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Anthropometric Measurement of Thai Older Farmers for Agricultural Tools and Workplace Design

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Abstract: Agricultural workers usually perform most occupational operations manually. Mismatch between farmers' anthropometric dimensions and tools or equipment are known to be contributing factors related discomfort, fatigue, injuries, and biomechanical stress to the users, especially for older farmers. A cross-sectional survey was carried out on 197 male and 284 female older farmers in Nong Suea District, Pathum Thani Province, Thailand. The convenience sampling method was used to select the subjects. Thirty-three anthropometric dimensions were measured. The mean; standard deviations; coefficients of variation; independent *t*-test; and 5th, 50th, and 95th percentile values were determined. The results revealed differences between dimensions for men and women, indicating that men showed prominent results. Moreover, there was a comparison between some dimensions with the results of other counties. The findings of this study provide values of anthropometric data in the aging population of Thailand. Implementing anthropometric data to reduce the mismatch between the aging workers and their work performance is crucial for designing farm tools and designing a safe variety of products and a healthy environment for the elderly.

Keywords: ergonomics; product design; safety; Thai farmers; hand tool

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1. Introduction

The World Bank reported that Thailand's working-age population was 57 million in 2019, of whom 67% participated in the labor market. Meanwhile, the share of the population 65 years of age or older is projected to rise from 13% of the population in 2020 to 31% in 2060. Agriculture still employs about 33% of all workers in Thailand compared with 23% of employment in the Philippines, 10% in Malaysia, and 5% in the Republic of Korea [1]. Agricultural workers and farmers in Thailand perform most of the various farm operations manually, starting from seedbed preparation to post-harvest. Agricultural workplace equipment such as warehouses, workstations, tractors, power trailers, machinery, and hand tools of varied sizes and dimensions are widely used in Thailand. It is possible that the workstations and agricultural tools/equipment do not meet the body dimensions of the users, which could lead to musculoskeletal disorders (MSDs) [2,3]. Previous studies revealed that using agricultural tools or equipment are known factors contributing to increased risk of developing MSDs among workers in agriculture [4–6].

In the workplace, ergonomics are applied to design work equipment, tasks, and work for the organization. Occupational ergonomics is often referred to as an integral part of occupational health and safety [7]. Lee et al. [8] found that the anthropometric dimensions of the elderly are different from the adult and adolescent groups. This result is consistent with a previous study by Mohammad [9]. He concluded that daily life tools or equipment and facilities should be designed separately to fit between gender and age population groups. In addition, working in the agriculture sector requires various agricultural tools in order to work, especially in rural areas. Mokhtarinia et al. [10] mentioned that anthropometric data should be considered for each major population age category, specifically because of the dimension changes occurring during ageing. In elderly persons, the physical activities and their capabilities become limited. Most agricultural tools and machines in Thailand are imported from foreign countries. When buying from manufacturers, farmers need to modify or produce farming tools, such as a shovel or spade shovel. There is strong evidence demonstrating that the anthropometry dimensions of the population in different countries and regions are different [8,11–14]. Although many anthropometric investigations have been conducted to improve the design of products/environments for different users, further research seems necessary, particularly for particular groups, such as children, the elderly, and people with disabilities [15]. Ergonomics is an essential and integral element of occupational health practice. Workers need to be placed and maintaining in an occupational environment adapted to their physical and mental needs [7].

For this reason, anthropometry is essential for designing safe products, farm tools, and agricultural work stations that deal with body measurements, particularly those of size, shape, and body composition. Therefore, this study aims to provide anthropometric data for ergonomically designed tools impacting elderly farmers. The anthropometric data from this study can be applied not only for design in agriculture sectors, but also for developing a safe, friendly living environment and updating the body dimensions for the elderly in Thailand.

2. Materials and Methods

2.1. Study Participants

This cross-sectional study collected data from 506 agricultural workers aged 60 years who were registered as farmers. They resided in nine sub-districts in the Nong Suea District, Pathum Thani Province, Thailand. When the data collection was completed, the sample consisted of 481 older farmers, which involved 95% of the total population. Twenty-five participants were dropped from the study for not meeting the inclusion criteria. A convenience sampling method was used to select participants. The participants were selected according to their availability and willingness to participate, without payment or reward. Every participant was informed of the purpose of the study before taking their measurements. Similarly, the details of the procedure were explained to them. All participants were barefoot and wore light clothing during the measurements. Each participant was in good health. Those with any musculoskeletal disorders and a history of movement disorders were excluded from the study. Informed consent was obtained from all participants taking part in the study, which the Ethics Review Sub-Committee approved for Research Involving Human Research Subjects of Thammasat University, no. 3 (101/2560).

2.2. Anthropometric Dimensions

Thirty-three anthropometric dimensions, including body weight, were collected. These dimensions were selected because they are helpful for the development of the design related to the agricultural sector, such as working places, hand tools, and manual equipment. In previous studies, these had been measured among the elderly population [8,16,17] and were also measured in agricultural workers in different countries, in India [11,18], Nigeria [4], Indonesia [5], and Jordan [19]. According to ISO 7250, each measurement was defined as basic human body measurements for technological design part 1: Body measurement definitions and landmarks [20]. The principal investigator trained six assistant researchers to perform the measurements. To ensure optimal precision, reliability, and accuracy with respect to anthropometric readings, body dimensions were measured and trained using these validated techniques.

2.3. Measuring Equipment

A manual anthropometer (Martin-type anthropolometer PM. SIN 052876) was used to measure the body dimensions for standing and sitting postures. A sliding caliper was used to measure small breadth and depth of body segments, such as hands and feet, and a measuring tape was used to measure body circumferences—this was done in the conventional manual way with an accuracy of 1.0 mm. A digital weight scale was also used to measure body weight with an accuracy of 0.1 kg. All participants were measured in the same way with the same equipment and all were seated in the same way for the sitting measurements (flat and horizontal) and the plane of the backrest following the standard procedures.

2.4. Statistical Analysis

The normality test was conducted using the Kolmogorov–Smirnov test before analyzing the data set in the current study. Descriptive statistics were calculated using the mean, standard deviation, coefficient of variation (C.V.), 5th percentile, 50th percentile, and 95th percentile. Significance independent *t*-tests for determining the differences between means were evaluated to compare males and females at a significant level of 0.05.

3. Results

A total of 481 participants involved 284 females (59.00%) and 197 males (41.00%) with an average age of 69.70 years (SD = 7.10) (minimum = 60.00, maximum = 82.00). The percentile values (5th, 50th, and 95th) and % C.V. for each anthropometric dimension for males and females. A comparison of the mean of all measured anthropometric dimensions between males and females of older farmers was made. The result indicated that males had significantly larger dimensions than females for all measurements ($p < 0.001$)—shoulder–elbow length, elbow to elbow breadth, head breadth, head circumference, hand circumference, and ankle circumference were found to be significant ($p < 0.05$). The non-significant difference in hip breadth between males and females is shown in Table 1.

A comparison the mean of male and female anthropometric data with that of other countries as shown in Tables 2 and 3.

Table 1. The 33 anthropometry dimensions in older farmers, by gender (n = 481).

Anthropometry Dimensions *	Male (197)						Female (284)							
	5th	50th	95th	Mean	S.D.	%C.V.	5th	50th	95th	Mean	S.D.	%C.V.	Difference	p-Value
Standing measurement														
1. Weight	41.50	58.60	84.00	60.60	11.60	19.19	40.00	58.55	75.90	58.50	11.0	18.87	1.00	<0.001
2. Stature	148.70	161.00	174.30	161.00	6.84	4.27	139.00	150.00	158.00	150.00	5.90	3.96	10.50	<0.001
3. Eye height, standing	139.00	150.50	158.00	149.50	6.00	4.05	128.00	139.00	148.00	138.40	5.95	4.29	10.70	<0.001
4. Shoulder height	121.30	133.25	145.00	133.50	6.90	5.23	114.00	124.00	134.00	124.40	7.60	6.18	7.10	<0.001
5. Elbow height	89.00	100.00	110.00	100.00	6.95	6.95	80.00	92.00	101.00	92.00	7.01	7.65	6.80	<0.001
6. Fingertip height	52.00	59.00	65.00	58.10	6.70	11.65	46.00	54.00	61.00	54.40	4.50	8.38	5.20	<0.001
7. Knuckle height	61.00	68.00	76.00	69.20	5.80	8.46	55.00	63.50	69.00	63.40	5.50	8.81	6.00	<0.001
8. Span	154.00	168.00	183.00	168.20	8.80	5.26	144.00	155.00	170.00	155.00	8.50	5.53	7.20	<0.001
9. Elbow span	73.00	82.00	90.00	82.00	5.00	6.17	66.00	74.00	81.00	74.00	5.50	7.49	7.30	<0.001
10. Wrist–wall length, extended	53.00	70.00	77.00	68.50	9.70	14.21	50.00	66.00	72.00	64.00	7.30	11.53	4.80	<0.001
11. Vertical grip reach, standing	166.00	193.00	205.00	191.10	14.80	7.78	158.70	180.50	196.00	178.0	16.8	9.45	6.42	<0.001
Sitting measurement														
12. Sitting Height	75.00	83.00	93.00	83.00	5.20	6.30	68.00	75.00	83.00	76.00	4.51	5.94	6.80	<0.001
13. Eye height	66.00	72.50	79.00	72.00	4.80	6.77	58.00	65.00	72.50	65.25	4.90	7.59	7.10	<0.001
14. Should height	49.00	57.00	65.00	55.70	8.40	15.15	43.00	51.00	59.00	50.80	5.10	10.19	6.20	<0.001
15. Shoulder–elbow length	23.00	30.00	35.00	30.70	8.00	26.30	23.00	29.00	34.00	29.00	3.20	11.09	2.00	0.039
16. Vertical reach height	101.00	118.00	131.00	117.00	10.70	9.21	94.00	107.00	120.10	108.00	14.30	13.30	5.60	<0.001
17. Knee height	41.00	50.00	55.00	50.00	3.90	7.96	42.00	47.00	51.50	47.00	3.00	6.61	4.00	<0.001
18. Popliteal height	39.00	43.50	46.00	43.00	2.50	8.25	36.50	38.00	42.00	40.00	1.30	8.60	7.00	<0.001
19. Thigh height	11.0	12.5	14.2	12.10	1.40	8.00	12.0	13.60	15.5	13.30	0.80	7.00	5.20	<0.001
20. Buttock–knee length	48.00	54.00	59.00	53.50	3.60	6.80	46.00	51.50	57.50	50.00	3.90	7.80	6.40	<0.001
21. Buttock popliteal length	37.50	43.00	50.50	43.50	3.80	8.70	35.00	40.00	47.00	40.00	3.80	8.40	6.60	<0.001
22. Shoulder breadth	38.00	43.00	49.00	43.30	7.10	16.56	32.00	38.00	45.00	38.30	4.30	11.31	6.40	<0.001
23. Elbow to elbow breadth	34.00	40.00	52.00	41.60	5.19	12.77	34.00	39.00	48.00	40.00	4.10	10.37	0.90	0.044

Table 1. *Cont.*

Anthropometry Dimensions *	Male (197)						Female (284)							
	5th	50th	95th	Mean	S.D.	%C.V.	5th	50th	95th	Mean	S.D.	%C.V.	Difference	*p*-Value
24. Hip breadth, sitting	37.00	33.00	40.00	33.50	3.70	11.04	28.00	33.00	39.00	33.40	3.30	9.99	0.10	0.895
Other measurements														
25. Head breadth	14.20	16.10	17.36	16.00	0.90	5.83	14.00	15.50	17.00	15.40	0.90	6.21	3.10	0.003
26. Head circumference	48.00	53.75	58.00	52.50	6.00	11.46	49.00	52.50	56.00	52.10	3.80	7.46	2.10	0.032
27. Hand length	16.50	18.30	19.60	18.20	0.90	5.32	15.80	17.00	18.30	17.00	0.80	4.75	7.80	<0.001
28. Hand breadth	7.50	8.50	10.20	8.70	1.90	21.96	6.90	7.70	15.00	8.10	2.00	25.52	6.30	<0.001
29. Wrist circumference	15.00	16.80	18.00	16.60	1.10	6.80	13.50	15.75	17.30	15.50	1.30	8.64	4.70	<0.001
30. Hand circumference	17.50	19.80	22.00	20.00	1.48	7.47	15.50	18.10	20.00	18.20	1.60	8.78	2.10	0.032
31. Grip diameter (inside)	3.50	4.70	6.20	4.60	0.70	12.00	3.10	4.20	5.40	4.10	0.60	14.20	4.65	<0.001
32. Foot length	20.50	23.80	25.80	23.40	1.60	6.82	19.30	22.00	24.00	21.80	2.00	9.40	5.45	<0.001
33. Foot breadth, horizontal	8.80	10.00	11.00	10.00	0.60	6.89	7.60	9.00	10.20	9.10	1.80	20.57	6.70	<0.001

* All dimensions are in cm.

Table 2. The mean anthropometric body dimensions of elderly males in different populations.

Dimensions *	This Study	Singapore [a]	Indonesia [b]	Malaysia [c]	Philippines [d]	China [e]	Japan [f]	Korea [g]	Australia [h]	British [i]	USA [j]
1. Stature	161.0	173.2	162.0	157.8	167.0	165.5	168.8	170.7	165.8	174.0	175.5
2. Eye height	149.5	161.6	151.2	146.2	155.0	154.5	157.7	158.8	153.2	163.0	170.9
3. Shoulder height	133.5	145.3	135.8	131.8	137.5	137.6	137.0	138.3	138.5	142.5	144.0
4. Elbow height	100.0	109.7	101.1	100.2	104.1	102.3	103.5	Nda	104.3	109.0	110.0
5. Knuckle height	69.2	76.4	70.2	71.29	72.5	72.6	74.0	nda	nda	75.5	76.5
6. Hand length	18.2	18.4	18.3	17.02	nda	17.9	nda	18.9	18.4	19.0	19.1
7. Hand breadth	8.7	8.1	8.3	7.99	nda	8.4	8.5	nda	8.6	8.5	8.9
8. Grip diameter (inside)	4.6	nda	4.3	nda	nda	nda	nda	nda	nda	nda	nda

* All measurement are in cm.; nda = no data available. [a] [8], [b] [5], [c] [16], [d] [21], [e] [22], [f] Kagimoto in [23], [g] [24], [h] [25], [i] [26], [j] [26].

Table 3. The mean anthropometric body dimensions of elderly females in different populations.

Dimensions *	This Study	Singapore [a]	Indonesia [b]	Malaysia [c]	Philippines [d]	China [e]	Japan [f]	Korea [g]	Australia [h]	British [i]	USA [j]
1. Stature	150.0	173.2	152.5	157.8	153.9	152.6	158.4	158.8	165.8	161.0	162.6
2. Eye height	138.4	161.6	139.4	146.2	143.1	141.1	142.5	148.0	153.2	150.5	152.4
3. Shoulder height	124.4	145.3	125.0	131.8	127.2	126.3	127.9	128.9	138.5	131.0	132.6
4. Elbow height	92.0	109.7	95.0	100.2	96.2	94.2	96.7	nda	104.3	100.5	102.1
5. Knuckle height	63.4	76.4	66.7	71.2	67.8	66.5	70.5	nda	nda	72.0	72.9
6. Hand length	17.0	18.4	17.2	17.0	nda	16.8	16.5	17.5	18.4	17.5	17.5
7. Hand breadth	8.1	8.1	7.8	7.9	nda	7.8	7.5	nda	8.6	7.5	7.6
8. Grip diameter (inside)	4.1	nda	3.8	nda	nda		nda	nda	nda	nda	nda

* All measurement are in cm.; nda = no data available. [a] [8], [b] [5], [c] [16], [d] [21], [e] [22], [f] Kagimoto in [23], [g] [24], [h] [25], [i] [26], [j] [26].

The anthropometric data based on usefulness and application in agriculture, and the recommended criteria related to workplace considerations, products, farm tools, and equipment design for older farmers are shown in Table 4.

Table 4. Application of anthropometric data in different agricultural situations [27].

No.	Anthropometric Dimension	Usefulness and Application in Agriculture [27]	Design Criteria	Values (cm)
Standing dimension				
1	Stature	- To design proper door height, ensuring that the farmer is standing erect while walking or operating	95th percentile of males for stature (minimum)	174.30
2	Eye height	- Shelf/storage eye height for items requiring visual inspection - Design of controls, display positions of equipment	5th percentile of females	128.00
3	Shoulder height	- Shelf/storage above shoulder height for light, less frequently used items	5th percentile of females from the floor with a 200 maximum joint flexion	114.00
4	Elbow height	- To design proper handle height. It should be designed to ensure that the operator is standing erect while operating - Design of controls and display positions of equipment - Doorknob height - Working manual area height - Handling of manual, semi-automatic, or fully automatic weeders - Handling of seed sowing equipment - Design of a lever operated knapsack (LOK) sprayer - Design of a power-operated thresher, feeding chute height	5th percentile of females	80.00
5	Knuckle height	- To design proper low location control, handle, and handrails - Lower shelves for medium to heavy items	95th percentile of males	76.00
6	Vertical grip reach standing	- To design appropriately the height of overhead controls operated by a standing person - Consider ease of motion and reach - Control button and lever positions must be designed within the operator's reach - Design of gear levers, position control levers and various pull type control levers	5th percentile of females	158.70

Table 4. *Cont.*

No.	Anthropometric Dimension	Usefulness and Application in Agriculture [27]	Design Criteria	Values (cm)
7	Span	- Workplace, working space design and design of controls - Lift, pick-up studies, workplace layout designs	95th percentile of males	183.00
8	Elbow span	- To design properly the space needed in the upper body for ease of motion and tool use - Design of door width	95th percentile of males	90.00
Sitting dimension				
9	Sitting height	- Design of seating system for tractors, power tiller, planter. - Work place layout design, working area space designs.	50th percentile of females	75.00
10	Sitting eye height	- Design of lever, push-pull buttons, control panels, and display devices from the sitting position. - Design of display systems and visual observation systems. - Steering wheel position and orientation.	5th percentile of females	58.00
11	Sitting thigh height	- Clearance between seat and steering system or inner portion of working table, seat, tractors, power tiller, planter	95th percentile of females	15.50
12	Sitting popliteal height	- Design for a height of a seat; chair, tractors, power tiller, planter - Design of sitting mechanisms for a thresher, cutter, harvester, and plant feeder.	5th percentile of females	36.50
13	Hand length	- To design handle length for hand tools and manually operated equipment - Design of hand-operated levers, braking systems, clutch mechanisms, and sprayer triggers - Design of hand gloves	95th percentile of males	19.60
14	Hand breadth	- Design handle length for hand tools and manually operated equipment - Design of hand gloves	95th percentile of males	10.20

Table 4. *Cont.*

No.	Anthropometric Dimension	Usefulness and Application in Agriculture [27]	Design Criteria	Values (cm)
15	Hand grip diameter (inside)	- To design handle grip diameter for hand tools and manually operated equipment - To design hand operating button and emergency knob diameters for push–pull operations	5th percentile of females	3.10
16	Foot length	- Design foot-operated pedals, knobs, buttons, or levers - Design of safety shoes	An adjustable within the range of 5th percentile of females and 95th percentile of males	19.30–25.80
17	Foot breadth	- Design foot-operated pedals, knobs, buttons, or levers - Design of safety shoes	An adjustable within the range of 5th percentile of females and 95th percentile of males	7.60–11.0

4. Discussion

This cross-sectional survey of anthropometric measurements of farmers found that 59% were female. This data are consistent with the statistics of Thailand and many countries worldwide, finding that the female worker population is greater than males [28,29]. A previous study concluded that the workforce is aging in many countries worldwide [28]. This conclusion may result from the combination of longer lives, declining birth rates, urbanization, and technological changes, and more women entering the workforce have resulted in a rapid change in the age profile of most countries [30]. This study highlights significant percentile values (5th, 50th, and 95th) of differences in anthropometric dimensions for males and females, which are presented in Table 1. The percentile values may be used as a guide for improving and redesigning the standard agricultural equipment, workstation, and machines in different farm operations for older workers. This study concurs with the findings of previous studies that claimed that the computed percentile values might be used as a guide for designing the hand tools and control panels in different workstation designs [8,9,11]. Phesant [31] concluded that the 5th percentile is essential for determining workplace facilities' reachability and limitations. The result agrees with Cacha [32], who recommended a design based on measures representing the shortest members of the study population, namely well-designed multi-level racks for farm products in the farmhouse or workroom. Frequently used items should be within easy reach; others should not be higher than the vertical grip reach standing height. When there is a mismatch between the physical requirements of the products and the physical capacity of the elderly, work-related musculoskeletal disorders (MSDs) can occur. Therefore, anthropometric data are an essential requirement for facilities' farm work design.

In recent studies, 33 anthropometric dimensions, including weight, indicated that most of the dimensions of male older farmers had a larger size than female older farmers (Table 1). This finding is similar to previous studies [5,8,13,22,33], which demonstrated a significant difference in dimensions between male and female older people. A study by Obi [4] concluded that some farm equipment/tools might not comfortably fit the hands of different in gender and age groups. The finding supports previous literature demonstrating that some women's anatomical and physiological characteristics may place them at specific risk for farm injuries [34]. For this reason, it seems appropriate that farm tools and equipment function best and are the safest and easiest to operate when they fit the user. It can be concluded that farm workplace tools/equipment should be considered separately when being provided to older farmers. For designing an agricultural work station, it is necessary to obtain relevant information about the task performance, equipment, working posture, and environment [35]. A pathway to prevent work-related musculoskeletal injuries among elderly farmers may be created in this way.

Tables 2 and 3 present eight anthropometric body dimensions in male and female elderly populations in different countries. This study indicated that in older Thai people, each body dimensions were more prominent than in the elderly Malaysian population [16]. There is a slight difference in the elderly Indonesian population [5]. They are smaller than the elderly populations in the Philippines [21], China [22], Japan [23], and Australia [25]. Furthermore, elderly Thai people are smaller than the elderly in Singapore [8], Korea [24], Britain, and the USA. [26]. It can be observed that older Southeast Asia populations have smaller body sizes compared with European and American populations. These results match those demonstrated in earlier studies [5,8,11]. Most agricultural machinery, tools, and equipment come from industrialized countries capable of producing them. These tools are designed based on their own anthropometric dimensions, rather than those of the importing countries [12,19]. Obi [4] mentioned that differences in all anthropometric dimensions of different nationalities emphasize the usefulness of this study in the design context of agricultural tools and implements. This implies that manufacturers of devices and implements should consider the anthropometry of the elderly in their design processes. Therefore, the agricultural environment and tools must be designed and organized in accordance with the user's anthropometric data [36,37]. For this reason, the current study reports that the anthropometric information of older farmers has significant differences and is essential when compared with the body proportion data in each country.

Traditional agricultural workers participate in many agricultural operations in Thailand, from land preparation to post-harvest operations. They use different workplaces, farm tools, machinery, and equipment. Several unnatural work positions are performed in agriculture, especially in rural areas. Strains and sprains are caused by excessive reaching, bending, lifting, gripping, squatting, or twisting of the hands, shoulders, or body [38]. Biomechanical research shows that high spinal compression forces occur in stooped postures. Sustained or repeated flexion of the spine may disturb the neuromuscular stability of the lower back and increase the risk of fatigue, leaving the back more vulnerable to injury [39,40]. Macleod [26] mentioned that a neutral posture is the optimal position for each joint as it provides the most strength, the most control over movements, and the least physical stress on the joint and surrounding tissue. This claim supports previous literature that concluded that repetitive movements in awkward postures, such as stooping and kneeling, individual characteristics, and improper tool design, were observed to contribute to the pathogenesis of MSDs [41]. Thus, efficient use of farm tools and machines requires proper design so as to increase the work efficiency, safety, and comfort of the users [4,26,31]. Therefore, redesigning farm work to avoid kneeling or stooping and achieving work-based line anthropometric data should be considered.

5. Application of Anthropometric Data for Agricultural Tools and Workplace Designs

Table 4 presents the 17 anthropometric dimensions based on the usefulness and application in agriculture and recommended criteria related to farm tool and equipment design considerations for older farmers in different agricultural situations. A previous study by Vyvahre and Kallurkar [11] concluded that anthropometric data based on user populations are useful for designing agricultural equipment for agricultural workers in order to reduce drudgery and increase efficiency, safety, and comfort. Working height is essential in agricultural tasks. Awkward postures may be caused by using poorly designed or arranged workplaces, tools, and equipment, as well as poor work practices. The space between shoulder height and elbow height is assumed to be optimum [42]. There are many kinds of farm work that are manually operated. According to ergonomics principles, the design and layout of the workspaces in which people live and work refers to anthropometric considerations of reach, clearance, and posture [43]. Thus, working height should often be used in this zone. The results of this study recommend the requirement of elderly farmers having an easy reach. An appropriate working height should be between elbow and shoulder height, between 100.00 cm and 133.20 cm for males and 92.00 cm and 124.00 cm for females.

For standing work, proper workstation height for light and heavy work, such as maintaining bag, tool, or box weight and mixing pesticides, should be maintained. Kreomer [44] mentioned that different working heights suit the same operator for doing different tasks. The primary determinant of the proper height of the workspace is the height of the person's elbow for light work, which should be located about 10 cm below elbow height [44]. Thus, the current study suggests that the standing position for working among elderly farmers Thai should range from 89.00 cm to 110.00 cm for males and 80.00 cm to 101.00 cm for females for light work, and from 79.00 cm to 100.00 cm for males and 70.00 cm to 91.00 cm for females in heavy work, as demonstrated in Figure 1.

Many activities of farm operations in Thailand are performed manually with hand tools. However, these tools, equipment, or machines with coupling or quality of the workers' grip on the object are fabricated locally with no design according to ergonomics principles [4]. They may affect various body areas such as the hands, wrists, arms, and shoulders, or unsupported positions that stretch physical limits, compress nerves, irritate tendons, and damage tendons and tendon sheaths. More exertion is needed to accomplish the same work if the grip is significantly larger or smaller than needed [26]. A previous study confirmed that older adults exhibited poor grip strength and stability control when performing arm-reaching movements [45]. NIOSH [46] reported that many injuries known as musculoskeletal disorders are attributable to hand tool use in occupational settings, resulting in unnecessary suffering, lost workdays, and economic costs. Relevant agencies recognize the importance of the design and selection of hand tools in strategies to reduce injuries of this type. It can be concluded that providing a good grip for all containers or handles should be considered in farm tool design. For this reason, the current study presents hand anthropometric values with design implications focused on elderly Thai farmers. Hand length, hand breadth, hand circumference, wrist circumference, and hand grip diameter (inside) should be considered when designing different dimensions related to hand tools (for example, the hand grip provides the maximum hand power for high-force tasks). All of the fingers wrap around the handle. For single-handle tools, handrails, or coupling used for power tasks, the diameter should conform with the 5th percentile of the female grip diameter, namely 3.10 cm. The 95th percentile of the male hand breadth dimension should be used when designing handle length, namely 10.20 cm. Consideration of agricultural tools should also attach long handles to tools based on the line hand anthropometric data among the users, as demonstrated in Figure 2.

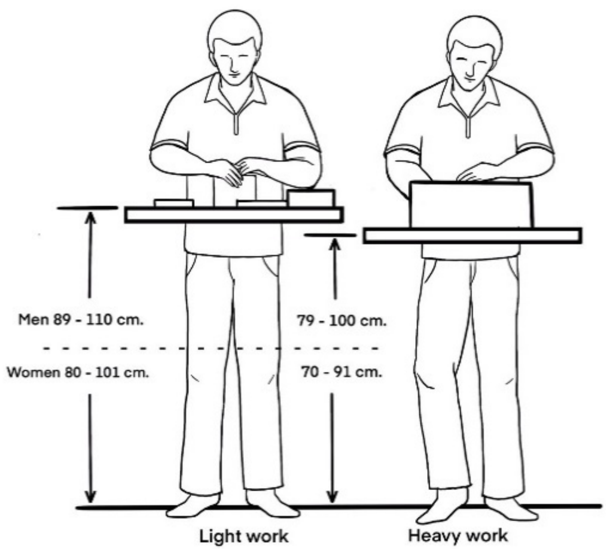

Figure 1. Working height in a standing position.

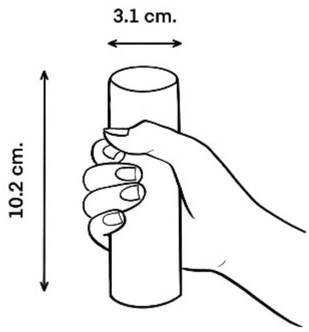

Figure 2. Single-handle tool dimensions for elderly Thai farmers.

6. Study Limitations

This study was conducted by collecting anthropometric data among elderly farmers who stayed in Pathum Thani Province, in the central area only, in Thailand. Wider anthropometric data collection will be necessary to increase representation for the Thai elderly Thai population in the future. Some of the results from comparisons from other countries may have been affected by differences in measurement techniques, measuring accuracy, and instruments used, but this information could still be can still be useful in the overall application. The present study focused on anthropometric measurement of one of the physical ergonomics domains. There are several ergonomics hazards in the workplace, such as working posture, work duration, individual characteristics, and psychosocial factors. Further studies should be conducted.

7. Conclusions

This study presented anthropometric data for elderly farmers in Thailand. Thirty-three body dimension recommended guidelines for designing essential products, tools/equipment, and workplace for older farmers in different agricultural situations are discussed. Anthropometric data from the present study were compared with similar studies conducted in other countries. The results indicated differences between older Thai farmers and those in other countries. Thus, farm tools or equipment designs from other countries are not ergonomically proper for the Thai population. There is a need to redesign and update existing tools or equipment based on the scientific application of anthropometric data of elderly Thai farmers. Proper anthropometric values can be used for relevant deliberation on a variety of product design applications for elderly farmers and older people from other regions of Thailand and from other countries.

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