ISSN: 0128-7680
Pertanika J. Sci. & Technol. **19 (2)**: 293 – 305 (2011)

A Biomechanical Study of Grip and Pinch Strength among Malaysian Elderly Population

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ABSTRACT

The physical strength of the elderly aged above 60 years is typically 10 to 30% less than the young adult population of ages between 25 to 35 years. This reduction of strength has a strong impact on the activity of the daily living (ADL) of the elderly population. There has been little research done studying on the physical strength of the elderly population in Malaysia. The objective of this study was to determine the static strength of the elderly population in Malaysia. In particular, the grip and pinch strength were investigated as these two static strengths are extensively used in their instrumental activity of daily living (IADL). The results were then compared to the strength of the university students. A total of 30 subjects (15 males and 15 females) participated in the study. Their age ranged between 60 to 83 years, with the mean of age of 67.1 years. The comparison group comprised a total of 30 university students (20 male, 10 female) aged between 23 to 24 years, with the mean of age of 23.2 years. Grip and pinch strengths of both groups were measured and analysed using a descriptive statistics. It was found that the elderly male subjects are stronger in both strength measurements than their female counterpart. The 95th percentile of the female grip strength was slightly lower than that of the male while the male pinch strength was 31.07% higher. It was also found that the male students had higher strengths compared to the females. The grip strength of the elderly was 30.66% lower than the university student, while their pinch strength was 13.42% lower. Both static strengths of the elderly were found to be lower than those of the university students. This supported the research hypotheses postulating that the static strength had a negative correlation with age. In terms of gender differences, the male subjects were found to be stronger than the females.

Keywords: Elderly, reduction of strength, ADL and IADL, grip and pinch strength, university students, age, gender differences

Received: 26 March 2010
Accepted: 6 October 2010
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INTRODUCTION

Task performance is closely related to the physical status of an individual. From the perspective of human ecology, the decline of human performance is significant with age. In other words, the older the person, the weaker and slower they are in their physical performance. Maximal muscle strength is reached at the age of about 20 for men, and a few years earlier for women. Grip strength may reach its maximum value in the middle to late 20s and then declines as age advances. The strength of a 65-year-old person is about 75-80% of that attained at the age of 20-30 years (Rodahl, 1989). Muscle strength in the sense of the maximum instantaneous force that can be exerted by various muscle groups, such as those responsible for hand grip, declines by about 15 - 40% from the 20s and 60s (Welford, 1985). In terms of gender differences, there are also strength differences between male and female. The grip strength of men is greater than that of the women (Falkel *et al.*, 1985). On average, the grip strength for the women is about 60% of men's (Fraser, 1983).

Grip and pinch are extensively used in everyday task performance. In human biomechanical study, grip and pinch strengths are categorised as static strength. Static strength is defined as the maximum voluntary muscle exertion (contraction) of a body part in a restrained position without movement (Tayyari & Smith, 2000). Static strength is also known as isometric strength, which is a steady force exerted while the limbs are in a stationary or static position. One of the methods to investigate biomechanical limitation is by using static strength measurement. In 1996, the FAA William J. Hughes Technical Centre developed and established a standard known as Human Factors Design Guide, which also included these measurements (Wagner *et al*., 1996).

Thus, testing and investigating elderly static strength of grip and pinch can provide valuable information about their functional ability towards improving ADL task design, and IADL products and tools design. This "accessible design" could be very beneficial for designers to design consumer products to increase user's accessibility, especially to the aging person as well as the disables (Trace R&D Centre of University of Wisconsin-Madison, 1992).

METHODS

The subjects of the study were elderly people between the ages of 60 to 83 years old, with a mean of age at 67.1 years. The strength of a total of 30 volunteered subjects (15 males and 15 females) was measured during the data collection session which was held in a Community Hall. All of them are in good health and live independently in their own home setting. The subjects were briefed on the data acquisition protocol and the equipment were also shown and demonstrated to them. The subjects were asked to apply one-handed peak grip and peak pinch using their dominant hand. Each of the maximum grip or pinch was performed three times with a 30-seconds rest intervals and the average was recorded. The static strength measurement procedure used in this study was referred to standard procedures introduced by Caldwell *et al.* (1974), although new equipment was also used.

During the screening session, the subject's background information was collected for demographic purposes. Only selected subjects were offered to take part in the data collection session. They should not have any hand problem, and possess normal healthy condition, age 60 years and over, live independently and were willing to participate. The subjects were also informed that the data they gave would be regarded as strictly confidential and used only for academic purposes. A small token was given as appreciations of their commitments.

The collected data were processed using the SPSS software (version 16.0; SPSS Inc., Chicago, IL, USA) to obtain the percentile and analysed using descriptive statistics.

Fig. 1: JAMAR Hydraulic Hand Dynamometer is a standard instrument used in measuring one-handed grip strength

Fig. 2: This figure shows the pinch gauge and how it was used to measure the subject's pinch strength

INSTRUMENT

The measurements taken from each subject were grip and pinch strengths. Both measurements were taken on the same day. This was to ensure that the data collection session had little impact on the subjects' daily routines. They were also given an alternative whether to come in the morning or afternoon session.

The data was collected using JAMAR Hydraulic Hand Dynamometer, which is standard grip measurement equipment (*Fig. 1*). For the thumb or pinch strength measurement, the JAMAR Pinch Gauge was used. *Fig. 2* shows how pinching and the readings were done.

RESULTS

The selected mode of reporting strength data recommended by Chaffin (1975) was used in this study. One of the most basic types of analysis is to compare groups of people, such as males to females, adolescents to parents, and clinical to normative samples (Hectner *et al*., 2007).

There are also comparisons made to two different age cohort groups, like the elderly aged between 60-85 years and university students aged 22-29 years to see the significant differences among the studied groups (Pennathur & Dowling, 2003).

In this study, a comparison was made between the genders and two different age groups. This was done to evaluate the biomechanical limitation differences. The elderly were between 60-83 years old, while the university students were between 23-24 years old. Tables 1, 2, and 3 show the results for the measurements done for the elderly. Meanwhile, Tables 4, 5, and 6 present the results of the measurements for the university students. Table 7 shows the comparison between Malaysian elderly and elderly from ADNFS, as well as with Malaysian Industrial Workers.

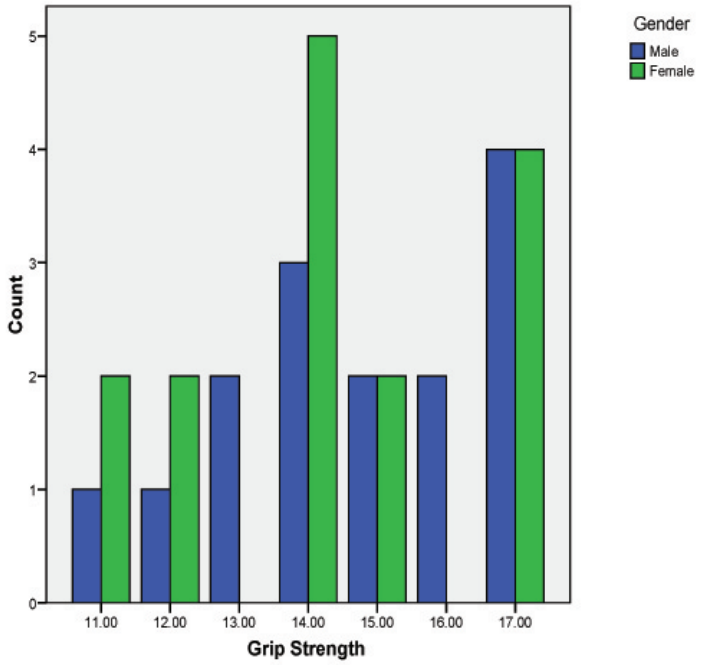

Fig. 3: Result of elderly grip strength

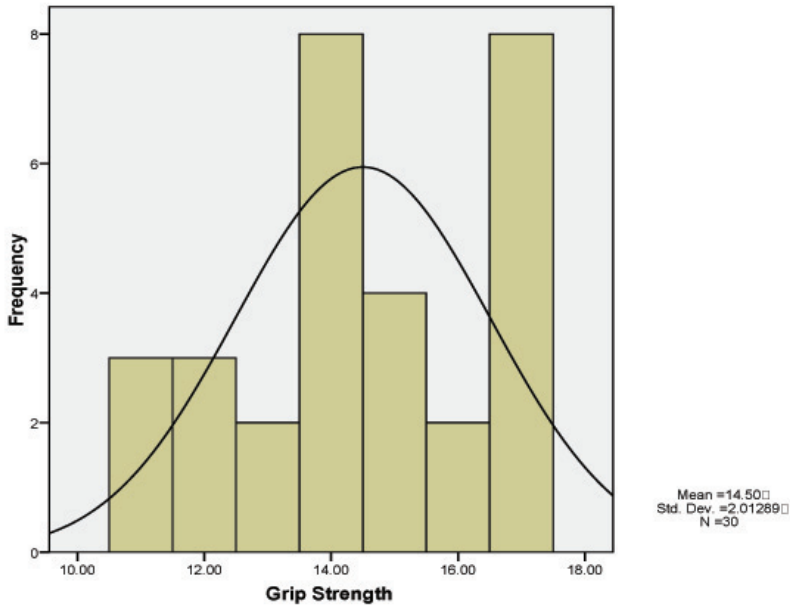

Fig. 4: Result of showing the grip strength of the elderly for both genders

Grip Strength

The results of the elderly grip strength are as shown in Table 1, as well as in *Figs. 3* and *4*.

Table 1 shows the result of grip strength measurement of both genders. It ranged between 11-17 kg. A slight difference was observed in the mean strength between the genders. The standard deviation shows that the female is higher than the male. The 5th and 95th percentile of the female population were slightly lower than the male.

TABLE 1
Elderly grip strength (N=30)

Range of strength	11 kg - 17 kg	
Gender	Male	Female
No. of subject	15	15
Mean (kg)	14.73	14.25
Std. Deviation	1.94	2.12
95th Percentile	17.93	17.75
5th Percentile	11.53	10.77

Fig. 3 shows an equal number of male and female recorded at the grip strength of 15 kg and 17 kg. However, there were more females recorded the grip strength of 11 kg, 12 kg and 14 kg, as compared to the males. On the other hand, only the male recorded grip strength at 13 kg and 16 kg compared to the females. *Fig. 4* shows the results for the grip strength of both genders. The bell curve shows a normal data distribution.

Thumb/Pinch Strength

The results of elderly pinch strength measurement are shown in Table 2, *Figs. 5* and *6.* Table 2 shows that the pinch strength for the elderly ranged between 4-12 kg. The mean difference of pinch strength between the male and female was 3.33, and that of the male strength is obviously high. There was a slight (0.2) difference in Standard Deviation. Meanwhile, the gap between the 5th percentile for the male and female is rather obvious (3.02). In fact, it is more than double. The 95th percentile shows the males have 3.65 kg higher than that of the females.

Fig. 5 shows that male elderly is stronger than the female. The frequency for the females is higher at 4 kg and 5 kg, while there is no male recorded at this low strength limit. The highest female pinch strength was 9 kg, while the males recorded 25% higher at the reading of 12 kg. The male highest frequency was at 8 and 9 kg. There is no female recorded at 10 kg, 11 kg and 12 kg pinch strength limit. *Fig. 6* shows the result of pinch strength for both genders. Once again, the bell curve shows a normal data distribution.

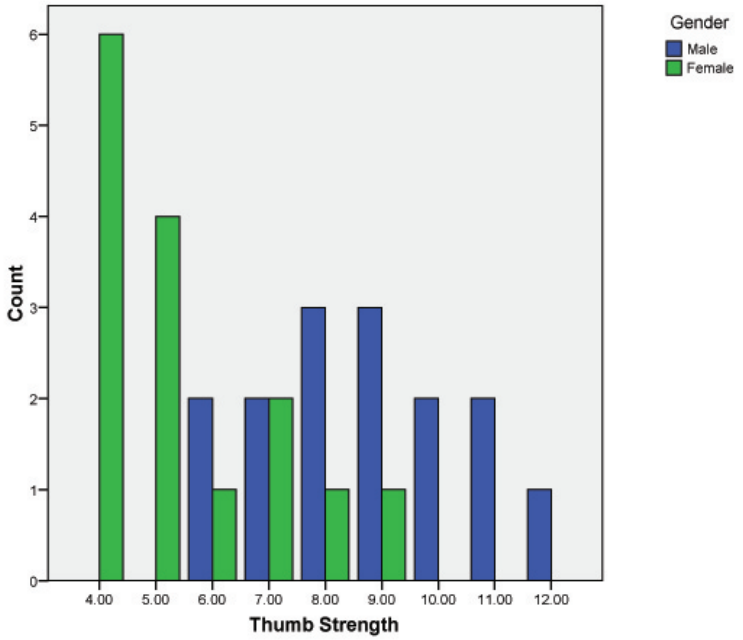

Fig. 5. Result of elderly thumb/pinch strength

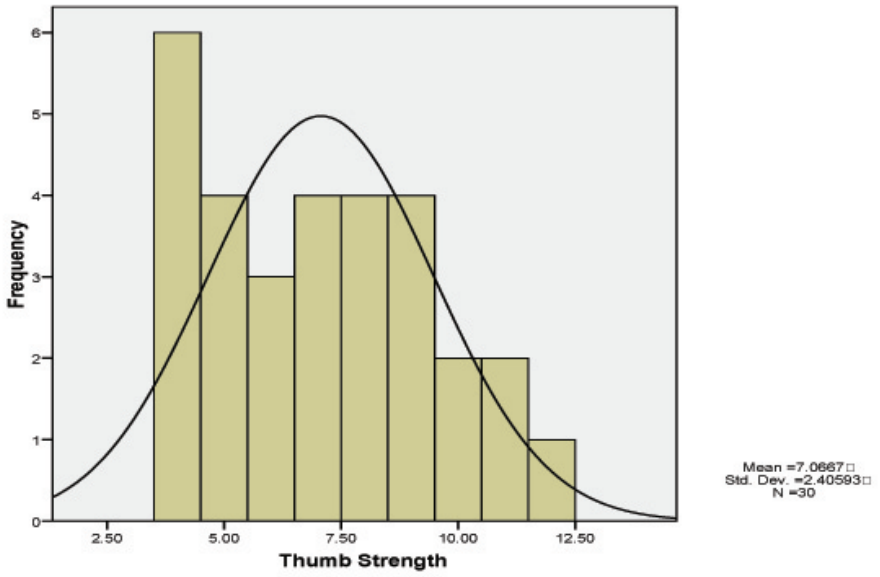

Fig. 6: Result of elderly thumb/pinch strength for both gender

TABLE 2
Elderly thumb/pinch strength (n=30)

Range of strength	4 kg - 12 kg	
Gender	Male	Female
No. of subject	15	15
Mean (kg)	8.73	5.40
Std. deviation	1.83	1.63
95th percentile	11.74	8.09
5th percentile	5.72	2.70

TABLE 3
Percentiles of elderly grip and pinch strength for both genders (N=30)

	Percentile		
	5th	50th	95th
Grip strength (kg)	11.00	14.00	17.00
Pinch strength (kg)	4.00	7.00	11.45

Since the task or product used to perform task should fit both genders, engineers or designers might refer to both genders, specifically on the 95th percentile to overcome task performing issues, although the result of split gender revealed some differences. Table 3 shows the percentile of strength measurements for both genders.

Comparison Group

In this study, the strengths of the students from the University of Malaya, Kuala Lumpur were measured and the results were compared to the results yielded for the elderly. The data collection session utilized the same equipment, measurements and protocol previously used for the elderly to ensure the validity of the results. A total of 30 subjects (20 male and 10 female) were involved in the data collection session. They aged between 23-24 years old, with the mean age of 23.2 years. The results of the gripping strength are as shown in Table 4, and *Figs. 7* and *8*.

TABLE 4
Grip strength of university students (N=30)

Range of strength	24 kg - 56 kg	
Gender	Male	Female
No. of subject	20	10
Mean (kg)	44.60	27.00
Std. deviation	7.27	2.53
95th percentile	56.56	31.17
5th percentile	32.63	22.82

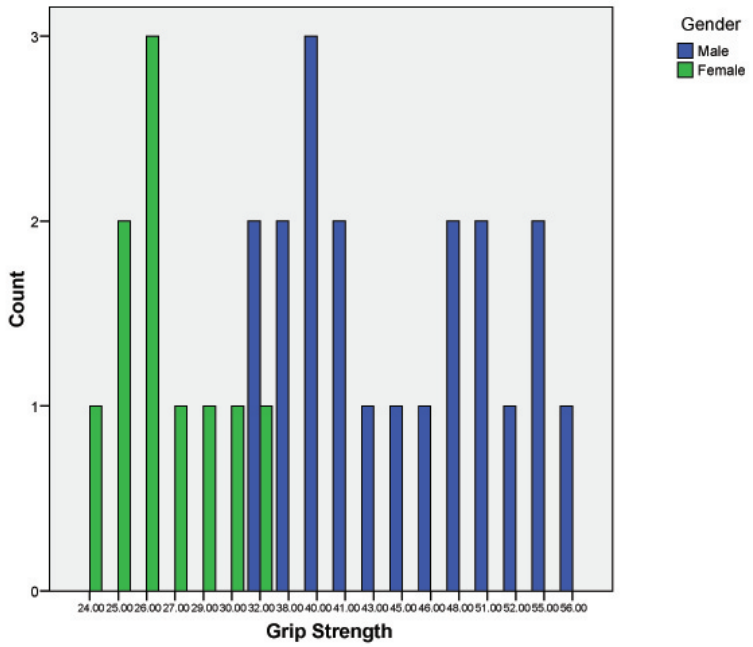

Fig. 7: Result of student grip strength

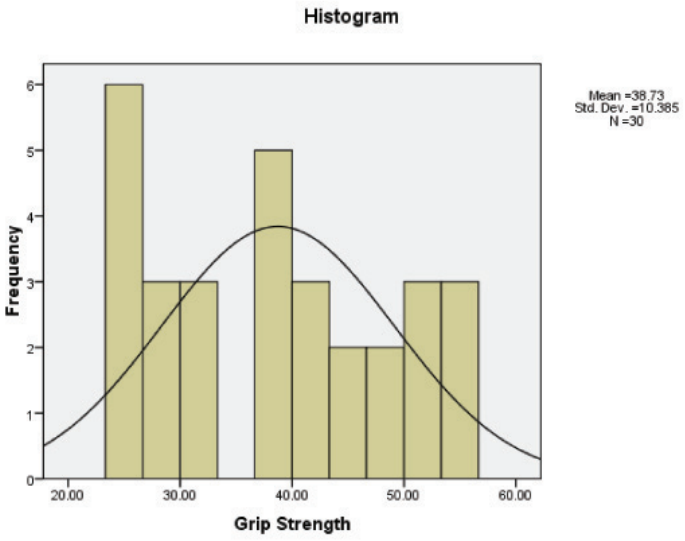

Fig. 8: Result of student grip strength for both genders

Table 4 shows the results of grip strength measurement of both genders. It ranged between 24-56 kg. It also reveals that the male student is much stronger in terms of gripping strength compared to that of the female. The mean difference between the grips of the male and female students was 17.6 kg. The difference of standard deviation was 4.74. The 95th percentile shows 25.39 kg difference, while the 5th percentile is 9.81 kg.

Fig. 7 illustrates that no male student recorded strength as low as the females, i.e. from the range of 24-30 kg. On the other hand, no female student was found to have grip strength up to 38 kg-56 kg as the males. Only 32 kg grip strength was recorded for both genders.

TABLE 5
Thumb/pinch strength of university students (N=30)

Range of strength	6 kg - 13.5 kg	
Gender	Male	Female
No. of subject	20	10
Mean (kg)	9.99	7.30
Std. deviation	1.69	0.94
95th percentile	12.78	8.86
5th percentile	7.20	5.73

The results for the students' pinch strength are shown in Table 5, as well as in *Figs. 9* and *10*. The male students have higher pinch strength, with 26.92% or 2.69 kg higher mean of pinch strength compared to that of the females. The males were also higher in standard deviation at 0.75, higher 3.92 kg on 95th percentile and 1.47 kg in the 5th percentile.

Compared to the elderly, the minimum pinch strength for the students was 2 kg higher and the maximum strength was 1.5 kg higher. Once again, based on both genders' statistics (Tables 3 and 6), the students' gripping strength was 69.34% higher than that of the elderly at 95th percentile. Meanwhile, the pinch strength of the elderly was 13.38% lower than that of the students.

TABLE 6
Percentiles of university students' grip and pinch strengths for both genders (N=30)

	Percentile		
	5th	50th	95th
Grip strength (kg)	24.55	40.00	55.45
Pinch strength (kg)	6.00	9.00	13.22

TABLE 7
Grip strength comparisons from previous research

Measurement	Malaysian elderly (60-83 years)		Malaysian industrial workers[a1] (18-40 years)		ADNFS (1992)[a2] (65-74 years)	
Gender	Male	Female	Male	Female	Male	Female
Mean (kg)	14.73	14.25	21.13	12.23	39.87	23.23
Std. deviation	1.94	2.12	1.43	2.79	8.74	5.59

[a1]Taha, Z and Nazaruddin.

[a2]Alan M. Nevill and Roger L. Holder.

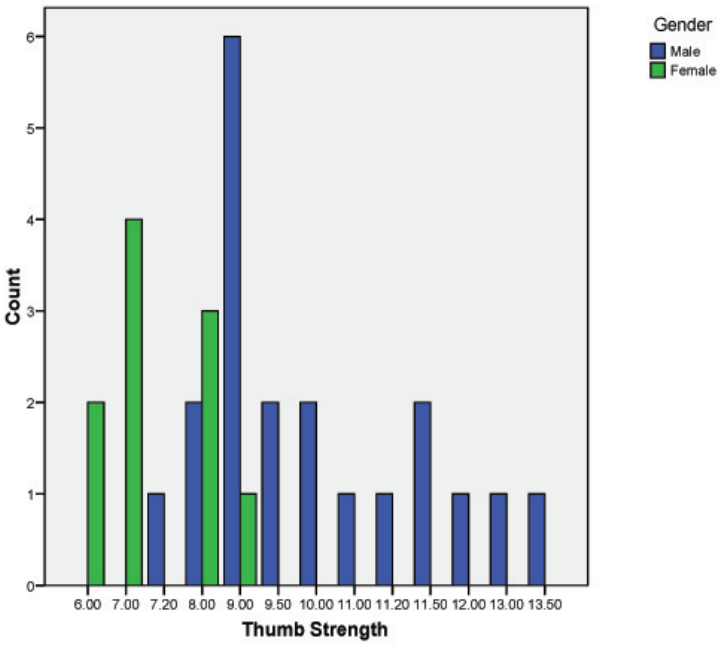

Fig. 9: Result of student thumb/pinch strength

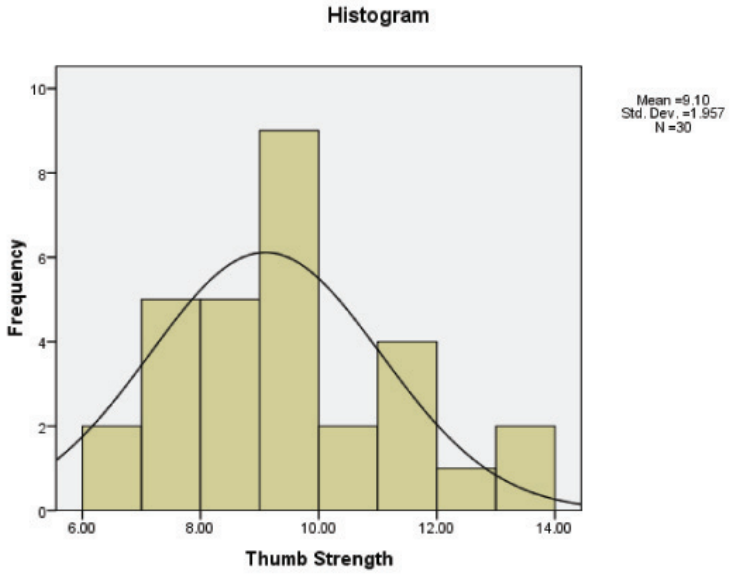

Fig. 10: Result of student thumb/pinch strength for both genders

Table 7 shows another finding on gripping measurement by Nevill & Holder (2000), as well as Taha & Nazaruddin (2005), as a comparison to the investigated group.

DISCUSSIONS

In terms of gender, the analysis shows differences in the gripping and pinching strengths among the male and female elderly. In more specific, the male elderly had better strength ability compared to that of the female. The university students also show the same strength pattern in terms of gender differences. This particular finding affirms the previous literature, i.e. age is significant with frail or physical breakdown as well as gender differences.

The males were slightly stronger both at 5th and 95th percentile of grip strength. Meanwhile, the thumb/pinch strength showed a wider gap between the male and female elderly. The females were 47.26% weaker than the males at 5th percentile and being much lower at 68.93% for the 95th percentile (Table 3). The high strength measurement in the females was contributed by younger elderly, namely those aged 70 years and below within the investigated age cohort. This was also applied to the highest frequency measurement in the male subjects. On the other hand, the lower strength measurements of grip and pinch for both gender groups were contributed by older elderly who aged between 75-83 years.

As compared to the younger university student group, the 5th percentile of grip strength of the elderly was 44.8% less. While at the 95th percentile, the elderly strength was 30.66% less than the students' grip strength (Table 6). The 5th percentile of university students' pinch strength was 33.33% stronger than the elderly. On the other hand, the 95th percentile shows that the elderly strength is 13.42% lower compared to that of the university students.

The results from previous research performed by Taha & Nazaruddin (2005) focused on gripping rather than pinching strength. Compared to the findings by Taha & Nazaruddin (2005), the grip strength of the elderly males was found to be 30.28% lower than the industrial worker. On the contrary, the result contradicted that of the females' grip strength. The elderly was found to be 14.23% stronger than the female industrial workers. These may be caused by several reasons. First, the females are light industrial workers. They are not hard labour. Second, psychologically, the subjects may not perform their actual peak strength because they are sent to another heavier task or another section. In other words, they are reluctant to leave their present comfort zone. Further investigation may discover these assumptions.

Another research was performed by Nevill & Holder (2000) through the Allied Dunbar National Fitness Survey (ADNFS) which had studied several age cohorts based on ten years range. One of the age cohorts comprised of people aged between 65-74 years old, who were categorized as the elderly. The results revealed that the mean grip strength value of the males was 63.05% stronger than that of the Malaysian male elderly while the females were 38.61% stronger than the Malaysian female elderly. It was also found that their female counterparts had stronger grip strength compared to that of the Malaysian elderly males. The gap between these two groups was obvious and this could probably be linked to the ethnic origin factor. In terms of gender, the gap shows that the male strength is 40% higher than that of the females.

The FAA William J. Hughes Technical Centre, USA DOT/FAA/CT-96/1 (FAA) reported the male mean grip strength was recorded to be 47.20 kg for momentary hold and 28.00 kg for sustained hold. Compared to the Malaysian elderly, the differences between the momentary hold of the FAA was 68.79% higher, whereas this was 47.39% higher for the sustained hold. The gap is obviously very wide. Therefore, the FAA Human Factors Design Guide (FAA-HFDG) cannot be used as a reference in designing products for the elderly population in Malaysia. In other words, there should be a special design guide for the Malaysian elderly population.

RECOMMENDATIONS

Based on the result illustrated in Table 3, it is recommended that any spring stiffness on future elderly IADL products related to gripping task should not exceed 11 kg. An example of the product is pruning scissor for gardening task, whereas for the products related to pinching, they should not exceed the maximum spring stiffness of 4 kg. An instance product of this kind is tong for meal preparation task. This recommendation is based on the 5th percentile of both elderly static strength limitations since it accommodates 90% of their total population.

CONCLUSIONS

Based on the findings, there was a significant difference in the grip and pinch strengths between the elderly population in Malaysia and the university students, as well as that of the FAA report. Nonetheless, the differences in the grip and pinch strengths between the university students and the FAA report are not obvious. Therefore, it can be concluded that the older the person is, the lower the grip and pinch strengths measurement will be; this also means that there is a negative correlation between age and static strength in human performance. The significant difference between the grip and pinch strength limitations of the male and female elderly affirms the research hypothesis although the percentages are not close to those in the previous findings.

The research on elderly biomechanical limitations should be investigated more deeply so as to determine the physical strength capability, particularly of the females, since not many strength data have been collected from them. Statistically, female elderly are more than the males in the Malaysian population. For future research, it is suggested that other elderly static strength measurements should be investigated to find their correlation with ADL tasks or job design. With the complete data, some recommendations could be made, specifically on material handling and product weight limits. In terms of product design, some sets of strength limitation could be very useful guidance in designing equipment or hand tools for the elderly population in Malaysia. These design criteria could later on be proposed to match the tasks and the capabilities of the elderly.

It is hoped that the finding from this study could improve the quality of life and independency of the elderly through the reduction or elimination of normal physical strains or fatigue caused by repetitive tasks or other IADL which involve either carrying, lifting or use of equipment. By applying the finding of this research, engineers and industrial designers may design and introduce certain assistive products to this population to enhance their task performance.

ACKNOWLEDGEMENTS

The authors thanked all the volunteers who had participated in this study. This research was funded under the University Malaya Research Grant No. IPPP/UPPiT/Geran (RU/PPP) PS040/2008A.

REFERENCES

Caldwell, L.S., Chaffin, D.B., Dukes-Dubos, F.N., Kroemer, K.H.E., Laubach, L.L., Snook, S.H., & Wesserman, D.E. (1974). A proposed standard procedure for static muscle strength testing. *American Industrial Hygiene Association Journal, 35*(4), 201-206.

Chaffin, D.B. (1975). Ergonomics guide for the assessment of human static strength. *American Industrial Hygiene Association Journal*, *36*, 505-510.

Falkel, J.E., Sawka, M.N., Lenine, L., & Pandolf, K.B. (1985). Upper to lower body muscular strength and endurance ratios for women and men. *Ergonomics*, *28*, 1661-1670.

Hektner, J.M., Schmidt, J.A., & Csikszentmihalyi, M. (2007). *Experience sampling method: Measuring the quality of everyday life*. California. Sage Publications, Inc.

Nevill, A.M., & Holder, R.L. (2000). Modelling handgrip strength in the presence of confounding variables: Results from the Allied Dunbar National Fitness Survey. *Ergonomics*, *43*(10), 1547-1558.

Pennathur, A., & Dowling, W. (2003). Effect of age on functional anthropometry of older Mexican American adults: A cross-sectional study. *International Journal of Industrial Ergonomics*, *32*, 39-49.

Rodahl, K. (1989). *The physiology of work*. London: Taylor & Francis.

Taha, Z., & Nazaruddin. (2005). Grip strength for Malaysian industrial workers using artificial neural networks. *International Journal of Industrial Ergonomics*, *35*(9), 807-816.

Tayyari, F., & Smith, J.L. (2000). *Occupational ergonomics: Principles and application*. London: Kluwer Academic Publishers.

Wagner, D., Birt, J.A., Snyder, M., & Duncanson, J.P. (1996). *Human factors design guide: for acquisition of commercial-off-the-shelf subsystems, non-developmental items, and developmental systems*. Final Report and Guide. FAA William J. Hughes Technical Center, USA. DOT/FAA/CT-96/1.

Welford, A.T. (1985). Changes of performance with age: An overview. In N. Charness (Ed.), *Aging and human performance* (pp. 336-337). Chichester: John Wiley & Sons Ltd.