94.3)	(90.5)	(87.0)	7.1

Notes. Normal Time (standard Method Time Measurement): 77.7 s; M1, M2, M3, M4—younger workers; M5, M8—older workers of inexperience doing assembling work; M6, M7—older workers of experience doing assembling work.

In Table 3, the results of analysis for product P2 are indicated. The analysis for P2 is the same as for P1, however, P2 was smaller than P1 and more difficult to handle. It appears from Table 3 that from the age difference aspect, young workers are superior to aged workers in regard to the ability to work on smaller, more difficult jobs. However, in this process, the following additional aspects were found:

1. Although the Actual Time of the young workers is within the Normal Time based on the standard MTM, the Actual Time of all the aged workers (including people of experience) was out of the Normal Time range. In Table 4, a breakdown of the motion elements is shown and the comparison between Normal Time and Actual Time by each type of motion is indicated.
2. It appears that the ratio of Actual Time to Normal Time has a tendency to increase, particularly for motion element #7, which was 75.3%. Taking note of this point, Table 5 shows a more detailed breakdown of motion element #7.
3. It is also evident from Table 5 that motion elements #7 are elements that have a high degree of difficulty (P1NSD, P1SSD*; each appears twice).

TABLE 4. Rate of Motion Time by Motion Element (Product P2), Aged Workers in Motion Element #7

Motion Element	Motion Time (s)	MTM (s)	Rate of Increase of Motion Time (%)
1. Loosen two screws	7.8	7.4	5.4
2. Loosen screw (a) and unfasten screw (b)	5.1	5.0	2.0
3. Fasten lead (a) on accessory	7.4	6.1	21.3
4. Fasten lead (a) on object	5.2	3.8	36.8
5. Combine accessory with object and set parts on assembly tool for next operation	3.4	2.6	30.8
6. Tighten screws on object	8.1	7.7	5.2
7. Fasten lead (b)	14.2	8.1	75.3

Notes. MTM—Method Time Measurement.

* For an explanation of the symbols, see Table 5.

TABLE 5. Motion Analysis of Motion Element #7

Motion of Left Hand	Motion	TMU	Motion	Motion of Right Hand
Stretch out hand for lead	R26C	13.0		
Hold	G1C3	10.8		
Move to object	G2	5.6		
Hold	MfC	11.8	M24B	Move screwdriver to screw
Position	P1NSD	16.0		
		2.0	MfC	
		14.7	P1SSD	Position
		30.0	MT	Screw
Move lead to screw hole	M10B	6.8	M10B	Lift screwdriver
Bend lead	M5B	4.5		
	MfC	2.0		
Position	P1NSD	16.0		
		13.0	M24C	Move screwdriver to screw
		14.7	P1SSD	Position
		30.0	MT	Screw
		10.5	M20B	Lift screwdriver
		2.0	RL1	Release

Notes. TMU—Time Measurement Unit, 1 TMU = 0.0036 s; P1NSD and P1SSD—symbols of analysis in Method Time Measurement; P—position, 1—case, 1—loose, 2—tight, 3—very tight; NS—asymmetrical, SS—semi-symmetrical; D—high difficulty of handling; MfC—corrective finger motion; MT—machine time. In R26C: R—reach, 26—distance (in cm), C—case. In M5B, M10B, M20B, M24B, and M24C: M—move, 5, 10, 20, 24—distances (in cm), B, C—cases. In G1C3 and G2: G—grasp, 1C3 and 2—cases. In RL1: RL—release, 1—case.

3.2. The Influence of Disparity in Age on Motion Velocity

Generally, in various motion elements, the Get-and-Place activity is a suitable operation for explaining the difference in motion characteristics according to age because special skill is not needed. As can be seen in Figure 2, the changes of the motion velocity waves of young workers and older workers was a Get-and-Place distance of 26 cm. Human motion velocity is generally composed of acceleration → constant speed → deceleration (Mandel, 1961). This figure shows that motion velocity waves are divided among Phase I (acceleration), Phase II (constant speed), and Phase III (deceleration). From Figure 2 it can be seen that in the aged worker's operation—when compared to the younger worker's operation—all phases were delayed. The transition of motion velocity of older workers is slower in the acceleration and deceleration areas presumably due to age. From this standpoint, considering the decrease of human functionality (especially muscle function) from the aging process, it is necessary to reexamine the coefficient of correction in MTM when the object's weight is below 1000 g.

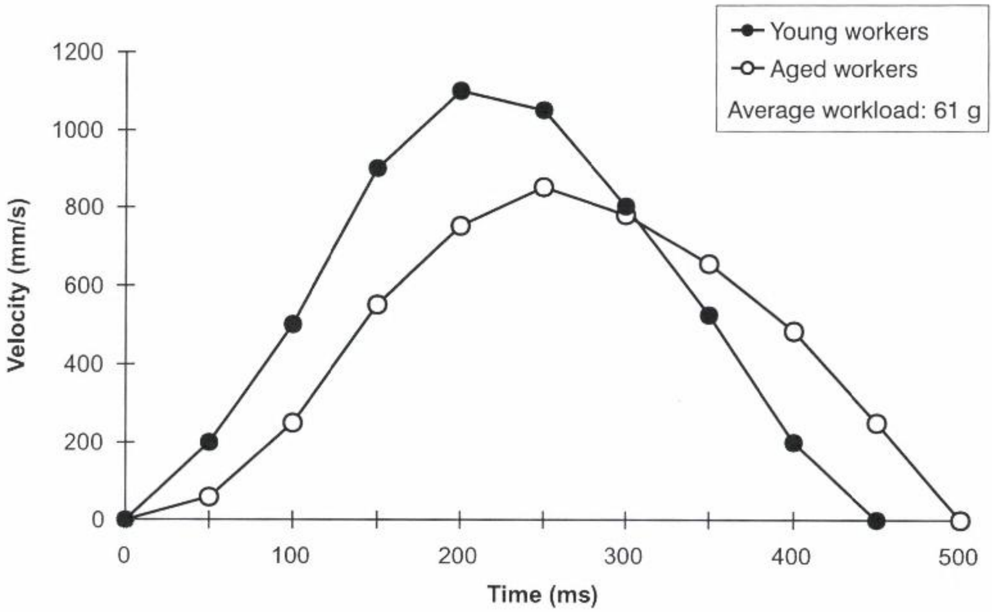

Figure 2. Motion velocity wave of the Get-and-Place activity.

3.3. The Elements of Productivity Improvement

Consequently, to examine the participants from this point of view, the following observation was conducted. The authors took note of the Get-and-Place activity mentioned in section 3.2. and considered how the difference in an object's weight (200, 400, 600, 800, and 1000 g) would influence the function of a worker's myoelectric potential and operation efficiency (Kawakami, Inoue, & Ukai, 1995). The evaluation index used in Experiment II was obtained by measuring motion velocity, myoelectric potential, motion time, and the difference in the work burden from the vertical and horizontal directions. The equipment used in Experiment II were a VTR (HSV-500; NAC, Japan) and Mac Quat 4 channel Memory from VINE Bionics System (Japan). The contents of Experiment II are explained in Table 6 and graphically shown in Figures 3, 4, 5, and 6.

TABLE 6. Contents of Experiment II

Workload	Shape: Column (radius of base: 55 mm, height: 157 mm) Weight: Five kinds of load (200, 400, 600, 800, 1000 g)
Work Area	Horizontal angle: 38.4° Vertical angle: 19.3° (Kawakami, Inoue, & Ukai, 1995)
Participants	4 men (ages: 21–24, height: 1640–1730 mm)
Type of Work	Get-and-Place Activity (distance: 300 mm, Time: 1 min/cycle) Participants well practiced in actions
Method of Gauged Muscles	Surface electrodes (Vitrode-S) placed in pairs with a 30-mm center distance upon carefully prepared skin over the muscles studied (i.e., Trapezius muscle, Deltoid muscle, and Brachioradialis muscle; Figure 6)

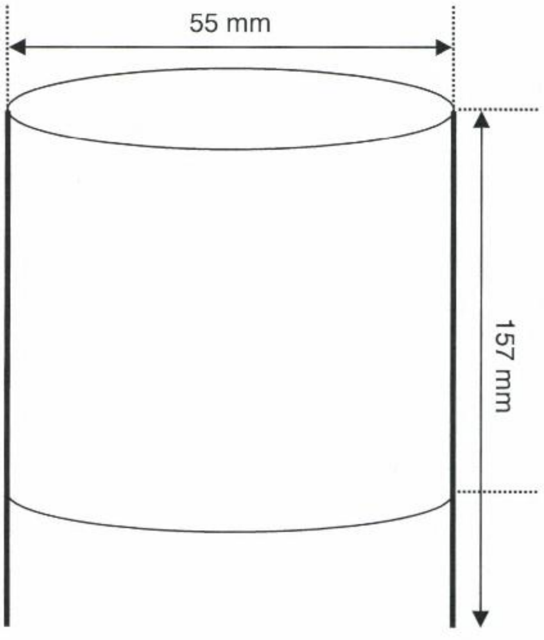

Figure 3. Workload.

The results of this experiment showed the following:

1. An object's weight seriously influences myoelectric potential (μV) and, as the object's weight increases, the load on the muscle involved increases. A significant level was accepted at $p < .01$.

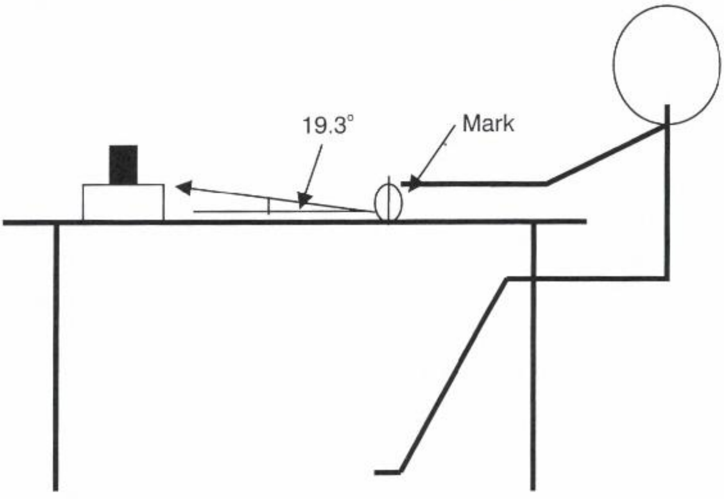

Figure 4. Vertical work area.

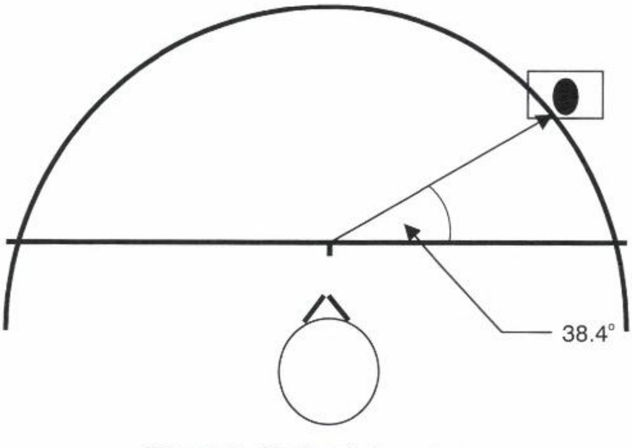

Figure 5. Horizontal work area.

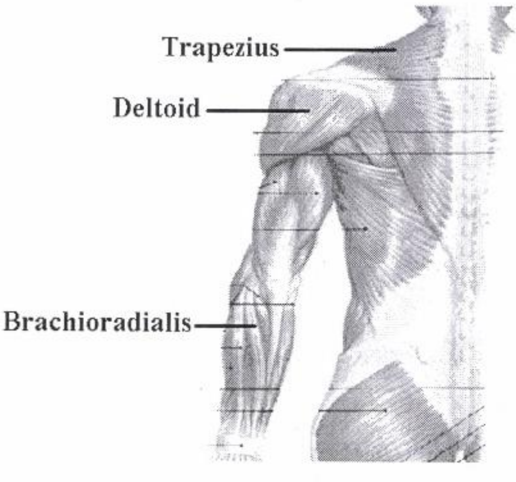

Figure 6. Gauged points of myoelectric potential (Sakai, 1990).

2. An object's weight seriously influences motion time and, when the object's weight is below 1000 g, it was confirmed that motion time depended on the weight (Figures 7 and 8). A significant level was accepted at $p < .01$. These results showed the necessity to reevaluate the coefficient of correction in MTM. Using the experimental formulas shown in Table 7, motion time and coefficients of corrections are shown in Table 8.

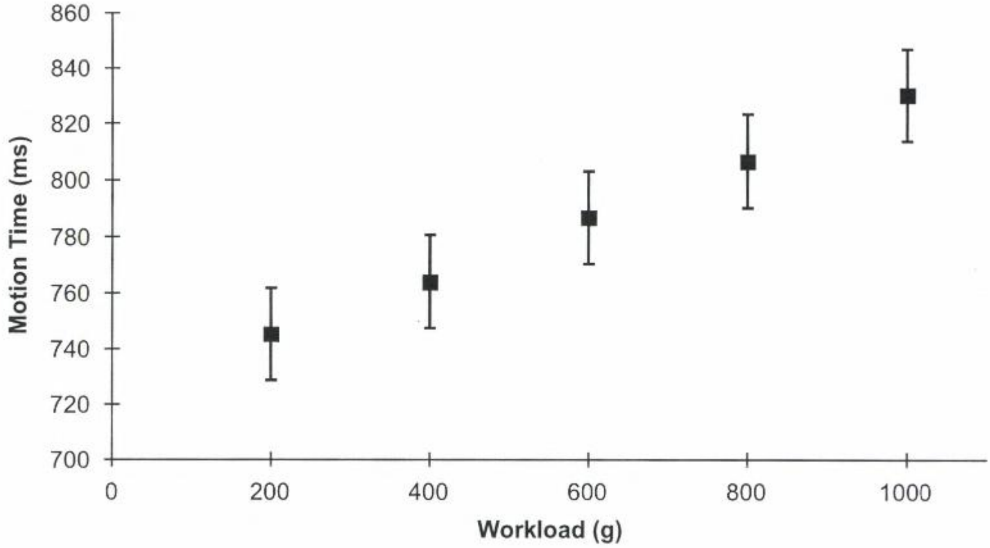

Figure 7. Interval estimation (approach route).

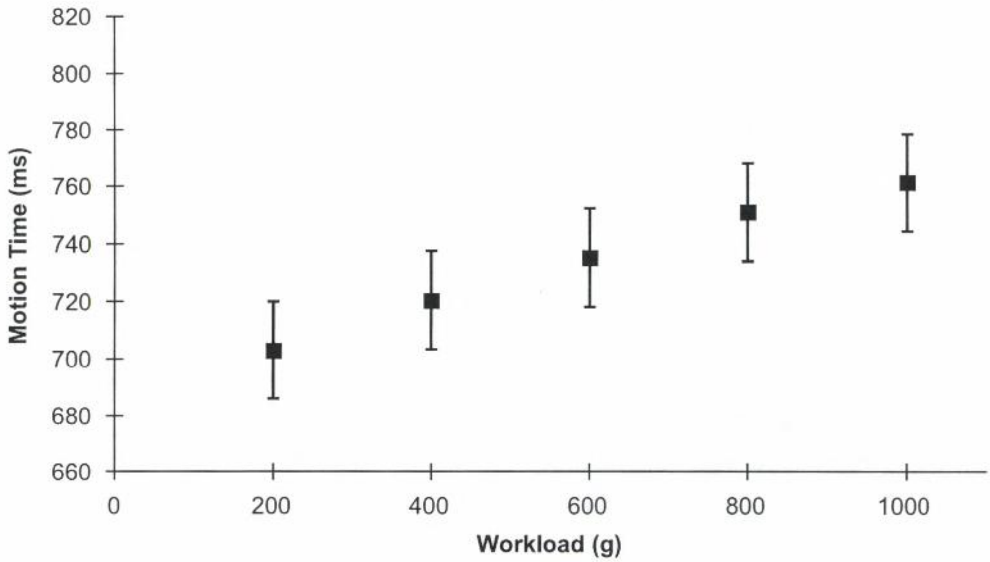

Figure 8. Interval estimation (return route).

TABLE 7. Experimental Formulas

Conditions	Experimental Formula
Approach	Y = (21.21 / 200) X + 722.8
Return	Y = (14.66 / 200) X + 690.2

TABLE 8. Motion Time and Coefficients of Corrections

Condition	Load (g)	Motion Time (TMU) (s)	Coefficients of Correction
Approach	200	20.67	0.99
	400	21.26	1.03
	600	21.84	1.06
	800	22.43	1.08
	1000	23.02	1.11
Return	200	19.59	0.95
	400	19.99	0.97
	600	20.40	0.99
	800	20.80	1.00
	1000	21.21	1.02

Notes. Method Time Measurement Standard Value: 20.77 (TMU); TMU—Time Measurement Unit, 1 TMU = 0.0036 s.

4. CONCLUSIONS

From the aforementioned considerations, the following points were shown to be important:

1. As a design element of job redesign, it is necessary to reduce handling factors of high difficulty (P1NSD and P1SSD in MTM) for aged workers.
2. As an estimate of standard time, it is necessary to consider the coefficient of correction in MTM according to the difference of an object's weight ranging from 200 to 1000 g when considering job productivity and workplace design for elderly workers.

This research needs to be explored on a wider range of jobs and job skills not only to improve productivity in manufacturing but also to make the lives of our aging society's workers more productive.

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